TROPICS Vol. 10 (4): 555-564 Issued March 10, 2001

# Effect of a *Sawah*-Based Farming System on Rice Cultivation in the Inland Valley Bottom of the Ashanti Region, Ghana

**Kwame Osafredu ASUBONTENG, Daisuke KUBOTA, Keiichi HAYASHI, Tsugiyuki MASUNAGA, Toshiyuki WAKATSUKI** Faculty of Life and Environmental Science, Shimane University, Matsue 690-8504, Japan.

**Ernest OTOO** Crops Research Institute, Plant Physiology Division, P.O Box 3785, Kumasi, Ghana

**ABSTRACT** The contribution of the *sawah* system (bunding, leveling, and puddled fields to irrigated rice cultivation) was studied alongside the traditional slash-and-burn, rain-fed lowland rice farming system in the inland valley bottom of the Ashanti region, a semi- deciduous forest zone in Ghana. Different organic and inorganic fertilizers were tested under the different systems. The results revealed that the *sawah* system resulted in a greater number of productive tillers, higher straw production, and higher grain yield compared to the farmers' rain-fed lowland practice.

Among the fertilizer treatments, the poultry manure, relatively rich in both N (nitrogen and P (phosphorous), and the use of the inorganic fertilizers N 90, $P_2O_5$ 60, and $K_2O$ 60 kg $ha^{-1}$ at the recommended rate for rice exerted similar effects on grain yield under both systems This means the soils were relatively deficient in available N and P. The *sawah* system had a remarkable effect on N uptake by rice grain and straw in the inland valley bottom. Agronomic uptake N efficiencies and agronomic N efficiencies of fertilized N in both mineral and organic forms were considerably higher under the *sawah* system in the valley bottom. The present rain-fed lowland condition of local farms in the inland valley bottoms of the Ashanti region of Ghana showed very poor efficiency in the use of fertilized N in both the mineral and organic forms. Our study results indicate that use of the *sawah* system is a prerequisite for the efficient use of fertilizer to increase rice yield in the inland valley bottom.

**Key words:** agronomic efficiency / Ghana & West Africa / inland valley bottom / inorganic fertilizers / rain-fed lowland condition / organic manures / phosphorous deficiency / sawah system

The agricultural productivity index in Ghana and other countries in West Africa fluctuates mainly because the country's agriculture is rain-fed and subsistence farmers relying on the rain are the main backbone of farming in the country. The majority of farmers still practice the traditional shifting cultivation method of farming. Under this system, farmers clear the native vegetation by the slash-and-burn method and then grow crops. The efficiency of shifting cultivation depends mostly on the duration of the fallow period and the nature and density of the fallow vegetation. Rapid increases in human population and the associated increases in demand for farmland and wood products have overburdened this traditional cultivation method. Long fallow periods, which in the past lasted 10 to 25 years, have been shortened drastically (to one or two years) or disappeared in areas like the valley bottom sites in Ashanti where rice is cultivated yearly. This has resulted in increasing degradation of farmland increasing infestation of problem weeds, and declining yields and production of food crops

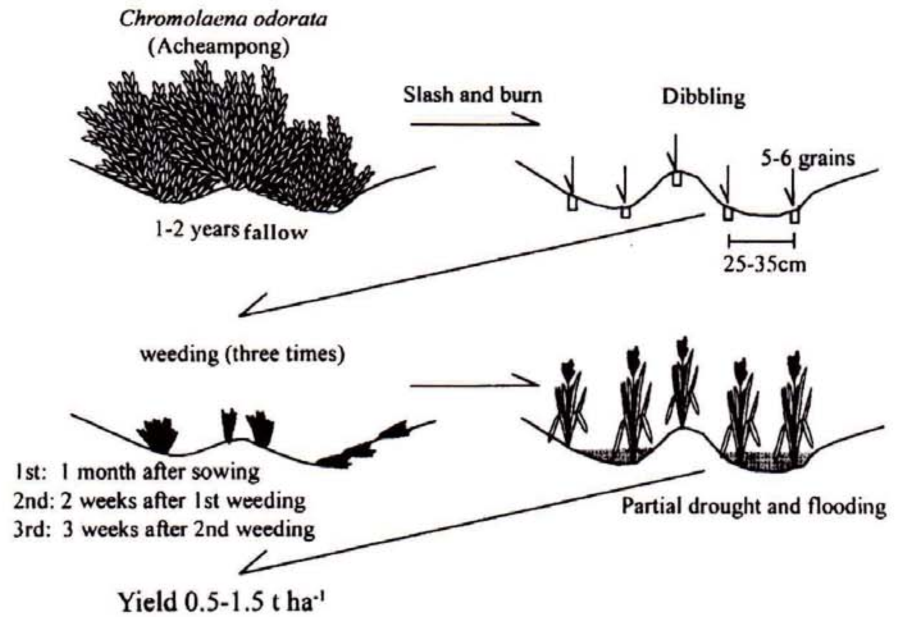


**Fig.1. Traditional rice farming practice in inland valley bottom of Ashanti region, Ghana.**

(Atta-Krah *et al.*, 1993). When food production targets are not met, food must be imported especially rice, to meet rapidly increasing domestic requirements. It is estimated that 42% of the country's rice needs of 400,000 metric tones is imported (PPMED, MOFA, 1999), which is more than double the amount imported 10 years ago. The imports constitute a heavy drain on the country's meagre foreign exchange reserves.

