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The Effect of Green Revolution Technology during the Period of 1970-2003 on Sawah Soil Properties in Java, Indonesia

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Abstract

Many countries reported that the green revolution (GR) technology caused some adverse effects on agricultural lands, but there is no research on the effects of GR in Indonesia. In order to evaluate the effect of GR technology on sawah soil in Indonesia, a comparative study between seedfarms, where GR technology has been continuously applied, and non-seedfarms was conducted in Java as a pioneer place of GR technology in Indonesia. Soil samples collected by Kawaguchi and Kyuma in 1970 and new samples taken in 2003 from the same sites or the sites close to the 1970 sampling were analyzed and compared. During the period of 1970- 2003 the land use pattern of sawah in seedfarms and non-seedfarms were not changed but cultivation intensity increased. The result showed total carbon (TC) and total nitrogen (TN) contents significantly increased from 31.90 to 40.42 Mg ha^{-1} and from 3.04 to 3.97 Mg ha^{-1}, respectively and mostly found accumulated in the surface soil layer. The difference of land management practices between seedfarm and non-seedfarm affected the change of TC and TN content in 0 – 20 cm soil layer during the period of 1970 to 2003. In seedfarms, where rice had been planted in monoculture system, the TC and TN contents in the soil layer of 0-20 cm increased from 34.50 to 39.24 Mg ha^{-1} and 3.16 to 3.95 Mg ha^{-1}, respectively. , mean soil pH and exchangeable sodium (Na) decreased from 6.90 ± 0.77 to 5.84 ± 0.90 and from 3.28 ± 2.76 to 1.67 ± 2.06 kmol$_c$ ha^{-1}, respectively; while the exchangeable acidity and available phosphorus (P) significantly increased from 9.32 ± 3.09 to 13.23 ± 3.72 kmol$_c$ ha^{-1} and from 136.62 ± 154.72 to 255.75 ± 292.41 kg P_2O_5 ha^{-1}, respectively.   the average content of available Si decreased from 1512±634 kg SiO_2 ha^{-1} to 1230±556 kg SiO_2 ha^{-1} and from 6676±3569 kg SiO_2 ha^{-1} to 5894±3372 kg SiO_2 ha^{-1} in the 0-20 cm and 0-100 cm soil layers, respectively. Cultivation intensities' difference between seedfarms planted with rice three times a year and non-seedfarms rotated rice and upland crop seemed affected the changing rates of available Si within the study period. In the 0-20 cm soil layer, the average content of available Si decreased from 1646±581 kg SiO_2 ha^{-1} to 1283±533 kg SiO_2 ha^{-1} (-22%) and from 1440±645 kg SiO_2 ha^{-1} to 1202±563 kg SiO_2 ha^{-1} (-17%) in seedfarms and non-seedfarms, respectively. The demerit of sawah system in Indonesia mostly because of improper land management and imbalance nutrient input over long period of time.

Key words: green revolution, Java, sawah, seedfarms, total carbon and nitrogen, chemical characteristic.

1. Introduction

Green Revolution (GR) is the term referring mainly to dramatic increases in cereal-grain yields in many developing countries beginning in the late of 1960s. The GR technologies broadly classified into two majors categories. The first one is the breeding of new plant varieties; the second is the development of new agricultural techniques. The design of hybrid strains was motivated by a desire to, first, increase crop yield, and also to increase durability for transport and longevity for storage. The techniques refined and developed by the GR consisted of extensive use of chemical fertilizers, irrigation, pesticides and herbicides (FAO, 1984).

The GR technology has been criticized on several grounds, but the primary argument is environmental problem. Runoff and leaching of fertilizer, pesticide and herbicide continue to be significant causes of environmental pollution, killing off beneficial soil microbes and other organisms; erosion of the soil; and loss of valuable trace elements (Pimentel, 1996). Some studies in India found that application of GR technology caused of soil degradation and produced scarcity by reducing the availability of genetic diversity of crops (Singh, 2000). The similar conclusions were reported by researchers in Bangladesh (Rahman, 2003), China (Zhang *et al.*, 2003) and Latin America (Redclift, 1989). In case of Indonesia, GR technology was implemented in Java from 1966, by using the new high-yielding varieties (HYVs) of rice (i.e. IR-8) developed by the

International Rice Research Institute (IRRI). This island was chosen as a pioneer place in adopting the GR technology, because it has some advantages as compared to the others. Indonesia had about 6 million hectares of irrigated sawah and more than the half was located in Java and as the center of the country, Java much easier to be monitored. The term sawah refers to leveled rice field surrounded by bound with inlet and outlet for irrigation and drainage (Wakatsuki *et al.*, 1998). To support the adoption of GR technology, Indonesian government established many research stations for rice (seedfarm) throughout Java and supported them with good irrigation facilities, chemical fertilizers, pesticides and also qualified staffs. Due to the abundance of cheap labors, the mechanization has not been occurred for the rice cultivation in Java and Indonesia as a whole. The main function of seedfarm was the bridge of technologies transfer from the researchers (mostly from IRRI) to the farmers and also as the food security buffering for the country (Indonesian Ministry of Agriculture, 1995).

The GR was not a once-and-for-all change in technology. In the beginning of the period, the new rice cultivation systems consisted of new HYVs of rice, application of chemical fertilizers and pesticides were just applied in the seedfarms. Java had more than 20 seedfarms, spreading all over the island (Indonesian Ministry of Agriculture, 1995). Implementation of GR technology caused a lot of changes in rice cultivation systems in Java. The difference of land management practices might have affected the soil chemical properties. In seedfarm, where rice has been planted continuously using high amount of chemical fertilizers showed different trend as compared with non-seedfarm where farmers used low amount of chemical fertilizers in not all the sawah at once but in rotation way. Kawaguchi and Kyuma (1977) noted that in 1970, all seedfarms in Java were practicing GR technology using HYVs of rice, chemical fertilizers and pesticides and produced about 2.5 Mg ha^{-1} of husked rice on average. The productivity of seedfarms was almost two folds compared with non-seedfarms, where local varieties had planted with traditional management ways. However, since the GR technology started to be adopted to non-seedfarms, this wide gap of productivity was gradually eliminated and both of them have been able to produce 5.5 Mg ha^{-1} per cropping season (Indonesian Ministry of Agriculture, 1995).

Although seedfarms and non-seedfarms were located in one island, their cultivation and land management practices were quite different. Indonesia government supplied seedfarms with all the needs for rice cultivation. And in order to promise the food security, most of the seedfarms planted rice over the whole year, using the modern cultivation management systems. On the other hand, rice cultivation in non-seedfarms was affected by the availability of water, and application of chemical fertilizers and pesticides depending on the farmers' budget. Most of non-seedfarms cultivated by rented farmers that made some difficulties to tracks the history chemical fertilizers application on those sites. However, according to Lansing *et al.*, (2001), application rates of chemical fertilizers by Java's and Bali's farmers are much lower than government recommendation. During the less rainfall season, from April to September, most of non-seedfarms planted upland crops, dominated by vegetables such as soybean, green bean, peanuts, chili, maize, cassava and sugarcane in some crop rotation patterns (Nair, 1985).

The difference in cultivation and land management systems between seedfarms and non-seedfarms might also affected the sawah soil properties. The purposes of this study are to evaluate the effects of GR technology on the changes of sawah soil properties during the period of 1970 and 2003, in relation to difference of the soil

2. Materials and Methods

2.1. Description of study area and sampling sites

Java is the smallest among the five biggest islands in Indonesia archipelago. It lies between 05^{o}52'34" S to 08^{o}46'46" S and 105^{o}12'40" E to 114^{o}35'38" E. Although the total land area of this island is just 132,187 km^{2}, which is about 7 percent of the total land area of Indonesia, but more than half of Indonesian people lives here. Figure 1 shows the study area and distribution of sampling sites both in 1970 and 2003 throughout the island. Most of the sampling sites were located in the northern part along the coastal plain, because southern part of Java is mountainous and difficult to access. Tables 1 gives the brief information on soil and land use pattern both in 1970 and 2003, including the general description in each sampling sites.

