Resource and Crop Management Program

Annual Report 1987

IMPROVEMENT OF RICE-BASED SYSTEMS

Research on rice-based cropping systems in inland valleys started in 1985 in Bida, Nigeria and in 1986 in Makeni, Sierra Leone. In October 1986, the Rice-Based Systems Working Group was constituted and a multidisciplinary research program was initiated which included agronomy, paddy improvement, water management, and socioeconomic components.

The working group had two general objectives: (1) to link the Resource Management Research Group with the Rice Improvement Program at IITA, and both IITA programs with the national programs; and (2) to develop appropriate technologies and conduct research to improve rice-based farming systems in selected environments representative of inland valley swamps (IVS) and hydromorphic soils in West and Central Africa.

Farmer-managed on-farm trials (OFR) in Bida, Nigeria

Although improved varieties of rice have been introduced in IVS, average yields obtained by farmers are still low. Most of these varieties were developed in favorable environments (irrigated lowland and flood plain). In unfavorable environments such as the rainfed inland valleys, improved varieties do not usually perform well. Another reason for low yields in IVS is that improved varieties have been mixed with local ones by farmers over time, so that seed quality and purity have declined. The objectives of this trial were:

(1) to determine the yield performance of improved rice varieties under farmer management practices;

(2) to collect information on the agronomic practices which determine these yields, and

(3) to analyze the effect of some agronomic determinants to rice yields in IVS.

Four improved varieties and a local variety were planted by farmers using their management practices (land preparation, planting density and weeding). The varieties were assigned as main plots and the fertilizer level as subplots in a split plot design. Each farm is a replicate. The improved varieties were ITA 306, FARO 29, ITA 212 and ITA 249. Two levels of fertilizer were applied. The low rate of 15-15-15 kg N-P-K ha^{-1} represents the recommended level. Using yield and other agronomic data, the effect of agronomic factors on rice yield and the interaction of environment and management were determined by grouping farmers according to management levels and physical conditions of their rice fields. The agronomic factors analyzed were seedling age, weed control, toposequence and water duration.

Effect of variety and fertilizer

Frequency of crop failure is a simple criterion for comparing overall performance of varieties across varying environments and management practices in IVS. Taking grain yield of less than 500 kg ha^{-1} as an indicator of crop failure, the data in figure 7.1 show that the improved variety ITA 306 is superior to other varieties. It was the only variety not to fail at any of the 19 sites. At a low fertilizer level ITA 306 outyielded the local variety at 90 percent of the sites, at a high fertilizer level, both ITA 306 and ITA 212 outyielded the local variety at 74 percent of the sites (table 7.1).

Table 7.13. Tuber yield of dry season sweet potato in inland valley swamps in a farmer-managed trial, Bida, 1987

Variety	Planting system		Variety mean
	Mound	Ridge	
	---------Yield (kg ha^{-1})----------		
TIS 2498	4140	3400	3770
Local	4230	1470	2850
Planting system Mean	4180	2440	

SE
for main effects of variety: ±776.8
for main effects of planting system: ±481.1

Note: Data from 7 sites (farmers')

Tuber yield in general was low and was similar to that obtained in 1986. Drought stress is the most limiting factor in dry season sweet potato production in IVS. Mounding seems to help conserve soil moisture, which could be the reason why there were higher yields in mounds than in ridging. It was observed that soil moisture was easily lost in ridges probably because of the smaller size of ridges and volume of soil in them. This phenomenon will be further investigated in 1988.

TIS 2498 tended to be more vegetative than the local sweet potato, and its growth was therefore favored by plentiful soil moisture. The local variety appeared to be drought-tolerant. However, the improved sweet potato seemed to take longer to mature than the local variety. Thus, for drier areas there is a need for improved early maturing sweet potato varieties which are drought-tolerant and high yielding. In wet areas, varieties that can withstand waterlogging and are tolerant to rotting will be required. This should be the basis for selecting sweet potato varieties for IVS.