Asian farmers solved their rice production problems partly by converting the tropical lowland soils of the humid zone into bunded, levelled, and puddled fields (known as the *sawah** system). The green revolution was realized in Asia in the 1960s mainly because of the adoption of high rice yielding varieties, fertilizers, pest control, and irrigation techniques based on the *sawah* technology developed previously (Wakatsuki *et al.* 1994; Wakatsuki *et al.*, 1998). Fortunately, inland valley swamps, according to many authors (Wakatsuki, 1988, 1991, 1994 Windmeijer & Andriesse, 1993; Hirose and Wakatsuki, 1997; Wakatsuki *et al.*, 1998), are environments suitable for efficient and sustainable rice production in Ghana and other West African countries.

In a previous report (Asubonteng *et al.*, 2001), reported results from a detailed characterization and evaluation of soils, water, and land use indicate that given their assured water supply and because of relatively fertile soils in the valley bottoms, inland valleys can contribute to the increase and stabilization of rice production. However, most farmers still use their traditional methods of cultivating rice in the valley bottoms. Farmers slash and burn their fields, dibble rice, and weed twice or thrice without water control or fertilizer application. The paddy yield obtained is often very low, 0.5 -1.5 t $ha^{-1}$ (Fig. 1).

In Ghana, the Valley Bottom Rice Development Project was initiated in 1989 to develop sustainable technologies for integrated soil, land and water, and crop management in the production of rice and other crops in the inland valley (Otoo, 1994). Although considerable progress has been made in addressing some of the researchers' constraints, the detailed characterization and evaluation of the study site have revealed that even though valley bottom soils are slightly richer than those of the uplands, they are still low in nutrient reserves to support intensive rice cultivation. Water control and weed infestation are also major constraints to rice production (Asubonteng *et al.*, 2000). Therefore, new farming systems that attain both soil restoration and high yield must be developed to achieve effective and sustainable rice production (Wakatsuki *et al.*, 1998).

Mineral fertilizers could be used to improve fertility management of these soils, and a large amount of literature on their comparative efficiency is available (Djokoto & Stephens, 1961; Kwakye, 1975; DeDatta *et al.*, 1983; DeDatta & Buresh, 1989). The fact that farmers are relying on rain-fed field conditions, without any water management, makes the efficiency of the fertilizer very low. In addition, the high prices, high cost of handling, and poor distribution networks of inorganic fertilizers have resulted in serious setbacks in their use by small-holder farmers who form the majority of the farming population.

Different sources of organic residues (cow dung, poultry manure, and decomposed rice straw) are available in reasonable quantities in farming communities of this area that could provide nutrients as well as increase the organic matter, which would in turn help improve the nutrients reserve especially nitrogen in the soil (Asubonteng, 1997; Asubonteng *et al.*, 2001). Nutrient retention, weed control, and water management could also be improved in submerged fields (Wakatsuki, 1994). The *sawah* system as implemented in some parts of Asia is known to be sustainable; it is characterized by nutrient replenishing mechanisms with intrinsic resistance to erosion (better water control and nutrient and weed management).

The implementation and adaption of a *sawah*-based rice farming system (Wakatsuki *et al.*, 1998) could be important in Ghana and West Africa to improve the nutrient status of their soils and achieve an appropriate water and weed management saystem, which promotes better economic fertilizer management practices, and a sustained rice yield. The purpose of the present investigation was therefore to compare the *sawah* system with the traditional rain-fed lowland rice cultivation method of local farmers.