The present land use patterns in each seedfarm and non-seedfarm were almost similar compared to 1970, but cultivation intensity increased. Most of the seedfarms grew rice three times a year and non-seedfarms planted with rice and upland crop in rotation patterns. Although rice is still the major crop in Java, the area of 112,000 hectares sawah decreased during the period 1984-2000 or about 7000 ha every year (Verburg *et al*., 1999). Among 46 sampling sites in 1970, four of them (site number 2, 4, 5, and 40) were not sampled in 2003 because land use changed to non-agricultural purposes and two sites (number 15 and 30) changed to other crop cultivation were also excluded in this study. For the remined 40 sites in 2003, twenty-five of them were identified as the original sites with 1970's (Table 1) consulting with the description sheets made by

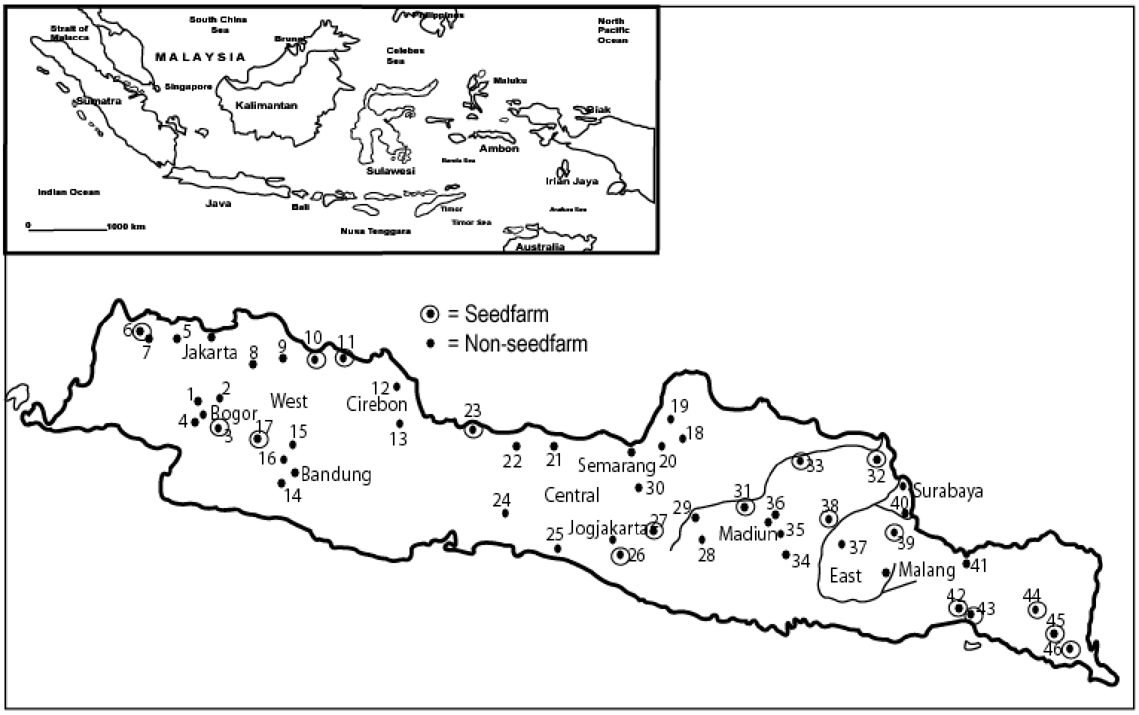

Figure 1. The map of Indonesia showing the Java Island with the main cities and distribution of sampling sites both in 1970 and 2003

Kawaguchi and Kyuma and/or information from the landowners and the old farmers nearby the sites. Since 15 sites could not be confirmed as the original due to land use changed and lack of information, soil were collected from the closest site to 1970's sampling areas. Among 40 sites in 2003, twenty-two sites were located in non-seedfarm sawah and the other eighteen were in seedfarms. Inceptisols and Vertisols were the main two soil types in the sites, dominating 24 and 14 locations, respectively. The other two, number 8 and 10 belonged to Ultisols and Alfisols (Table 1).

2.2. Soil sampling and interview

The study used soil samples taken by Kawaguchi and Kyuma in 1970 as references. These soil samples had been air dried and kept in sealed plastic bottles in a storage room. The second sampling was done in April and December 2003 from the same or closest to original sites in 1970. Soil samples were collected from each horizon in a profile at the respective sites by using 100 cm^3 core samplers to determine the bulk density of soil. Composite soil samples from the each horizon were also collected as well for chemical analyses. To ensure the reliability of 1970 soil samples, our analytical data and the original data from Kyoto University was compared. Both analytical results were found very similar with less than 5% difference (data not published).

In order to get the latest information about the changes of rice cultivation systems and productivity in seedfarms and non-seedfarms during the period of 1970 and 2003, we interviewed the seedfarms staffs and the farmers on the respective sites assisted by the counterparts as interpreter.

2.3. Laboratory analyses.

Total carbon and nitrogen. Air-dried soil samples were ground and passed through a 2 mm sieve and stored in plastic boxes for laboratory analyses. Soil samples from both 1970 and 2003 were treated similarly. A total of 349 soil samples (165 for 1970 and 184 for 2003) were analyzed for total carbon (TC) and total nitrogen (TN) contents. Finely ground soil samples were oven dried at 80^{o}C for about 24 hours. Total carbon and nitrogen were determined by dry combustion method (Nelson and Sommers, 1982) using Yanaco CN Corder Model MT-700 (Yanagimoto MFG. Co. Ltd., Kyoto, Japan).

Table 1. Descriptions of sampling sites and land use pattern during the period between 1970 and 2003 Java, Indonesia.

