Proceeding

Symposium on Natural Resources and Environment Management

Yogyakarta, January 21-22, 2002

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43rd Anniversary

UPN "Veteran" Yogyakarta Press
Jl. Lingkar Utara, Condong Catur Yogyakarta 55283
Telp. (0274) 486401, 486733 Fax. (0274) 486400
Y o g y a k a r t a
2002

ISBN 979-8918-32-0

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Proceedings of Symposium on Natural Resources and Environment Management
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SOIL CHEMICAL CHANGES ON THE ALTERATION OF MANGROVE FOREST TO RICE CULTIVATION IN CILACAP WETLAND

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ABSTRACT

There is a specific ecosystem in mangrove forest, especially for environmental aspect. In the mangrove ecosystem, flora and fauna may grow in a good condition., Problems generally occur in the mangrove ecosystem when people expand their activity for their living or more land for other purposes. As a consequence, there are many changes in environment. This research was aimed to examine the effect of land use alteration on the chemistry of mangrove soil after 50 years rice cultivation and mangrove preservation in Cilacap. To conduct this research, soil samples from three kinds of land use, i.e.: natural mangrove forest, mangrove forest preservation, and rice cultivation; were collected for several soil chemical analysis. There were different soil chemical properties of the soil by changing the mangrove vegetation to rice cultivation. The rice cultivation was able to change the exchangeable base cations and lower redox potential (Eh), electric conductivity (EC), and CEC. Mangrove preservation in this area gradually reclaimed the soil properties to the natural mangrove ecosystem.

INTRODUCTION

Lands that are needed for human life always increased as time to time. Problem of land scarcity generally occurs in high population area with low economic status. Prinz, (2001) reported on the global availability of cropland has now fallen by 25 per cent over two decades, from 0.32 hectares per capita in 1975 to 0.24 hectares in 1995. Farmers have traditionally satisfied increasing demand by plowing new land but opportunities for expansion are now limited. Extension of agricultural land is easily done by deforestation. People that live in estuarine wetland also need land resource for agricultural practice in production of foodstuff. It is realistic because this wetland is generally favorable for mangrove growth. The mangrove soil is considered as one of the biologically most productive ecosystems on the earth. Mangrove forest is characterized by accumulation of sediment resulting from mud trapping by the root system of mangrove trees. In addition mangrove ecosystem also can act as filter of salty sea water.

Research on mangrove soil in Indonesia is still very limited, especially in outside of Java. Sumodiharjo et al. (1993) reported that there were few data of mangrove soil in Indonesia, there were Jambi (Sumatra), Baran estuary (East Kalimantan) and Segoro Anakan (Central Java). They reported some properties of mangrove soil in Segoro Anakan as follow: clay (53-86%), silt: 6-13%, organic matter 24-56%, phosphorus content low, potassium and calcium contents high.

Some area of mangrove forests in Segoro Anakan were cleared and changed into paddy field from the second world war. It was done by farmers to achieve the foodstuff need for their families. The activity may resulted in some problem because tidal swamplands are environmentally fragile and highly sensitive to mistakes (Conway 1985). Mangrove proliferates and mud containing significantly amount organic matter and elements accumulates. On the other hand, sulfur compound also presents as potential and or as dissolved materials that termed as acid sulfate soils. Reese and Moorhead (1996) reported on the changes in organic carbon, pH and CEC and base saturation of the A horizon in Carolina Bay. According to their results they recommended that the relationship between soils and vegetation of wetland need further investigation. This paper tried was aimed to show the soil properties of mangrove land after was changed into rice field.

MATERIALS AND METHOD

Soil samples were collected from wetland with three kinds of land use on the east side of Tritih River at Tritih village Cilacap. There were natural mangrove forest, mangrove preservation, and rice field that located at the sequence from upper to lower area (Figure 1). The rice field was originally converted from a natural mangrove area for 50 years ago. The mangrove preservation was established in 1986 after deforestation, and at the same time was converte into rice field. Soil sampling was done by boring the soil until 30 cm in depth. Each land use type was sampled three sites, and each site the soil sample was divided into three parts of 0-10 cm, 10-20 cm, and 20-30 cm. The soil samples were then stored in freezer to keep in wet and reduction condition, and considered as the original samples. Aliquot of the samples were air dried for further analysis. Electric conductivity (EC), Eh (redox potensial) and pH were determined for the original and air-dried sample. Cation exchange capacity (CEC), exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}), water soluble cations cations (Ca^{2+}, Mg^{2+}, and Na^{+}) were analyzed for the air-dried sample. Sodium absorption ratio (SAR) was calculated from water-soluble cations.