## MATERIALS AND METHODS

**Study Area** The experiment was conducted at the Potrikrom site of Dwinyan inland valley which is part of the Mankran valley system in the Ahafo-Ano South District of Ashanti. The site is located in the semi-deciduous rainforest vegetational zone. The area has a bimodal rainfall pattern; the annual rainfall was 1363.1 mm during this experiment. The major rainy season lasted from mid-March to the end of July with a peak in July. The minor rainy season began in September and ended in mid-November. Relative humidity figures ranged between an average of 87.9% at 0900 hours to 62.8% at 1500 hours The experimental site was located at the valley bottom under a bush-fallow for the last two years before initiation of the experiment. The soil type was Haplic Gleysol with low nutrient levels (Asubonteng *et al.*, 2001). The experimental land was first cleared by slashing the vegetation. A split-plot design with a farmer's field and a *sawah* field as the main plots and six fertilizer treatments as subplots was used(Table 1). There were 4 replications. Each subplot measured 5 m × 5 m. Bands 50 cm high were mounted around the edges of each *sawah* plot in order to hold water (Fig. 2 and Table 1 ). The *sawah* fields were bunded, levelled, and puddled using a power tiller. When necessary, sawah fields were irrigated using a small hand pump to lift water from the river. In the field representing the

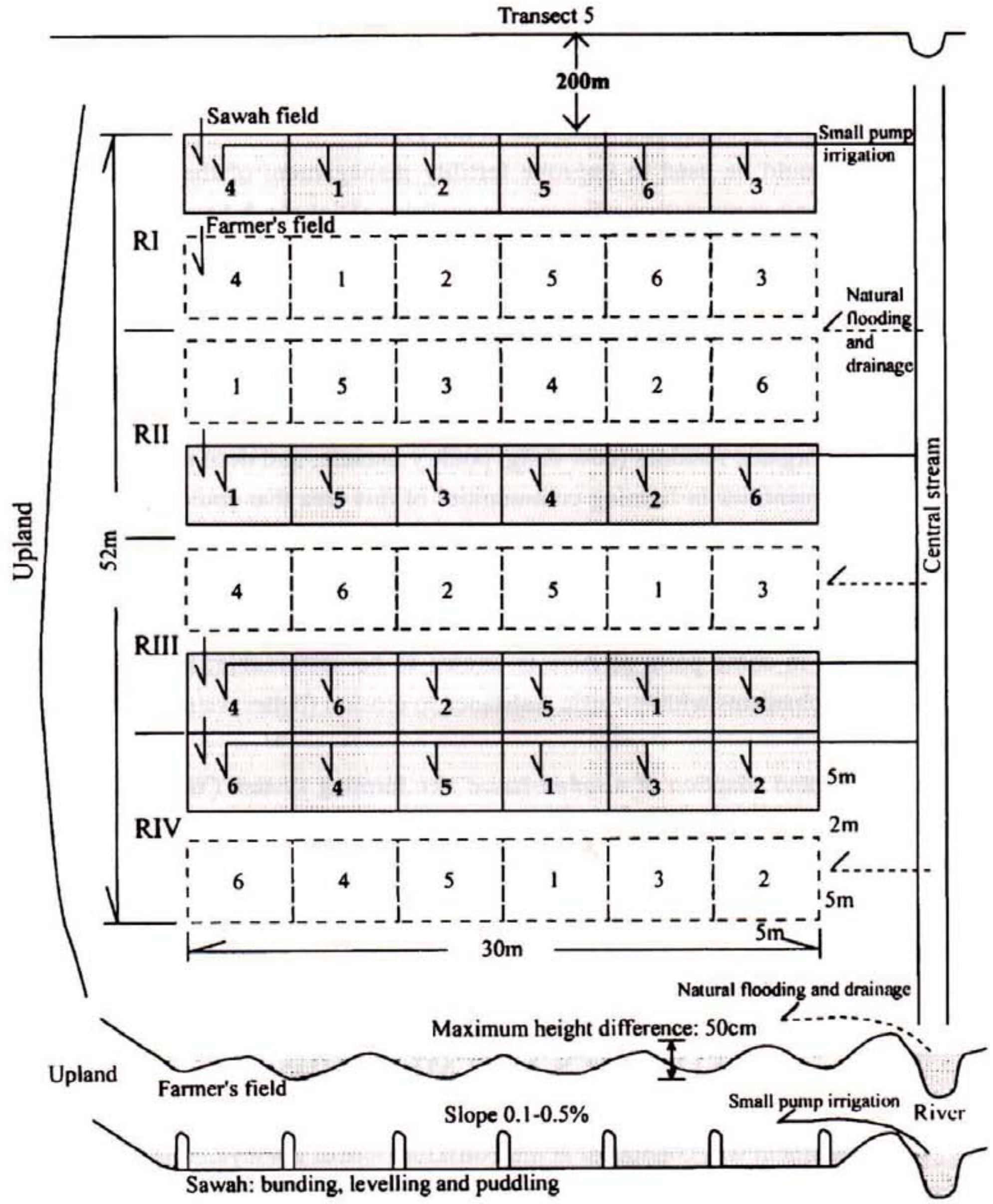


**Fig.2. The field experimental layout of experimental plot in Potrikurom site near the Transect 5** (Fig. 1, 2 and 5 in Asubonteng *et al.*, 2001).