Sampling Code	Location name	GPS reading		Elevation	Land use pattern		USDA Taxonomy	Note
		South	East		1970§	2003		
In-1	Kedung Halang, Bogor	S 06° 33'0.6.3"	E 106° 48'26.4"	213 meter	rice-upland crop	upland crop	Aeric Epiaquepts	B-NS
In-3	Bendungan Ciawi, Bogor	S 06° 39'43.2"	E 106° 51'40.4"	529 meter	rice-rice	rice-rice-upland crops	Aeric Epiaquepts	A-SF
In-6	Kebun Percobaan Singamerta, Ciruas	S 06° 07'14.7"	E 106° 14'36.5"	26 meter	rice-rice	rice-rice-rice	Typic Epiaquepts	A-SF
In-7	Petung Sentul, Kragilan Serang	S 06° 07'52.0"	E 106° 16'16.5"	31 meter	rice-upland crop	rice-rice-upland crops	Typic Halaquepts	B-NS
In-8	Pasir Gombong Lemahabang, Bekasi	S 06° 07'52.0"	E 106° 16'16.5"	31 meter	rice-upland crop	rice-rice-upland crops	Typic Kanhapludults	B-NS
In-9	Palawad, Karawang	S 06° 17'30.0"	E 107° 21'13.6"	32 meter	rice-rice	rice-rice-upland crops	Vertic Epiaquepts	B-NS
In-10	Balitpa Sukamandi, Subang	S 06° 21'27.1"	E 107° 38'38.2"	31 meter	rice-rice	rice-rice-rice	Aeric Endoaqualfs	A-SF
In-11	LPPP Pusakanegara, Subang	S 06° 16'43.0"	E 107° 52'26.6"	22 meter	rice-rice	rice-rice-rice	Vertic Epiaquepts	A-SF
In-12	Sudikampiran, Sliyeg Indramayu	S 06° 29'00.7"	E 108° 22'44.4"	22 meter	rice-rice	rice-rice-upland crop	Vertic Endoaquepts	B-NS
In-13	Sampora, Cilimus Kuningan	S 06° 51'32.3"	E 108° 29'26.1"	452 meter	rice-upland crop	rice-rice-upland crops	Typic Dystropepts	B-NS
In-14	Pamoyanan, Ketapang Bandung	S 06° 00'08.5"	E 107° 33'10.1"	685 meter	rice-rice	rice-rice-upland crops	Typic Endoaquepts	B-NS
In-16	Warungkaweni Cipageran, Cimahi	S 06° 51'17.4"	E 107° 32'54.1"	825 meter	rice-upland crop	upland crop	Mollic Fragiaquepts	B-NS
In-17	LPPP Ciheya, Ciranjang, Cianjur	S 06° 50'15.7"	E 107° 16'26.5"	209 meter	rice-rice	rice-rice-rice	Aeric Epiaquerts	A-SF
In-18	Medini, Undaan Kudus	S 06° 55'04.6"	E 110° 47'43.7"	22 meter	rice-upland	rice-rice-rice/upland crops	Vertic Endoaquepts	A-NS
In-19	Mayong Lor, Mayong Jepara	S 06° 45'41.7"	E 110° 45'08.4"	25 meter	rice-upland crop	rice-rice-upland crops	Aquic Eutropepts	B-NS
In-20	Katonsari, Demak	S 06° 54'42.2"	E 110° 36'59.0"	17 meter	rice-upland crop	rice-rice-upland crops	Typic Calciaquepts	A-NS
In-21	Kartoharjo, Buaran Pekalongan	S 06° 55'19.5"	E 109° 40'16.5"	14 meter	rice-upland crop	rice-rice-upland crops	Aeric Epiaquerts	A-NS
In-22	Sirandu, Pemalang	S 06° 54'11.5"	E 109° 22'53.2"	25 meter	rice-upland crop	rice-upland crop	Aeric Epiaquerts	A-NS
In-23	Seedfarm Bulakamba, Brebes	S 06° 21'27.1"	E 108° 57'07.0"	11 meter	rice-rice	rice-rice-upland crops	Typic Natraquerts	A-SF
In-24	Bojong, Purbolinggo	S 07° 24'44.4"	E 109° 22'31.0"	45 meter	rice-upland crop	rice-rice-upland crops	Typic Endoaquepts	B-NS
In-25	Lajer Ambal, Kebumen	S 07° 44'45.6"	E 109° 43'28.8"	22 meter	rice-upland crop	rice-rice-upland crops	Vertic Endoaquepts	A-NS
In-26	Seed farm Wonocatur, Bantul	S 07° 48'02.5"	E 110° 24'27.3"	118 meter	rice-rice	rice-rice-rice	Aeric Epiaquepts	A-SF
In-27	Humo Seed farm, Semangkak	S 07° 42'29.5"	E 110° 35'51.6"	159 meter	rice-rice	rice-upland crop	Aeric Epiaquepts	A-SF
In-28	Jumapolo, Karanganyar	S 07° 42'29.5"	E 111° 00'04.8"	339 meter	rice-upland crop	rice-rice-upland crops	Typic Dystrustepts	B-NS
In-29	Papahan, Tasikmadu Karanganyar	S 07° 42'38.2"	E 111° 17'17.2"	182 meter	rice-upland crop	rice-rice-rice/upland crops	Typic Epiaquerts	A-NS
In-31	LPPP Ngale, Paron Ngawi	S 07° 24'37.6"	E 111° 22'18.3"	68 meter	rice-rice	rice-rice-upland crops	Typic Calciaquerts	A-SF
In-32	BPMD Sukodadi, Lamongan	S 07° 05'28.0"	E 112° 19'41.7"	26 meter	rice-upland crop	rice-rice-upland crops	Typic Epiaquerts	A-SF
In-33	BPMD Brenggolo, Bojonegoro	S 07° 07'39.4"	E 111° 45'21.1"	37 meter	rice-upland crop	rice-rice-upland crops	Aeric Endoaquerts	B-SF
In-34	Kresek Wungu, Madiun	S 07° 41'47.9"	E 111° 36'58.0"	277 meter	rice-upland crop	rice-rice-upland crops	Aeric Epiaquepts	B-NS
In-35	Banjarsari, Dagangan Madiun	S 07° 41'01.5"	E 111° 35'49.2"	214 meter	rice-upland crop	rice-rice-rice	Typic Calciaquerts	B-NS
In-36	Patang, Nglames Madiun	S 07° 35'31.1"	E 111° 32'51.6"	74 meter	rice-rice	rice-rice-upland crops	Typic Epiaquerts	A-NS
In-37	Pelem, Paree Kediri	S 07° 45'58.8"	E 112° 10'02.4"	113 meter	rice-upland crop	rice-rice-upland crops	Typic Epiaquepts	B-NS
In-38	Seed farm Waung, Baron Nganjuk	S 07° 35'51.7"	E 112° 02'03.3"	56 meter	rice-upland crop	rice-rice-upland crops	Aeric Epiaquepts	A-SF
In-39	LPPP Mojosari, Mojokerto	S 07° 30'27.9"	E 112° 31'36.6"	33 meter	rice-upland crop	rice-rice-rice	Aeric Epiaquepts	A-SF
In-41	Maron Kulon, Maron Probolinggo	S 07° 50'48.8"	E 113° 21'02.2"	78 meter	rice-upland crop	rice-rice-rice/upland crops	Typic Epiaquepts	A-NS
In-42	Labruk Kidul, Lumajang	S 08° 08'45.4"	E 113° 12'18.6"	89 meter	rice-rice	rice-rice-rice/upland crops	Typic Epiaquerts	A-SF
In-43	BPMD Yasowilangun, Lumajang	S 08° 12'58.8"	E 113° 18'06.7"	30 meter	rice-upland crop	rice-rice-rice	Aeric Endoaquerts	A-SF
In-44	Balai benih Srimurni, Arjasa Jember	S 08° 07'10.4"	E 113° 44'47.9"	181 meter	rice-upland crop	rice-rice-rice	Fluvaquentic Epiaque	A-SF
In-45	LPPP Genteng, Banyuwangi	S 08° 22'47.4"	E 114° 08'37.0"	159 meter	rice-rice	rice-rice-rice/upland crops	Aeric Epiaquepts	A-SF
In-46	Seed farm Sukorejo, Banyuwangi	S 08° 29'30.7"	E 114° 08'13.3"	93 meter	rice-upland crop	rice-rice-rice	Typic Calciaquerts	A-SF

Note: A = original sites; B = close to original sites; SF = seedfarms; NS = non-seedfarms; §= data from Kawaguchi and Kyuma (1977)

Available nitrogen. Six grams of soil in a glass tube was submerged with distilled water and cover with rubber stopper. These tubes were incubated at 30 ^{o}C for 28 days. After incubation, the inorganic nitrogen of soil was extracted with 2 M KCl and the content was determined by steam distillation method with MgO and Devarda alloy (JSSPN, 1986).

Bulk density. Bulk density is necessary for converting carbon and nitrogen contents on a weight basis to content on the volume basis (e.g. Mg ha^{-1} to the 100 cm depth). Bulk density of a soil was calculated by using the sample in a 100 cm^3-core. After oven dried at 105°C for about 72 hours, the weight of soil per core sample volume (100 cm^3) was measured. The bulk density values in 2003 were used to calculate the carbon and nitrogen contents for both samples taken in 1970 and 2003, since the bulk density of 1970's samples was not determined.

Chemical properties of soils. The air-dried soil samples were ground and passed through a 2-mm sieve. Soil pH was measured by using a glass electrode method with a soil: water ratio of 1:2.5 (IITA, 1979; Mclean 1982). Exchangeable acidity was determined by first extracting with 1 M KCl and titrating with NaOH (Mclean, 1965). Exchangeable base cations (Ca, Mg, K and Na) were extracted by 1 M neutral ammonium acetate (Thomas, 1982) and then exchangeable Ca and Mg were determined by using Inductively Coupled Plasma-Atomic Emission Spectroscopy (Shimadzu ICPS 2000) and exchangeable K and Na determined by Atomic Absorption Spectrophotometer (Shimadzu AS 680). Effective cation exchange capacity (eCEC) represents the sum of the amount of exchangeable bases and the exchangeable acidity. Available P was extracted by Bray 2 method and the content was determined by colorimetry with UV/VIS Spectrophotometer (Jasco V-530, Tokyo-Japan) (Bray and Kurtz, 1945).