RESULTS AND DISCUSSION

Land Use Type

Natural mangrove forest, mangrove preservation and rice field were located in a sequence at east side of Donan River. Rainfall in this area is more than 3000 mm per year, and distributed almost all months except at August and September. Natural mangrove forest has several kinds of mangroves type. The dominant mangroves in this area were *Rhizophora Apiculata* and *Rhizophora Macronata*. The age of trees was variable, and also the performance of the tree showed as natural forest. The mangrove trees in the preservation area were dominated by *Rhizophora*, they were cultivated at 1978 and managed by *Perum Perhutani*. The rice field managed by local farmer as a conversion from natural mangrove forest was rainfed irrigation. For isolating the rice field from brackish water it was built a concrete levee at riverside. Farmers cultivate rice twice a year without rotation with other plant, and they use urea as nitrogen source and triple superphosphate as phosphorus source for growing rice.

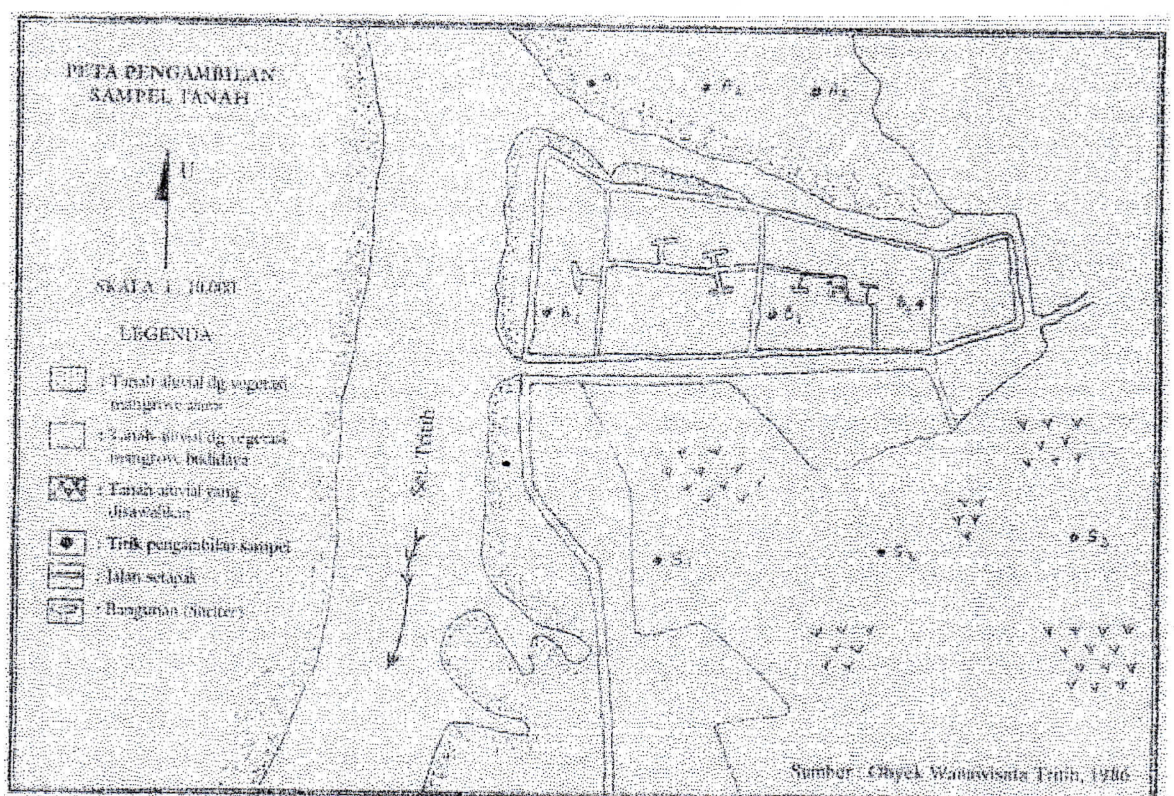

Figure 1. Layout of research area

Soil Properties: pH, Eh and EC of the Soil

The soil at natural mangrove forest showed an acidic to neutral reactions. There was a few different in pH(H_2O) between original and air dried soils. Generally the soils showed acidic, except at A_2 sample has neutral reaction in original soils but lower at air dry soils. The soils of preservation area showed weakly acidic in original soils, and the air dried soils showed a similar with the soils at natural mangrove. In the rice field, although soils has neutral to little basic reactions at original soils, at the air dried condition the soils were similar with soil reaction at the soils of the natural mangrove. The pH(H_2O) of soil may use to show a fertility in roughly. The neutral pH may give a good condition for plant growth. The soil at rice field still has a potential to acidic. Although the pH of soil was already raised to neutral, when the soil was dried the pH would drop again. Problem of tidal soils in South Kalimantan are: low pH, deficiencies in N, P, K, and Ca and high contents of Al, Mg, and Fe (Hans Anwarhan, 1985). In this research pH(H_2O_2) was failed to measure, because all the soil samples were extremely reactive that pyrite (FeS) in soil was oxidized and the soils discarded together with H_2O resulted from reduction of H_2O_2. Mangrove mud is a fine-sediment which trapped and collected by mangrove roots (Subagyo and Widjaja-Adhi, 1998), its reaction in situ with hydrogen peroxide leads to vigorous effervescence and the pH drops to below 2 (Furukawa, 1994).