farmers' rice cultivation practices the vegetation was burnt after slashing. Organic manure was applied and mixed with topsoils three weeks before transplanting. The rice variety "sikamo" was used as the test variety and was transplanted at 20×20 cm spacing. T1 was a control plot in which no fertilizer or organic manure was applied. On T3, a basal application of 60 kg N $ha^{-1}$ ammonium sulphate, 60 kg $P_2O_5$ $ha^{-1}$ triple superphosphate, and 60 kg $K_2O$ $ha^{-1}$ muriate of potash were applied just before plowing and/or puddling for transplanting. Thirty kilograms of N $ha^{-1}$ ammonium sulphate was applied for top dressing at the maximum tilling stage. T2 received only a basal application of 45 kg N $ha^{-1}$, 30 kg $P_2O_5$ $ha^{-1}$, and 30 kg $K_2O$ $ha^{-1}$ of the same types of fertilizers. Organic manure at a rate of 4t

**Table 1.** Fertilizer treatments in two experimental plots of farmer's rain-fed field and *sawah* field.

| | Treatment | Organic residue application ratein dry weight($ha^{-1}$ $year^{-1}$) | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|---|---|
| | | | ) | (kg $ha^{-1}$ $year^{-1}$) | |
| T 1 | Control | | 0 | 0 | 0 |
| T2 | Chemical fertilizer | | 45 | 30.0 | 30 |
| T3 | Chemical fertilizer | | 90 | 60.0 | 60 |
| T4 | Poultry manure | 4 ton | 81 | 28.0 | 36 |
| T5 | Cowdung | 4 ton | 57 | 6.4 | 36 |
| T6 | Decomposed Rice Straw | 4 ton | 31 | 2.8 | 72 |

**Table 2.** Comparison of *sawah* and farmer crop (rice) husbandry practices.

| | 1st w. of June | 3rd w. of June | 3rd w. of July | 2nd w. of Aug. | 1st w. of Sept. | 1 st w. of Oct. | 3rd w. of Oct. |
|---|---|---|---|---|---|---|---|
| Famer's field | Application of organic manure | Transplanting and basal application of inorganic fertilizer | Weeding | 2nd weeding | 3rd weeding Top dressing (T3) | - | Harvest |
| Sawah | Application of organic manure | Transplanting and basal application of inorganic fertilizer | No weeds | No weeds | Pick up weed Top dressing (T3) | - | Harvest |
| | Flooding of *sawah* field using small pump | | | | | Drain water from *sawah* field | |

Organic manure: Poultry manure, Cowdung, Decomposed rice straw
Inorganic fertilizers: Ammonium Sulphate, Triple Super Phosphate, Muriate of Patash

$ha^{-1}$ (dry basis) was used. Total N, $P_2O_5$, and $K_2O$ contents of poultry manure, cow dung, and decomposed rice straw used were 2.02% 0.7%, and 0.9 %, 1.42%, 0-16%, and 0.9%, and 0.78%, 0.07%, and 1.8%, respectively. The increase in the amount of N and other nutrients as a result of various treatments is depicted in Table-1. The farmers'practice was weeded three times. The *sawah* fields received no weeding (Table 2). The number of productive tillers, the panicles, and straw and grain yield were recorded, and N uptake of the grain and straw was analyzed. The top 20 cm of the soil was sampled for analysis before fertilizer application. Soil samples were air dried, ground and passed through a 2-mm mesh sieve. Soil pH was determined using a pH meter (with a glass electrode) with a soil-to-water ratio of 1:2.5, according to the methods described by the IITA (1979) and McLean (1982). Total carbon content was determined by the wet combustion method as described by Walkley and Black (1934). Total N content was determined using an N-C analyzer (Sumigraph NC-9OA) as described by Geiger and Hardy (1971). Available P was determined by the Bray No.1 method (Bray & Kurtz, 1945). Exchangeable Ca, Mg, K and Na were first extracted with 1.0 M ammonium acetate. Contents of exchangeable K and Na were determined by atomic absorption spectrophotometry as described by Thomas (1982). Contents of exchangeable Ca and Mg were determined by inductively coupled plasma-atomic emission spectroscopy (Shimadzu ICPS 2000) Exchangeable acidity was determined by first extracting with potassium chloride (1 M KCl) and titrating the extract with sodium hydroxide as described by McLean (1965). Effective cation exchange capacity (ECEC) was calculated as the sum of exchangeable cations (K, Ca Mg, Na) and exchangeable acidity. Particle size analysis

**Table 3.** Chemical and physical properties of soil, Oda series (Haplic Gleysol, FAO), at the experimental site (0-20cm depth).