2.4. Calculation and statistical analyses

The calculation method of soil carbon and nitrogen content. The depths of the identical horizons were not perfectly the same but very similar in the 1970 and 2003 (Figure 2 and 3). The carbon and nitrogen contents were estimated on per hectare basis using the equation below (Ali *et al.*, 1997). For an individual profile with *n* horizons, the calculation of the total carbon and nitrogen contents on a volume basis was as follow:

$$Td = \sum_{i=1}^{n} piPiDi \qquad (1)$$

where, $Td =$ total content of carbon or nitrogen (Mg ha^{-1}) at a depth d, $pi =$ bulk density (Mg m^{-3}) of horizon i, $Pi =$ proportion of carbon or nitrogen (g kg^{-1}) in horizon i, $Di =$ thickness of the horizon i *(cm)*. The similar calculation also applied for another soil characters.

Statistical analyses. To examine the effect of land management differences on the change patterns of all data were analyzed by SPSS (Version 11.0 for Windows). Paired-samples T-test was used for comparing means of TC and TN contents using land management differences refered to seedfarm and non-seedfarm as blocks

3. Results and Discussion

3.1. Change of the carbon and nitrogen stocks in sawah soil during the period of 1970 - 2003.

Table 2 described the mean and the changes of TC and TN contents in each site. The change of TC content ranged from -29.5 % (site number 8) to 137.9 % (site number 27), but most of the sites changed by bigger than 25 %; while the changed of TN content ranged from -26.3 % (site number 45) to 121.3 % (site number 24), and most of them also changed by more than 25 %. Figure 2 and 3 show the profile distributions of TC and TN contents in 1970 and 2003 in seedfarms and non-seedfarms, respectively. The TC and TN contents highly varied among the sites. The mean TC content seedfarms sites was increased throughout the soil profile in from 8.23 ± 5.06 g kg^{-1} to 9.81 ± 5.01 g kg^{-1} during the period of 1970 and 2003; while in non-seedfarms that changed from 8.37 ± 5.11 g kg^{-1} to 10.27 ± 6.26 g kg^{-1}. The mean values of TN content in seedfarms increased from 0.85 ± 0.46 g kg^{-1} to 1.05 ± 0.46 g kg^{-1} and 0.91 ± 0.42 g kg^{-1} to 1.04 ± 0.52 g kg^{-1} in non-seedfarms sites.

Table 2. The changes of TC and TN (Mg ha^{-1}) content in topsoil layer of each sampling sites during the period between 1970 and 2003 in Java, Indonesia and in Bangladesh during the period of 1967 and 1995.

Profile no./location	Total Carbon (Mg ha^{-1})			Total Nitrogen (Mg ha^{-1})			Bulk density
	1970[a]	2003 [b]	% change	1970[a]	2003 [b]	% change	(Mg m^{-3})
1. Kedunghalang Bogor	39.29	39.15	-0.4	3.77	3.88	2.8	1.11
3. Bendungan Ciawi	43.93	48.55	10.5	4.37	5.27	20.5	1.15
6. Singamerta Ciruas	38.70	37.76	-2.4	4.01	4.20	4.6	1.18
7. Petung Sentul	11.22	12.61	12.4	1.10	1.60	45.9	1.10
8. Pasir Gombong	40.41	28.50	-29.5	1.94	3.15	62.7	1.21
9. Palawad Karawang	48.14	39.95	-17.0	4.01	4.09	2.0	1.18
10. Balitpa Sukamandi	24.93	34.74	39.4	3.15	3.80	20.7	1.21
11. LPPP Pusakanegara	41.33	50.33	21.8	3.28	5.38	64.2	1.26
12. Sudikampiran Sliyeg	20.09	29.13	45.0	3.72	3.25	-12.7	1.24
13. Sampora Cilimus	21.18	39.00	84.1	2.86	3.92	37.3	1.19
14. Pamoyanan Ketapang	52.92	58.63	10.8	5.80	5.63	-2.9	1.26
16. Warungkaweni Cipageran	38.56	48.91	26.9	3.81	4.86	27.7	1.19
17. LPPP Ciheya	40.25	45.62	13.4	4.13	4.58	10.9	1.29
18. Medini Undaan, Kudus	30.21	71.63	137.1	4.10	6.03	47.1	1.28
19. Mayong Lor Jepara	27.82	28.33	1.8	2.68	2.77	3.2	1.22
20. Katonsari Demak	29.97	54.43	81.6	4.57	5.23	14.5	1.27
21. Kartoharjo Buaran	20.99	46.65	122.2	2.56	4.24	65.6	1.28
22. Sirandu Pemalang	24.70	38.47	55.8	2.02	4.08	102.2	1.26
23. Bulakamba Brebes	27.90	33.54	20.2	2.05	4.10	100.0	1.28
24. Bojong Purbolinggo	33.92	70.05	106.5	2.95	6.53	121.3	1.22
25. Lajer Ambal, Kebumen	35.70	46.36	29.9	2.86	4.29	50.2	1.19
26. Wonocatur Bantul	18.64	18.88	1.3	1.65	2.51	52.2	1.18
27. Semangkak Klaten	18.41	43.79	137.9	2.12	4.67	119.7	1.18
28. Jumapolo Karanganyar	19.72	26.21	32.9	1.62	2.82	73.5	1.16
29. Tasikmadu Karanganyar	13.46	30.67	127.9	1.78	3.26	83.2	1.27
31. LPPP Ngale	34.58	48.00	38.8	2.66	3.75	40.8	1.33
32. BPMD Sukodadi	32.23	31.03	-3.7	1.83	2.69	46.8	1.31
33. BPMD Brenggolo	46.70	58.05	24.3	3.61	4.91	35.9	1.29
34. Krese Wungu	38.84	45.64	17.5	3.74	4.23	12.9	1.22
35. Banjarsari Dagangan	30.99	39.34	27.0	1.78	3.61	102.8	1.27
36. Patang, Nglames	34.27	60.19	75.6	3.02	5.08	68.1	1.26
37. Pelem Paree	16.42	21.65	31.8	1.83	2.04	11.1	1.19
38. Waung Baron Nganjuk	27.38	37.32	36.3	2.60	3.61	39.2	1.18
39. LPPP Mojosari	23.13	24.25	4.9	2.12	2.46	15.8	1.18
41. Maron Kulon	26.14	34.75	32.9	2.18	3.00	37.7	1.21
42. Labruk Kidul Lumajang	37.00	38.85	5.0	3.50	4.28	22.4	1.25
43. BPMD Yosowilangun	50.55	46.60	-7.8	5.33	4.69	-12.0	1.27
44. Srimurni Arjasa	27.38	32.26	17.8	2.60	3.32	27.9	1.18
45. LPPP Genteng	47.34	34.60	-26.9	4.88	3.60	-26.3	1.22
46. Sukorejo Bangorejo	40.57	42.20	4.0	3.02	3.26	7.8	1.26
Mean Java, Indonesia	31.9	40.4***	26.7	3.0	3.96***	30.6	1.22
Mean Bangladesh §	23.7	21.1	-11.0	2.5	2.2	-11.8	1.45

[a] Calculated base on the bulk density in 2003

[b] Paired samples T-test; *** significant at 0.001 level

§ data from Ali et al. (1997)

The variation in changing rates of TC and TN content among the sampling sites could be affected by the management practices in each site. For instance, although the site number 45 was seedfarm that planted with rice over the whole year, the TC content decreased by -26 %; the content in site 18 that was non-seedfarm increased more than 100 %. This disparity might be due to the difference of harvesting management practices between these two sites. In the site 45, whole rice straw was always taken away from the sawah by farmers nearby to feed their cattle's; on the other hand, the farmers in site 18 only took out the rice grain and left the plant residues decomposed in the field, which was the typical harvesting management in Java. Lansing *et al.,* (2001) wrote that most of Java's and Bali's farmers thresh the rice stalks in situ and remove only the grain, leaving the rest of the plant to be plowed under or burned. The change

Table 2. The changes of TC and TN (Mg ha^{-1}) content in topsoil layer of each sampling sites during the period between 1970 and 2003 in Java, Indonesia and in Bangladesh during the period of 1967 and 1995.