Table 1. pH, redox potential and electric conductivity

Sample	pH(H2O)		pH(KCl)		Eh(mV)		EC(mmhos/cm)	
	Original	Air dry	Original	Air dry	Original	Air dry	Original	Air dry
A1-1	4.91	4.58	4.18	3.20	200	340	1.31	5.08
A1-2	4.67	4.50	3.75	3.15	220	365	1.44	5.44
A1-3	4.99	4.95	4.10	3.33	215	355	1.61	4.88
A2-1	6.94	4.97	6.22	3.86	185	320	1.73	5.16
A2-2	6.87	4.94	6.43	3.64	190	325	1.31	5.13
A2-3	6.87	4.78	6.17	3.82	205	320	1.21	5.69
A3-1	4.22	4.56	4.08	2.97	280	305	2.12	4.86
A3-2	4.79	3.66	4.19	2.57	320	385	2.13	4.57
A3-3	3.82	3.62	3.63	2.76	320	410	3.07	4.20
B1-1	5.34	4.56	5.00	4.12	245	335	1.26	3.88
B1-2	5.28	4.40	4.34	4.10	265	375	1.40	3.08
B1-3	4.30	4.22	4.08	3.92	275	395	1.88	3.07
B2-1	5.48	3.79	4.11	2.96	310	355	1.83	3.95
B2-2	4.69	3.76	3.82	3.06	320	365	1.33	3.74
B2-3	3.83	3.68	3.69	3.20	325	375	1.96	3.21
B3-1	5.88	4.07	4.62	3.46	245	365	1.57	4.19
B3-2	5.58	4.23	3.41	3.52	255	380	1.25	3.56
B3-3	4.48	4.01	3.33	2.97	275	395	1.98	3.92
S1-1	6.45	4.85	4.17	4.07	115	275	0.07	0.18
S1-2	6.04	4.88	4.05	3.95	115	280	0.05	0.17
S1-3	6.68	4.96	5.53	4.04	120	285	0.05	0.22
S2-1	7.34	4.71	4.93	3.87	125	295	0.09	0.49
S2-2	6.55	4.58	5.19	4.36	130	285	0.03	0.42
S2-3	6.91	4.38	5.68	4.20	125	280	0.03	0.46
S3-1	7.14	4.78	5.96	4.34	130	275	0.08	0.52
S3-2	6.81	4.82	5.38	4.24	145	280	0.07	0.55
S3-3	6.95	4.84	5.32	4.24	155	275	0.07	0.22

The pH(KCl) of the original soils showed a variation from very acidic to neutral in nature. Air drying on some soil samples at natural mangrove forest and mangrove preservation was able to lower the pH(KCl) to ≤ 3, while on the soil samples from rice field showed slightly higher than pH 3. Because the pH(KCl) as a potential acidity of soil, it can be said that the mangrove soils have a higher potential for decreasing pH until very acidic than in the rice field. According to the results, it is interesting that converting the mangrove forest soil into agricultural uses have to be carefully thought because when the soil is dry the pH may drop to very acidic. In this case plant can be injured by the low pH and plant nutrients are not in the available form.

The redox potential (Eh) of the soil sequentially decreased from natural mangrove, mangrove preservation and rice field. The redox potential indicate the oxygen content in soil. A high value of Eh of the mangrove soil was probably resulted in oxygen production in photosynthesis of mangrove. As the oxygen in the atmospheric space was high that might enter to soil. While the rice could not produce oxygen as high as mangrove tree so that the oxygen content of soil was lower.

Electric conductivity (EC) of the soils also showed a similar pattern with Eh. Saline soil is indicated when EC is higher than 4 mmhos/cm or percentage of soluble salt is higher than 0.15% (ILACOB, 1981). According to the result (Table 1.), drying the soil may increase the electric conductivity. The soil at the natural mangrove forest showed salinity when soil was dried. Soemodihardjo et al. (1993) reported that mangrove soils are generally characterized by high salinity, sodium ion saturation and high sodium absorption ratio. Electric conductivity, which is an indicator of salt contents, a higher value is better, except values above 8 mmhos/cm represent too high of salt concentration (Furukawa, 1994).