| pH | Exchangeable cations | | | | Exch. Acid. | ECEC | Base Sat. |
|---|---|---|---|---|---|---|---|
| $H_2O$ | Ca | Mg | K | Na | Al + H | | |
| | cmol(+) kg $^{-1}$ | | | | | | % |
| 5.4 | 11.91 | 1.47 | 0.13 | 0.07 | 0.05 | 13.63 | 99.6 |

| Org. C | T-N | O.M. | C/N | Avail. $P_2O_5$ | Sand | Silt | Clay |
|---|---|---|---|---|---|---|---|
| | % | | | mgkg$^{-1}$ | | % | |
| 1.51 | 0.13 | 2.6 | 11.6 | 5.04 | 57.0 | 31.5 | 13.5 |

was conducted by the pipette method as described by Gee and Bander (1986). N in the plant samples was also determined using a NC analyzer (Sumigraph NC-9OA).

## RESULTS AND DISCUSSION

Results of the soil analysis are given in Table 3. Although exchangeable Ca and Mg were nearly as high as in the inland valley soils in West Africa (Issaka *et al*., 1997), the soil pH was slightly acid and medium ib organic matter and N content. The base saturation is very high (99.63%). The levels of available P and exchangeable K were low. The soil tested was Haplic Gleysol (Oda series), typical in the valley bottom in this area (Asubonteng *et al*, 2001). Table 4 gives the main effect of the farming practices (*sawah* and local farmers' practice) on growth, yield components, and N uptake. Regardless of the type of treatments, grain and straw yield, effective tillers, and agronomic efficiency, were significantly higher with the *sawah* method than the local farmers' practice. It must be noted that even in the control plots under the *sawah* system, where there was no application of fertilizer, the grain yield was 2.5 t ha$^{-1}$ which was equal to the grain yield obtained in the farmers' plots where the recommended rate of fertilizer (N90 P60 K60) was applied.

A possible explanation for the success of the *sawah* technology is that flooding of paddy soil changes its chemistry for rice growth, including generally eliminating soil acidic problems (Ragland & Boonpukdee, 1987) by increasing soil pH, which contributes to the rise in N availability (Willet & Intrawech, 1988; Ragland & Boonpukdee, 1987). In contrast to that, in local famers' practice with no water management there are large changes in the chemistry of the soils due to the fluctuation in soil water with intermittent wetting and drying cycles. Even when there is a small undulation as shown in Fig. 1, the micro depression and crest accentuate the wetness and dryness. Wetting and drying cycles can cause large losses of N in the soil of a farmer's field. During drying phases in the soil, reduced forms of N, particularly $NH_4^+$, are nitrified to $NO_3^-$ (Sanchez, 1976). After soil flooding, a sometimes occurs in farmers' fields lacking water control, $NO_3$ may be lost by leaching or by denitrification to N, and N,O gasses. Flooding and reduction of topsoil also increase P availability under the *sawah* system, which may have also contributed to the high rice yield.

N uptake was more efficient and significant in treatments under the *sawah* system. The recommended rate of inorganic fertilizer for rice (N90 P60 K60) resulted in the highest uptake of N in both grain and straw (Table 4). In order to examine the effect of N fertilizer in the *sawah* system on

**Table 4.** Productive tillers, yield and N uptake under *sawah* (S) and local farmers' field (F).

| Treatment | Productive tillers (stock$^{-1}$) | | Straw yield (t ha$^{-1}$) | | Grain yield (t ha$^{-1}$) | | N uptake in grain (kg ha$^{-1}$) | | N uptake in straw (kg ha$^{-1}$) | | N uptake in grain & straw (kgha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | F | S | F | S | F | S | F | S | F | S | F | S-F |
| T1 | 8.8 | 5.5 | 4.50 | 2.22 | 2.5 | 1.5 | 42.3 | 25.6 | 25.5 | 18.1 | 67.8 | 43.6 | 24.2 |
| T2 | 11.8 | 7.0 | 6.49 | 2.97 | 3.5 | 1.9 | 51.0 | 36.4 | 35.0 | 25.0 | 86.0 | 61.4 | 24.6 |
| T3 | 17.5 | 10.5 | 9.60 | 4.10 | 4.9 | 2.5 | 86.7 | 50.3 | 53.2 | 35.5 | 139.9 | 85.8 | 54.1 |
| T4 | 13.8 | 8.3 | 7.15 | 4.05 | 4.5 | 2.3 | 67.4 | 50.8 | 43.2 | 34.8 | 110.7 | 84.9 | 25.8 |
| T5 | 12.5 | 7.8 | 6.71 | 3.84 | 3.9 | 2.1 | 60.4 | 46.0 | 40.1 | 30.0 | 100.5 | 76.0 | 24.5 |
| T6 | 11.5 | 7.5 | 6.30 | 3.65 | 3.0 | 1.9 | 59.9 | 48.0 | 39.1 | 29.5 | 99.0 | 77.5 | 21.6 |
| LSD 5% | 1.1 | | 0.28 | | 0.3 | | 1.8 | | 2.5 | | 6.7 | | |
| 1% | 1.5 | | 0.38 | | 0.4 | | 2.5 | | 3.3 | | 8.9 | | |