The application of GR technology in Java caused the accumulation of TC and TN in sawah soils with the changing rate of about 30 % during the period of 1970-2003. On the other hand, within the similar period, Bangladesh decreased by -11 % for these two parameters (Table 2). The differences of changing rate of sawah productivity in these two regions could be a reason for these results. During the period of 1966 to 1996, the rice production increased from 1.8 Mg ha^{-1} to 4.5 Mg ha^{-1} (150 %) in Indonesia, which was much higher compared with the case in Bangladesh in which that just increased from 1.7 Mg ha^{-1} to 2.8 Mg ha^{-1} (65 %) (Otsuka, 2000). The farming systems were also different. Rice cultivation was predominant in Indonesia, which might accumulate more organic matter as main resources of carbon and nitrogen in the soils compared with those in Bangladesh, where the upland crop was dominated (Ali *et al.,* 1997). The amount of carbon stored in sawah system is greater than upland because of different biochemical processes and mechanisms mainly caused by the presence of flooded water in sawah (Guo and Lin, 2001). The fraction of remaining carbon from total quantities added is higher under flooding than under non-flooding condition. Both decomposition and mineralization rates of organic matter in anaerobic condition are considerably retarded compared with those under aerobic condition. Therefore, sawah has a tendency to enhance carbon and nitrogen accumulation in the soil (Zhang and He, 2004).

3.2. Vertical distribution of carbon and nitrogen under different land use management

Figure 2 and 3 show the effect of GR on the profile distribution of TC and TN contents in respective sites in seedfarms and non-seedfarms in 1970 and 2003. It was clear that the changes and accumulation of TC and TN contents in each site were predominantly found in topsoil. In the deeper layers, the TC and TN contents of soils in 1970 were not so different compared with samples collected in 2003 for both seedfarms and non-seedfarms. This means that the difference of land use management practices did not affected the TC and TN distribution in deeper layers of soils. The International Rice Research Institute (IRRI-1986) and Zhang *et al.*, (2003) reported that intensive use of sawah would form compacted and impermeable layer below the puddle layer that will protect the movement of nutrient and water to the deeper soil layer. This attributed TC and TN accumulation in top soils. The greater accumulation of TC and TN in top soil layers could be explained by increased input of plant residues, reduced decomposition rate of organic matters and increased nitrogen fixation in the sawah systems (Kundu and Ladha, 1995; Roger and Ladha, 1992).

There were no significant difference both in TC and TN distribution between Inceptisols and Vertisols. The long-term intensive use of sawah already eliminated the difference of the original characteristic in Inceptisols and Vertisols in 1970. Vertisols are clayey soil characterized with the ability to form the deep crack in dry condition and the surface soils rich in nutrient move down through the crack (Kirby *et al.*, 2000 and Tomar *et al.*, 1996), so that TC and TN were expected to distribute more to deeper horizon in Vertisols as compared to the other soil type. However, under sawah condition it seemed that phenomenon did not occur frequently. As shown in Table 1, most of Vertisols were found in seedfarms sampling sites, where the intensive rice cropping kept soil always in wet condition and might prevent Vertisols to form deep cracks, and the movement of nutrient included carbon and nitrogen to the deeper horizon.

3.3. Effects of land management on the changes of total carbon and nitrogen.

Table 3 shows the difference of management practices in seedfarms and non-seedfarms influenced the changing rates of TC and TN contents in 0 – 20 cm and in 0 – 100 cm soil layers. The mean value of the TC in seedfarms increased from 34.50 to 39.24 Mg ha^{-1} (change by 13.7 %) for 0 – 20 cm soil layer, and from 92.68 to 112.83 Mg ha^{-1} (change by 21.7 %) in 0 – 100 cm soil layer, respectively. Within the same period the TC content in non-seedfarms significantly increased from 29.77 to 41.37 Mg ha^{-1} and from 79.6 to 114.8 Mg ha^{-1} in 0 – 20 cm and 0 – 100 cm of the soil layer, respectively, with the relative changes of about 40 % in both soil layers. In case of TN, seedfarms and non-seedfarms increased from 3.16 to 3.95 Mg ha^{-1} (change by 25.0 %) and 2.94 to 3.98 Mg ha^{-1} (change by 35.4 %) in 0 – 20 cm soil layer, which was significantly different at 0.01 and 0.001 levels, respectively. And in 0 – 100 cm soil layer, the TN was changed by 28 % in both sites (Table 3). Although, the TN contents in seedfarms were much higher as compared with those in non-seedfarms in 1970, they were found to be similar in 2003 (Table 3).

Kawaguchi and Kyuma (1977) reported that in 1970 seedfarms and non-seedfarms sites produced husked rice about 2.5 Mg ha^{-1} and 1.5 Mg ha^{-1}, respectively, but from 1990's both of them have been able to produce about 5.5 Mg ha^{-1} of husked rice per cropping season (Indonesian Ministry of Agriculture, 2001). It means that the increasing rate of rice productivity during the period between 1970 and 2003 in non-seedfarms was more than three folds, which was much higher than that in seedfarms. The increase of rice productivity probably related with the increase of TC and TN contents in both sites. Increase of the rice production augmented the amount of plant residues such as straw, leaf and root remained in sawah field, especially in non-seedfarms in which residues were usually left in the field. This might has contributed to the increment of the TC and TN in both seedfarms and non-seedfarms. Tiessen *et al.*, (1994) reported that increase of plant production would increase the organic matter input to the soils as a major resource of carbon and nitrogen in the soils.