Cation Exchange Capacity (CEC) and Exchangeable Bases

In general, the CEC of the soil at natural mangrove forest and sequentially decrease at the mangrove preservation and rice field (Table 2). The CEC of the soil may indicate the ability of the soil to keep cations in the available form. The mangrove ecosystem has a cycle of organic matter which able to keep a nutritional balance between the absorbed nutrient by roots and supplying plant nutrients from litter fall. Also flora and fauna living in the mangrove ecosystem may help in organic matter decomposition, and also supply the organic matter by their body to soils. In this case the mangrove ecosystem is able to give a balance system. The rice plant needs abundant nutrients for production. Sometimes farmer could not make a cycle to keep a fertility of soil, because farmers in this area did not return the rice straw to soil but they used it for feeding their animal.

Soils at the natural-mangrove forest were dominated by Na+, because the soil was influenced by seawater tide. The contents of the cations were in the following order: Na+>Mg2+>Ca2+>K+ (Table 2). The soil at mangrove preservation showed in a similar cationic composition, however Ca2+, Mg2+, and K+ were lower than in the natural-mangrove forest. It is caused by the dominant mangrove in the study area is Rhizophora. Research on mangrove soils in South Sumatra by Soemodihardjo et al. (1993) found that composition of cationic bases in the soil was depended on the kind of mangrove. They reported that soil in the Rhizophora forest the cations was in order: Na+>Mg2+>Ca2+ or K+; in the Nypa forest was in order: Mg2+>Ca2+>Na+> K+., and in the swamp and peat forest was in order: Ca2+>Mg2+> Na+ or K+. The results of the present study showed that composition and contents of the exchangeable bases of soil at rice field were different from mangrove soils from both natural and preservation. Low contents of Ca2+, Mg2+, and K+ were probably due to nutrition uptake by rice. Isolation of soil from river by concrete building might also decrease the exchangeable bases.

Sodium Absorption Ratio (SAR)

Conversion of mangrove forest into rice cultivation could decrease the sodium absorption ratio (SAR) (Table 2). De Coninck (1978) reported lowering of SAR which caused by leaching and followed by increasing of pH significantly. In hydrolysis process Na^+ of the Na-clay is replaced by H^+ and liberate OH^-. In the present study the lowering of SAR was not followed by strong increase of pH (Table 1). It was caused by the high content of strong acidic compounds in the river water, such as SO_4^{-2} and Cl^-, and were able to liberate H^+ and neutralize the OH^-. But, the SO_4^- ion has a potential causing an acidity problem, and must be carefully managed.

Table 2. Exchangeable bases, CEC and SAR

Sample	Exchangeable bases (me%)				CEC(me%)	SAR(%)
	Ca^{2+}	Mg^{2+}	K^+	Na^+		
A1-1	8.42	30.96	6.27	58.94	35.68	18.47
A1-2	8.01	29.78	6.59	57.96	37.80	16.39
A1-3	8.80	27.46	5.05	50.83	32.75	15.02
A2-1	8.42	29.40	7.40	56.93	40.23	20.16
A2-2	9.57	29.00	5.83	54.39	37.78	19.22
A2-3	8.34	28.97	6.87	57.53	39.35	18.96
A3-1	7.15	26.11	5.34	44.88	29.60	12.90
A3-2	6.15	25.99	1.80	34.98	29.28	7.26
A3-3	6.65	24.79	2.18	37.19	28.42	8.49
B1-1	5.83	25.94	4.50	51.23	30.17	17.73
B1-2	4.59	12.63	2.69	25.87	13.97	5.78
B1-3	3.23	10.28	2.56	24.03	13.95	5.47
B2-1	6.04	17.53	2.40	33.84	22.62	6.96
B2-2	4.38	12.82	1.41	28.19	18.68	5.08
B2-3	4.06	12.81	1.12	30.16	18.67	6.86
B3-1	10.41	27.02	6.90	57.97	39.85	6.38
B3-2	4.55	12.82	3.46	29.20	19.51	6.86
B3-3	3.93	12.58	2.26	22.15	14.58	4.58
S1-1	6.28	4.11	0.25	10.90	13.96	0.91
S1-2	8.19	5.04	0.10	13.62	13.48	1.19
S1-3	10.14	6.39	0.08	16.92	15.01	2.26
S2-1	2.29	6.80	0.87	15.13	10.83	3.51
S2-2	2.08	7.01	0.89	15.35	10.26	3.05
S2-3	2.29	6.94	0.81	15.21	10.83	1.61
S3-1	2.93	8.89	1.06	17.99	12.90	0.27
S3-2	3.13	8.47	1.12	18.50	12.96	2.66
S3-3	3.64	10.75	1.46	23.35	15.56	4.71

CONCLUSIONS

Conversion of the mangrove forest into rice cultivation in the study area resulted in alteration of the soil chemical properties. Management of coastal wetland soil for agricultural usage must be done carefully to avoid the hazardous effect of salinity and extremely lowering of pH that potentially occured. Agricultural extension is better controlled by authorized governmental institution to preserve the presence of mangrove area in the coastal zone as a buffer of inland area from the influence of marine salt water.

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