**Table 5.** AANUE, AUNE and ANE.

| Treatment | N add. (kg ha$^{-1}$) | ΔGrainyield (kg ha$^{-1}$) | | ΔN uptake (kg ha$^{-1}$) | | AANUE (N up./ N add.) | | AUNE (Grain t/N kg) | | ANE (Grain t/N kg) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | S | F | S | F | S | F | S | F | S | F |
| T1 | 0 | - | - | - | - | - | - | 36.9** | 34.4** | - | - |
| T2 | 45 | 1000 | 400 | 18.2 | 17.7 | 0.40 (0.94)* | 0.39 | 55.1 | 22.5 | 22.2 | 8.9 |
| T3 | 90 | 2400 | 1000 | 72.1 | 42.2 | 0.80 (1.07)* | 0.47 | 33.3 | 23.7 | 26.7 | 11.1 |
| T4 | 81 | 2000 | 800 | 42.9 | 41.3 | 0.53 (0.83)* | 0.51 | 46.7 | 19.4 | 24.8 | 9.9 |
| T5 | 57 | 1400 | 600 | 32.7 | 32.4 | 0.58 (1.00)* | 0.57 | 42.8 | 18.5 | 24.6 | 10.6 |
| T6 | 31 | 500 | 400 | 31.2 | 33.9 | 1.00 (1.79)* | 1.08 | 16.0 | 11.8 | 16.0 | 12.8 |

**Δ Grain yield**: Gf - Gc, where **Gf** is grain yield of the fertilized plot (T2 - T6); **Gc** is that of the control plot (T1).
**Δ N uptake:** NUf - NUc, where **NUf** is N uptake in grain & straw of the fertilized plot (T2-T6); **NUc** is that of control plot (T1).
**AANUE:** Apparent Agronomic N Uptake Efficiency (ΔN uptake / N add.)
**AUNE:** Agronomic Uptake N Efficiency (Δ Grain yield / Δ N uptake)
* values in parenthese were calculated as (Δ Nf uptake / N add.), where Δ Nf uptake is NUf - NUcf (NUc in farmers' plot).
**ANE:** Agronomic N Efficiency (Δ Grain yield / N add.)
** Gc / NUc
**N add.:** N addition by fertiliztion (the values are the same as Table I )

grain yield, the apparent agronomic N uptake efficiency (AANUE), agronomic uptake N efficiency (AUNE), and agronomic N efficiency (ANE) of each treatment in both types of fields were calculated. The results are shown in Table 5. AANUE was defined as N uptake of grain and straw of T2 to T6 minus T1 per the amount of N addition of each T I to T6. AUNE was defined as the increment of grain yield per the increment of N uptake of each treatment compared to the control. ANE was defined as the increment of grain yield per the increment of N addition of each treatment compared to the control. The equations are shown in Table 5.

Although even in the farmers' fields the practice N uptake is higher for all the treatments than it is in the control field, there was not much difference between the recommended rate of NPK and the organic residues (Table 4). When there is no water control, the uptake and the efficiency of both N fertilizers and organic manure applied remain limited. AANUE of T2, T4. T5, and T6 were similar in both types of fields. Following the greater application of N, P, and K fertilizers, T3 showed more efficient uptake in the *sawah* than in the farmers' field. The difference of N uptake of T1 between the *sawah* and farmers' field was 24.2 kg ha$^{-1}$. This shows, apart from the addition of N fertilizer, the effect of the sawah system itself in enhancing N uptake. If the AANUE of T2-T6 in the *sawah* system is calculated based on the Tl of the farmers' field, the value increases from 0.40-1.00 to 0.83-1.79, as shown in the parentheses in Table 5, which also shows the effect of the *sawah* system. In the farmers' field. AUNE of treatments T2-T6 were considerably smaller than the uptake N efficiency, 34.1 (grain yield/ N uptake in grain + straw), of the control plot in the farmers' field (Table 5). This means, in the present farmers' field condition, that the applied mineral and organic fertilizers is not effectively utilized by rice plant. Under the *sawah* system with water control, both mineral and organic fertilizers gave higher grain yield and N uptake as well as higher AUNE, except for the rice straw treatment, T6, and the recommended fertilizer plot, T3. In the T6 treatment, P availability may be another limiting factor because of the small addition of P (Table 1) and the poor amount of available P in the soil (Table 3). In the recommended fertilizer plot of T3, this lower apparent agronomic N efficiency means that the amount of this N level may be close to optimum. ANE showed a similar trend to AANUE. This is the indictor for the economic production obtained per unit of nutrient applied. In every case, the *sawah* system had superior performance. ANEs of the *sawah* fields were more than double than those of the farmers' field. The biggest difference was 2.4 times in T3, which received the highest rate of chemical fertilizer. As for the effect of the application of organic manures and the inorganic fertilizers under the different crop husbandry practices, the inorganic fertilizer resulted in higher grain and straw yield under both systems, although it was not significantly different than treatments of poultry manure. As for the effect of the application of organic fertilizers and manures on paddy additional yield, the maximum yield resulted from the application of poultry manure and the lowest yield, significantly, resulted from rice straw incorporation This means that the soils used were deficient in not only N but also P, as shown in Tables I and 3.