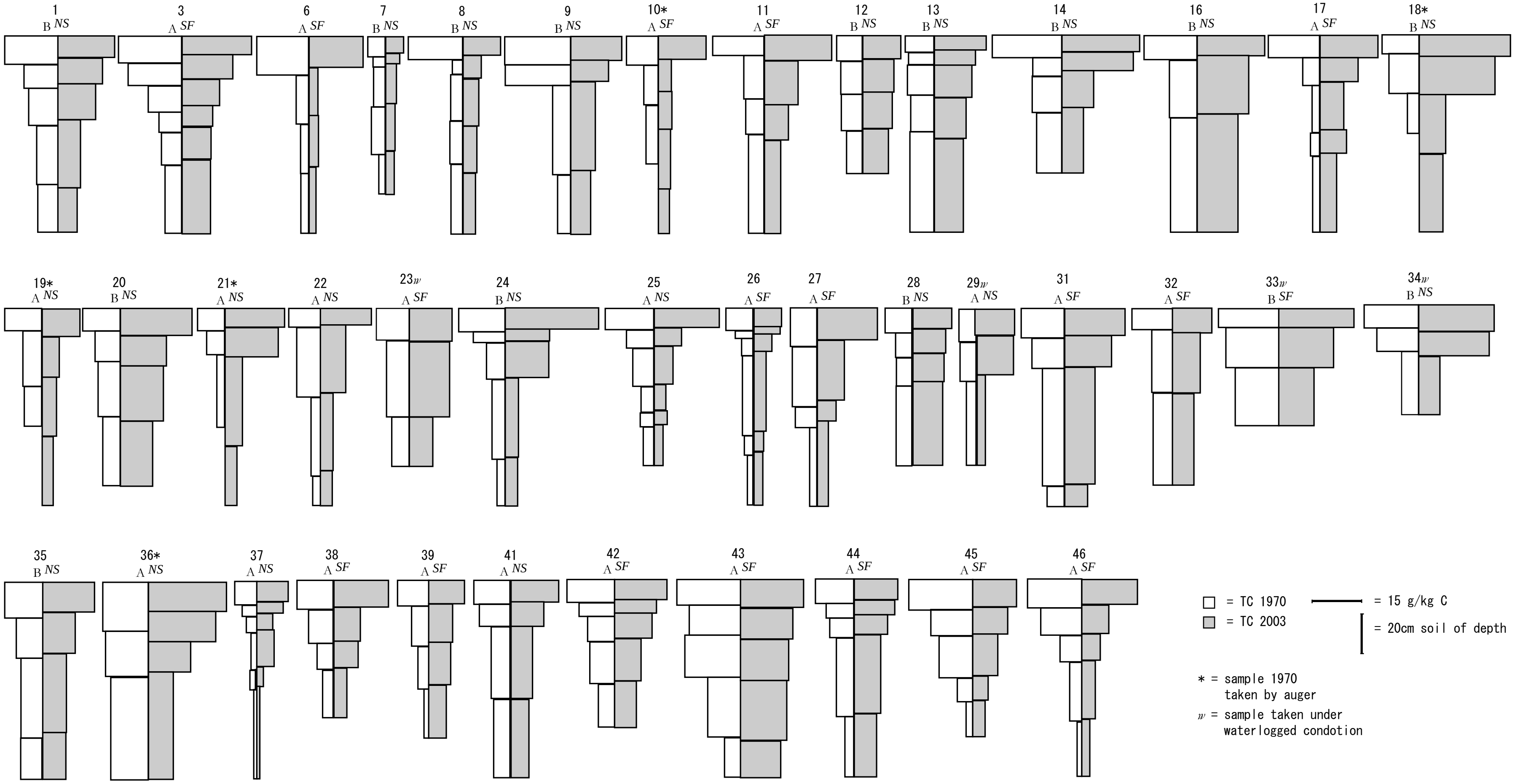

Figure 2. The effect of GR technology application on the profiles distribution of TC (g kg^{-1}) content of soil in seedfarm (^{SF}) and non-seedfarm (^{NS}) sites during the period between 1970 and 2003, in Java Island, Indonesia. A = original sites; B = closest to original sites.

Figure 3. The effect of GR technology application on the profiles distribution of TN (g kg^{-1}) content of soil in non-seedfarm (^{SF}) and non-seedfarm (^{NS}) sites during the period between 1970 and 2003, in Java Island, Indonesia. A = original sites; B = closest to original sites.

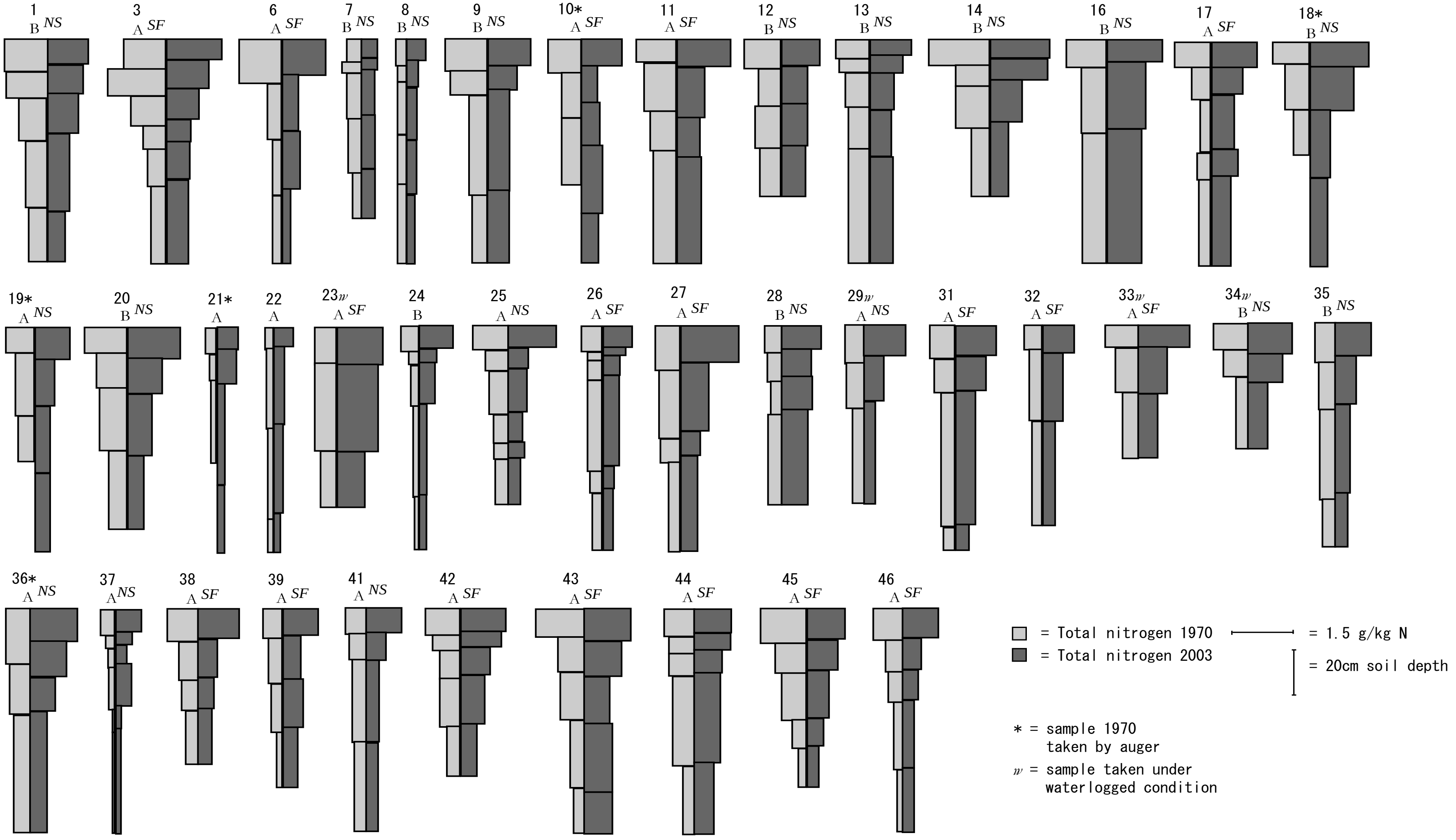

Table 3. The changes of TC and TN (Mg ha^{-1}) content in 0 – 20 cm and 0 – 100 cm soil layer in seedfarms and non-seedfarms during the period of 1970 and 2003 in Java, Indonesia.

Total Carbon (Mg ha^{-1})

	Seedfarm				Non-Seedfarm			
	0 - 20 cm		0 - 100 cm		0 - 20 cm		0 - 100 cm	
	1970	2003	1970	2003	1970	2003	1970	2003
n	18	18	18	18	22	22	22	22
mean	34.50	39.24	92.68	112.83	29.77	41.37	79.60	114.86
SD	9.95	9.70	39.47	40.91	10.88	15.12	28.07	40.50
mean change		4.74		20.15		11.60		35.26
% change		13.7		21.7		39.0		44.3
T -test		*		***		***		***

Total Nitrogen (Mg ha^{-1})

	Seedfarm				Non-Seedfarm			
	0 - 20 cm		0 - 100 cm		0 - 20 cm		0 - 100 cm	
	1970	2003	1970	2003	1970	2003	1970	2003
n	18	18	18	18	22	22	22	22
mean	3.16	3.95	9.34	12.03	2.94	3.98	8.93	11.44
SD	1.07	0.89	4.01	4.10	1.15	1.24	3.16	3.30
mean change		0.79		2.69		1.04		2.51
% change		25.0		28.8		35.4		28.1
T -test		**		***		***		***

n = number of sampling sites
Significant level: * ≤ 0.05 < ** ≤ 0.01 < *** ≤ 0.001

Continuous cultivation of rice in monoculture system with more than 2.5 planting index (PI) per year in seedfarms promoted anaerobic condition in soils, which might inhibit the decomposition process of organic matter. To avoid the accumulation of fresh organic matters on the land surface, the plant residues in the seedfarms were burned several days after harvesting of rice (according to the interview). This management was quite different with those in the non-seedfarms, in which rice and upland crop planted in rotation systems. Within a rotation period, soil changed from reduction to oxidation condition frequently, resulting in the acceleration of decomposition of the plant residues (Lansing *et al*., 2001). The difference in post-harvesting managements between seedfarms and non-seedfarms seemed to play an important role in the changing pattern of TC and TN contents in the soils.