## CONCLUSION

The results and observations indicate that under the *sawah* system rice production can be increased more than 400 % (Ave. 4.5 t/ha) over what the local farmers now obtain (Ave. 1.0 t/ha). This shows that if the *sawah*-based farming system is adapted in even 100,000 ha of the 1,000,000 ha of land in inland Valley suitable for rice cultivation, the country can be self sufficient in rice production. However, futher studies are needed to understand the chemistry of the interaction of water and the organic and inorganic amendments under the *sawah* system compared to the present farmer's field condition in Ghana and other West African countries. Such studies would help farmers in these countries to realize the full potential of the *sawah* technology in food production, in particular the production of rice.

**ACKNOWLEDGEMENT** We thank the Japan International Co-operation Agent (JICA), for providing the necessary support in carrying out this study.

## REFERENCES

Asubonteng, K. O., 1997. Use of organic residues for soil tertility management in Manir valley. *Annual Report, Soil Research Institute, Ghana*, 19-24.

——; Wknow I. A., Kubota, D., Hayashi, K., Masunaga, T. & Walaluli, T., 2001. Characterization and evaluation of inland valley atersheds for sustainable agriculture production: Case study of semi-deciduous forest zone in Ashanti Region of Ghana. *Tropics* **10**: 537-553.

Atta-krah & Kang, B. T., 1993. Alley farming as a potential agricultural production system for the humid and sub-humid tropics. *In*: *Technologies for Sustainable Agriculture in the Tropics*, 66-74. ASA Special Publication No. 56, ASA, SSSA, CSSA Madison.

Bray, R. N. & Kurtz, L. T., 1945. Determination of total, organic and available forms of phosphorus in soil. *Soil Sci* **59**: 39-45.

DeDatta, S. K. & Buresh, R. J.,-1989. Integrated N management in irrigated rice. *Ad. Soil Sci*. **10**: 143-169.

———, Obcemea, W. N., Chen, R., Calobio, J. C. & Evangelista, R .C., 1987. Effect of water depth on N use efficiency and $N^{15}$ balance in lowland rice. *Agro Jour.* **79**: 210-216.

Djokoto, R. K. & Stephens, 1961. Thirty long-term fertilizer experiment under continuou cropping in Ghana, crop yields and response to fertilizer and manure. Empire journal of Experimental Agriculture **29**: 181-195.

FAO-1990. *Guidelines for Soil Profile Description*. 3rd ed. (revised). FAO, Rome,.

Gee, G. W. & Bauder, J. W., 1986. Particle-size analysis. *In*: Klute A., (ed.), *Methods of Soil Analysis* (Number 9, Part 1), pp. 383-411. ASA, SSSA, Madison.

Geiger, P .J. & Hardy, J. P., 1971. Total carbon by dry combustion. *In*: Page A. L., Miller R. H. & Keeney D. R. (eds.), *Methods of Soil Analysis* (Number 9 Part 2), pp. 543-553. ASA. SSSA, Madison.

Hirose, S. & Wakatsuki, T. 1997: Restoration of Ecology and Rural Life in Savanna Zone of West Africa, 484 pp. Norin Kyokai (in Japanese),

IITA, Ibadan, Nigeria, 198. Selected methods for soil and plant analysis, Manual Series No. 1, p. 3.

Issaka, R. N., Ishida, F., Kubota, D. & Wakatsuki, T., 1997. Geographical distribution of selected soil parameter of inland valleys in West Africa. *Geoderm* **75**: 99-116.

Kwakye, P. K., 1975. Organic matter studies. *Annual Report. Soil Research Institute Ghana*, pp. 14-20.