3.4. Effect of land management's on the changes of soils chemical properties.

The effects of land management differences between seedfarms and non-seedfarms on the changes of soil properties are presented in Table 4. The mean pH value in 0 – 20 cm and 0 – 100 cm soil layers on both sites significantly decreased at 0.001 level. The mean values of soil pH in seedfarms decreased from 7.13 ± 0.66 to 5.88 ± 1.02 (-17 %) and from 7.26 ± 0.46 to 6.38 ± 0.64 (-12 %) in 0 – 20 cm and 0 – 100 cm soil layer, respectively; while in non-seedfarms changes from 6.71 ± 0.81 to 5.81 ± 0.81 (-13 %) and from 7.01 ± 0.70 to 6.28 ± 0.72 (-10 %) within the respective soil layers. Although the percentage changes of mean pH between seedfarms and non-seefarms in both soil depth showed some differences, but statistically there not significant (Table 4).

The mean exchangeable acidity showed reverse trend with pH and significantly increased from 8.68 ± 3.40 to 12.80 ± 4.60 kmol$_c$ ha^{-1} (47 %) and from 29.70 ± 12.00 to 41.40 ± 16.00 kmol$_c$ ha^{-1} (39 %) in 0 – 20 cm and 0 – 100 cm soil layers respectively in seedfarms (Table 4). The similar trend was also found in non-seedfarms with lower changing rate. Mean exchangeable acidity in non-seedfarms also significantly increased from 9.80 ± 2.80 to 13.60 ± 2.80 kmol$_c$ ha^{-1} (38 %) and from 35.10 ± 17.90 to 43.80 ± 13.40 kmol$_c$ ha^{-1} (25 %) in the respective soil layer (Table 4). The effect of land management difference between seedfarms and non-seedfarms on the change rate of exchangeable acidity was not statistically significant. Although the application rate of nitrogen fertilizers that could be acid source in seedfarms always followed the government recommendation, that in non-seedfarms depended on the farmer's budget, creating the dissimilarity in the change pattern of pH and exchangeable acidity. Brady and Weil (2002) reported the intensive application of nitrogen fertilizer has brought about significant acceleration of soil acidification.

The exchangeable base cations that showed certain distinctive trends as the effect of land management practice are different between seedfarms and non-seedfarms. Mean values of exchangeable Ca content in 1970 and 2003 were not statistically different in

Table 4. The effects of land managements on the changes of some chemical properties of sawah soil in 0 – 20 cm and 0 – 100 cm soil layers in seedfarm and non-seedfarm sites during the period of 1970 - 2003 in Java, Indonesia

0 - 20 cm

	Seedfarm				Non-seedfarm				
Soil properties	*n*	mean±SD 1970	mean±SD^{a} 2003	Change (%)	*n*	mean±SD 1970	mean±SD^{a} 2003	Change(%)	T-test^{b}
pH H_2O (1:2.5)	18	7.13±0.66	5.88±1.02***	-1.25(-17)	22	6.71±0.81	5.81±0.81***	-0.90(-13)	-1.259^{ns}
Exch. Acidity (kmol_c ha^{-1})	18	8.68±3.40	12.80±4.60***	4.11(47)	22	9.84±2.78	13.60±2.90***	3.26(38)	1.919^{ns}
Exch. Ca (kmol_c ha^{-1})	18	60.10±52.20	64.20±61.60^{ns}	4.15(7)	22	61.90±49.50	66.80±64.20^{ns}	4.92(8)	0.470^{ns}
Exch. Mg (kmol_c ha^{-1})	18	18.80±10.80	19.30±11.70^{ns}	0.49(3)	22	13.20±9.20	14.70±9.30*	1.58(12)	-1.074^{ns}
Exch. K (kmol_c ha^{-1})	18	1.62±0.84	1.75±1.13^{ns}	0.14(8)	22	1.27±0.56	0.98±0.67*	-0.30(-23)	1.864^{ns}
Exch. Na (kmol_c ha^{-1})	18	3.49±2.63	2.07±2.88*	-1.42(-41)	22	3.11±2.91	1.34±0.96***	-1.77(-57)	0.423^{ns}
ECEC (kmol_c ha^{-1})	18	92.70±56.40	100.20±66.80^{ns}	7.47(8)	22	89.30±57.10	97.50±67.50^{ns}	8.19(9)	0.880^{ns}
Available P (kg P_2O_5 ha^{-1})	18	198±211	393±382***	194(98)	22	86±49	143±105**	57(67)	3.054^{ns}

0 - 100 cm

	Seedfarm				Non-seedfarm				
Soil properties	*n*	mean±SD 1970	mean±SD^{a} 2003	Change (%)	*n*	mean±SD 1970	mean±SD^{a} 2003	Change(%)	T-test^{b} 1970
pH H_2O (1:2.5)	18	7.26±0.46	6.38±0.64***	-0.89(-12)	22	7.01±0.70	6.28±0.72***	-0.72(-10)	-0.842^{ns}
Exch. Acidity (kmol_c ha^{-1})	18	29.70±12.00	41.40±16.00***	11.67(39)	22	35.10±17.90	43.80±13.40**	8.75(25)	0.895^{ns}
Exch. Ca (kmol_c ha^{-1})	18	267.1±179.1	278.5±196.7^{ns}	11.45(4)	22	303.8±268.5	261.0±224.4*	-42.8(-14)	2.241^{ns}
Exch. Mg (kmol_c ha^{-1})	18	98.70±58.60	99.60±53.10^{ns}	0.85(1)	22	62.70±40.70	60.00±40.20^{ns}	-2.66(-4)	0.484^{ns}
Exch. K (kmol_c ha^{-1})	18	7.94±3.20	7.14±4.74^{ns}	-0.80(-10)	22	6.01±2.13	4.05±2.56***	-1.96(-33)	1.477^{ns}
Exch. Na (kmol_c ha^{-1})	18	15.50±4.90	10.60±12.20*	-4.88(-31)	22	13.20±7.80	6.98±5.09***	-6.24(-47)	0.530^{ns}
ECEC (kmol_c ha^{-1})	18	419.0±196.6	437.3±216.5^{ns}	18.28(4)	22	420.8±299.9	375.9±243.0^{ns}	-44.9(-11)	2.336^{ns}
Available P (kg P_2O_5 ha^{-1})	18	654±690	1198±1148***	544(83)	22	301±255	436±379*	135(45)	2.841^{ns}

[a] Paired samples T-test [b] Independent-samples T-test between changes of the mean values from 1970 to 2003 of seedfarms and non-seedfarms

Significant level: * ≤ 0.05 < ** ≤ 0.01 < *** ≤ 0.001; ns = not significant

both 0-20 and 0-100 cm soil layers in seedfarms and non-seedfarms, except the 0-100 cm soil layer of non-seedfarms which decreased from 303.80 ± 268.50 to 261.00 ± 224.40 kmol_c ha^{-1} (-14 %) (Table 4). Mean values of exchangeable Mg content also showed similar trend with Ca both in 0 – 20 cm and 0 - 100 cm soil layer. Application of GR over three decades did not much influence the exchangeable Ca and Mg content in both soil layers in seedfarms and non-seedfarms.

Mean values of exchangeable Na content decreased most significantly among the base cations in studied sites. In seedfarms, the exchangeable Na decreased from 3.50 ± 2.60 to 2.10 ± 2.90 kmol_c ha^{-1} (-41 %) and from 15.50 ± 4.80 to 10.60 ± 12.20 kmol_c ha^{-1} (-31 %) in 0 – 20 cm and 0 – 100 cm soil layers, respectively; while within the same layers, non seedfarms decreased from 3.10 ± 2.90 to 1.30 ± 0.90 kmol_c ha^{-1} (-57 %) and from 13.20 ± 7.80 to 7.00 ± 5.10 kmol_c ha^{-1} (-47 %) (Table 4). The difference of the change in exchangeable Na content from 1970 to 2003 in seedfarms and non-seedfarms might be not only because of land management practice but also because of the difference of topographical position in which seedfarms and non-seedfarms located. Na is supplied mainly from the parent materials through weathering processes. It is well understood that Na is a highly soluble element and easy to be lost through water movement. During the rainy season from September to April, abundant water flow solubilizes Na and brings from upland to lowland. Since non-seedfarms sites were mostly located in upland, they lost Na more than did in seedfarms sites which were generally located in the low coastal plain areas (Verburg *et al*., 1999).