Kyuma, K & Wakatsuki, T., 1995. Ecological and economic sustainability of paddy rice systems in Asia. *In*: *Agriculture and Environment, Bridging Food Production in Developing Countries*, pp. 139-159. ASA Special Publication No.60, ASA, SSA, CSSA. Wisconsin

McLean, E. O., 1965. Aluminum. *In*: Page A. L., Miller R. H. & Keeney D. R. (eds.), *Method of Soil Analysis* (Number 9 Part 2). pp. 978-988. ASA, SSSA, Madison.

Moormann, F. R., 1985. Problems in characterizing and classifying wetland soils. *In*: Proceeding of a Workshop on Wetland soils. Characterization, Classification. Utilization, pp. 53 - 68, IRRI, Los Banos.

Otoo, E. & Asubonteng, K. O., 1994. Reconnaissance characterization of inland valleys in Southern Ghana. *In*: *Proceeding of a Workshop on Characterization of Inland Valley Agro-ecosystems.* A tool for their sustainable use, 149-160. WARDA, Bouake.

PPMED, & MOFA, 1999. *Policy, Planning and Monitoring Evaluation Division.* Ministry of Food and Agriculture Report. Ghana, pp. 12-14.

Ragland, J & Boonpukdee, L., 1987. Fertilizer response in Northeast Thailand. N use and soil acidity. *Thai J. Soils and Fertility* **9**: 122-130.

Sanchez, P. A., 1987. Low input cropping for acid soils of the humid tropics. *Science* **238**: 1521-1527.

Thomas, G. W., 1982. Exchangeable cations. *In*: Page A. L., Miller R .H. & Keency D. R. (eds.). *Methods of Soil Analysis* (Number 9 Part 2), pp. 159-165. ASA, SSSA, Madison.

Wakatsuki, T., 1991. Regeneration of Subsaharan Africa by sawah based agriculture, A strategy for spreading african adoptive version of *sawah* farming in small inland valley swamps. *Jpn. J. Tropical Agriculture* **35**: 306-314.

———., 1994. Soils, people and sustainable agriculture in tropics, potential of sawah based agriculture in tropical Africa. *Tropics* **3**: 3-17.

———; Kosaki, T. & Palada, M. C., 1988. Rice soil fertility of inland valley swamp in West and Central Africa. *In*: *Proceedings of the First International Symposium o Paddy Soil Fertility*, Part 2, 695-715. Chiangmai, Thailand.

———., Shinmura, Y., Otoo, E. & Olaniyan, G. U., 1998. *African basal Sawah Systems for the Integrated Watershed Management of small Inland Valley in West Africa*. FAO water reports no 17, 56-79. Workshops for Sustainable Agriculture Forestry and Fisheries Development organized by FAO, MAFF (Japan and Japan FAO Association, 3 - 6 February-1998), Tokyo.

Walkley, A. & Black, I. A., 1934. An examination of the method of determining soil organic matter and proposed modification of the chronic acid titration method. *Soil Sci.* **37**: 29-38.

Windmeijer, P. N. & Andriesse, W., 1993. *Inland Valleys in West Africa. An Agro-Ecological Characterization of Rice-Growing Environment*, 28-37. ILRI, Wageningen.

Willet, R. & Intrawech, 1988. The effects of flooding for rice culture on soil chemical properties and subsequent maize growth. *Plant and Soil* **52**: 373-383.

Received Aug. 3, 2000
Accepted Nov. 25, 2000

**K. O. ASUBONTENG, 久保田大輔，林慶一，増永二之，若月利之，E. OTOO**

**ガーナ，アシャンテ地域の内陸谷地低地の稲作における *Sawah*（水田）農業システムの効果**

ガーナの半落葉樹林帯に位置するアシャンテ地域の内陸谷地低地において，*sawah*（水田）システム（畦作り，均平化，代かきによる灌漑稲作）の効果を伝統的な焼畑による天水田と比較して研究した。異なる栽培システムのもとにいくつかの有機と無機肥料の施肥試験を行った。*Sawah* システムは農民の天水低地栽培法と比べ有効分けつ数，ワラ生産量，籾収穫量が大きかった。肥料の中で，比較的NとPに富む鶏糞たい肥と無機肥料 N 90, $P_2O_5$ 60, $K_2O$ 60 kg $ha^{-1}$ の推奨量施肥が，両稲作システムにおいて籾収穫量に同様の効果を示し，このことは土壌中の可給態 NとP が欠乏気味であることを示した。谷地低地において sawah システムは稲籾とワラの N 九州に大きな効果を示し，また無機・有機態ともに施肥 N の吸収 N 利用効率と N 利用効率は，谷地低地の *sawah* システムで高くなった。現在のアシャンテ地域の谷地低地における天水低地の条件では，無機・有機態ともに施肥 N の利用効率は非常に低かった。本研究結果は，内陸谷地低地において稲生産量増加のための肥料の効率的な使用には *sawah* システムの導入が必要であることを示した。