Changes of mean values of exchangeable K from 1970 to 2003 showed significant different trend in seedfarms and non-seedfarms. During the study period, the exchangeable K content in seedfarms did not show the statistical difference and was kept stable at about 2 kmol_c ha^{-1} and 7-8 kmol_c ha^{-1} in 0 – 20 cm and 0 – 100 cm soil layers, respectively; while in non-seedfarms those value decreased significantly from 1.30 ± 0.60 to 1.00 ± 0.70 kmol_c ha^{-1} (-23 %) and from 6.00 ± 2.10 to 4.00 ± 2.60 kmol_c ha^{-1} (33 %) in respective soil layers (Table 4). As an essential macro nutrient, K had been added to the soil as potassium chloride (KCl) fertilizer in seedfarms, but not in non-seedfarms as well (Lansing *et al.*, 2001). The chemical fertilizer used in non-seedfarms sites mostly depended on the farmer's budget condition, and among the three kinds of chemical fertilizers (Urea, Super-phosphate and KCl), KCl was less frequently used by the farmers (personal communication).The removal of K through harvest or leaching without enough replacement might contribute to the decrease of exchangeable K in non-seedfarms site where the application of K fertilizers was not as much as in seedfarms.

Available P content significantly increased from 198.5 ± 211.1 to 393.0 ± 382.3 kg P_2O_5 ha^{-1} (98 %) and from 653.6 ± 690.5 to 1198.2 ± 1147.9 kg P_2O_5 ha^{-1} (83 %) from 1970 to 2003 in 0 – 20 cm and 0 – 100 cm soils layer, respectively (Table 4); while in non-seedfarms increased from 86.0 ± 49.3 to 143.5 ± 105.6 kg P_2O_5 ha^{-1} (67 %) and from 301.3 ± 254.8 to 436.3 ± 378.6 kg P_2O_5 ha^{-1} (45 %) in respective soil layers. The rate of increase was higher seedfarms as compared with non-seedfarms (Table 4). The results obviously appeared the difference of land management practice, such as fertilizer application, between seedfarms and non-seedfarms as well as exchangeable K which affected the change rates of available P during the period of study. Seedfarms, which was planted with rice and applied with P fertilizer following the government recommendation after the GR technology started, accumulated more available P than did in non-seedfarms, where the application of P fertilizer was not as much as in seedfarms. The excess of available P in Java sawah soils, especially in seedfarm, seemed to create an environmental problem. Water flow through run-off and drainage brought dissolved P into the water body downstream. During the filed research in this study, an evidence of the water pollution was observed such as aquatic plant grew and covered the water surface on the drainage canals in lowland areas. According to Brady and Weil (2002), runoff, leaching and erosion from agricultural land will move some phosphorus into the streams, lakes, ponds and reservoirs, triggering the process of eutrophication. Lansing *et al.*, (2001) found the concentration of P in the stream increasing gradually from upper to lower area in Bali. Those results were also in agreement with Zhang *et al.*, (2003) who reported that P losses from sawah is one of the potential factors relating to water eutrophication because P content in runoff and leachate were detachable, even the sawah receive low dose of P fertilizer.

3.5. The effects of rice cultivation intensity in the decreasing of available silica.

The effects of rice cultivation intensity between seedfarms and non-seedfarms on the decreasing rate of available Si during the period 1970 to 2003 in Java sawah soils presented in Table 5. Available Si in seedfarms decreased with higher statistical level ($p<0.01$) than in non-seedfarms ($p<0.05$). It is clear that the seedfarms sites lost more available Si as compared with in non-seedfarms. In the 0 – 20 cm soil layer, the average content of available Si in seedfarms decreased from 1646±581 kg SiO_2 ha^{-1} to 1283±533 kg SiO_2 ha^{-1} (-22%) in the 0-20cm soil layer; while in non-seedfarms decreased from 1440±645 kg SiO_2 ha^{-1} to 1202±563 kg SiO_2 ha^{-1} (-17%) (Table 5). Within the 0-100 cm soil layer, the change rates of available Si in both seedfarms and non-seedfarms found similar. In the 0-100 cm soil layer the average available Si in seedfarms decreased from 7853±4187 kg SiO_2 ha^{-1} to 6906±4024 kg SiO_2 ha^{-1} (-14%) while in non-seedfarms decreased from 5710±2700 kg SiO_2 ha^{-1} to 5063±2528 kg SiO_2 ha^{-1} (-12%) (Table 5).

Although, the available Si content in Java sawah soils is the highest among the Southeast Asian countries (Kawaguchi and Kyuma, 1977) but the intensive rice cultivation had been mined Si and export them through the harvesting processes. Due to the transported of Si out of the field, the seedfarms site cultivated rice with higher intensity decreased available Si faster as compared with non-seedfarms (Table 3). Ma and Takahashi (2002) stated that the rice husk account for about 20% of the weight of rice grain and up to 20% consists of SiO_2. Assuming the rice productivity in seedfarms and non-seedfarms was similar (about 5.5 Mg husked rice per hectare per cropping season), the seedfarms site planted rice three times a year lost silica in SiO_2 form about 660 kg ha^{-1} every year; which is much higher than in non-seedfarms. And within the study period, seedfarms and non-seedfarms had been sent the silica out of sawah through harvesting processes about 21780 kg SiO_2 and 14520 kg SiO_2, respectively. These values were much higher as compared with the decreasing rate of available Si in soils. Table 3 showed, during the period 1970 to 2003, the available Si content in the 0 – 20 cm soil layer decreased by 363 kg SiO_2 ha^{-1} and 238 kg SiO_2 ha^{-1} in seedfarms and non-seedfarms, respectively. Contribution of other natural silica resource such as irrigation water seemed to play important role to maintain the available Si content in the

Table 4. The effects of cultivation intensity between seedfarm and non-seedfarm on the changes rate of available silica (kg SiO_2 ha^{-1}) during the period of 1970-2003 in Java sawah soil, Indonesia.

	Seedfarm				Non-seedfarm			
	0 - 20 cm		0 - 100 cm		0 - 20 cm		0 - 100 cm	
	1970	2003	1970	2003	1970	2003	1970	2003
n	18	18	18	18	22	22	22	22
Mean±SD	1646±581	1283±533	7853±4187	6906±4024	1440±645	1202±563	5710±2700	5063±2528
Change mean		-363		-947		-238		-647
% change		-22		-14		-17		-12
T-test		**		*		*		*

Significant level: * ≤ 0.05; ** ≤ 0.01

soil. Kawaguchi and Kyuma (1977) found the average of Si content in the rivers water which are the dominant sources for irrigation in Java was 29.82 mg SiO_2L^{-1}. Although the average Si content measured in the irrigation water was much lower than in river water (14.00 mg SiO_2L^{-1}), the Si input from this resource could be possible to retain the decreasing rate of available Si in sawah soil (Table 4).

Conclusion

Application of GR technology during the period between 1970 and 2003 was changed some soil properties of sawah soil in Java, Indonesia. The TC and TN contents in sawah soils increased both on seedfarms and non-seedfarms. The non-seedfarms that planted with rice and upland crops in some rotation patterns accumulated higher TC and TN as compared with seedfarm sites where rice was planted in monoculture system over the whole study period. Application of chemical fertilizer without any consideration of the natural supply from the soils or (irrigation) water resulted in a considerable variation in the changes of soils properties among the sites within the study period in both seedfarms and non-seedfarms site. This study showed that the decreasing rate of available Si affected by cultivation intensity of rice and topographical position. Seedfarms site planted rice with higher intensity lost more Si as compared to non-seedfarms. The decreasing rate of available Si was counted much lower as compared to the amount of Si lost through harvesting, due to contribution of Si from the irrigation water. Within the similar land management practices and cultivation intensity, sampling sites located in upland position decreased in available Si higher than in lowland. The adverse effect of GR in Indonesia mainly because of improper land management over long period of time.

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