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Physical characteristics of IVS in benchmark research sites

Water balance and soil fertility are the two major natural physical factors which determine the productivity of rice-based farming systems in IVS. The water balance of IVS is determined not only by rainfall patterns and soil characters associated with water holding capacity, but also by the catchment factor, or in other words the contribution of water from the catchment to the IVS. Although soil, vegetational cover and topography modify the catchment factor, the ratio of total catchment area to IVS is the main determinant. The ratio varies from higher than 100:1 to lower than 5:1 in West Africa. In general, IVS in the drier regions have a higher ratio and a bigger catchment contribution than IVS in the wetter regions. This is why some IVS in the Sudan Savanna zone or even in the Sahel zone can grow lowland rice.

Soil texture and slope are the most important soil characters controlling water holding capacity. The soils of most IVS in West Africa are sandy. If clay sedimentation predominates over erosion, soils may be relatively fertile with finer texture. Since the valley bottom has a 1-2 percent slope or less, sedimentation may predominate, resulting in loamy or finer soil. The reverse is true at the fringe, which has a 2-9 percent slope. Heavy rainfall and sparse vegetational cover promote erosion on any slope. Therefore, sandy soils are often widespread even at the valley bottom.

IVS selected for on-farm research at Bida in central Nigeria have mean annual rainfall of about 1100 mm; and since the ratio between total catchment and IVS is about 100:1, the catchment factor may be large. The valley fringes are exclusively sandy, but bottom lands are partly loamy to clay topsoils. However, 10-50 percent of the bottom lands are also subject to erosion resulting in the formation of sandy soils and, finally, waste land.

IVS at Makeni in Sierra Leone receive a mean annual rainfall higher than 3000 mm. The catchment contribution is probably smaller than at Bida. The area ratio is only about 5-10:1. Heavy rainfall means that erosion predominates over sedimentation. Thus, very sandy soils are common at both fringe and bottom land at Makeni.

The actual water balance of each field where rice and other crops are grown is site specific, depending on topographical position and seasonal changes. Human practices such as irrigation, drainage, leveling, bunding and puddling also modify water balance. At the first stage of research, it is important to monitor the actual water balance in each field directly. After data have been gathered from various IVS, and correlated with the factors controlling water balance, a method can be developed for extrapolating the water balance of each field without direct field measurement.

Rainfall and water discharge relationships were investigated at Gara (catchment area 800 ha), Anfani (1300 ha) and Gadza (6000 ha) inland valleys, in the Bida area of Nigeria.

Direct monitoring of ground and surface water levels and land use patterns of the three inland valleys began in July 1986 in Gara and Anfani, and in Gadza in June 1987. Thirteen transect lines in Gara, 10 in Anfani and 7 in Gadza were monitored every 2 weeks. Each transect had 5-18 plastic tubes measuring groundwater. Some examples of the fluctuation of groundwater depth in the middle, upper and lower streams of Gara valley are shown in figures 7.2, 7.3 and 7.4 respectively. Each figure shares a cross-section of topography along the transect line.

Figure 7.2 shows the relations between rainfall pattern and ground water dynamics in the IVS soils. In 1987, August had the highest rainfall. Major flooding, defined as flooding that covers more than 50 percent of the valley bottom, started at the end of August, whereas in 1986, it had started at the end of September. Farmers started planting rice earlier in 1987 than in1986. Major flooding of the bottom land had continued until 3 December 1986 whereas in 1987 it lasted only until 9 November. Total length of the major flooding period was similar in 1986 (76 days) and 1987 (77 days). The mean for the 13 transects in Gara was 102 days in 1986, whereas it was 93 days in 1987. These results are well correlated with annual rainfall: 1085 mm in 1986 and 870 mm in 1987. The amount of rainfall in 1987 was near the lowest recorded in Bida. Rice fields at the fringe part suffered from a continuous shortage of water.

Figure 7.3 shows the results from transect 3 in Gara, which is in the upper stream position. The soils became driest in May. However, the groundwater level stayed at between 25 and 75 cm depth. This shows that the bottom land soils in this part of the IVS have enough moisture for growing a range of dry season crops between February and July, although farmers planted only cassava.

Figure 7.4 shows transect 13 in Gara, which is in the lower stream position. The unusually shallow groundwater level along tubes No.1 to 3 during August to November was due to seepage water. Although farmers tried to cultivate rice using this water, it was not enough to grow a crop of rice. Other crops may be suitable for growing in this part of the *fadama* during these periods.

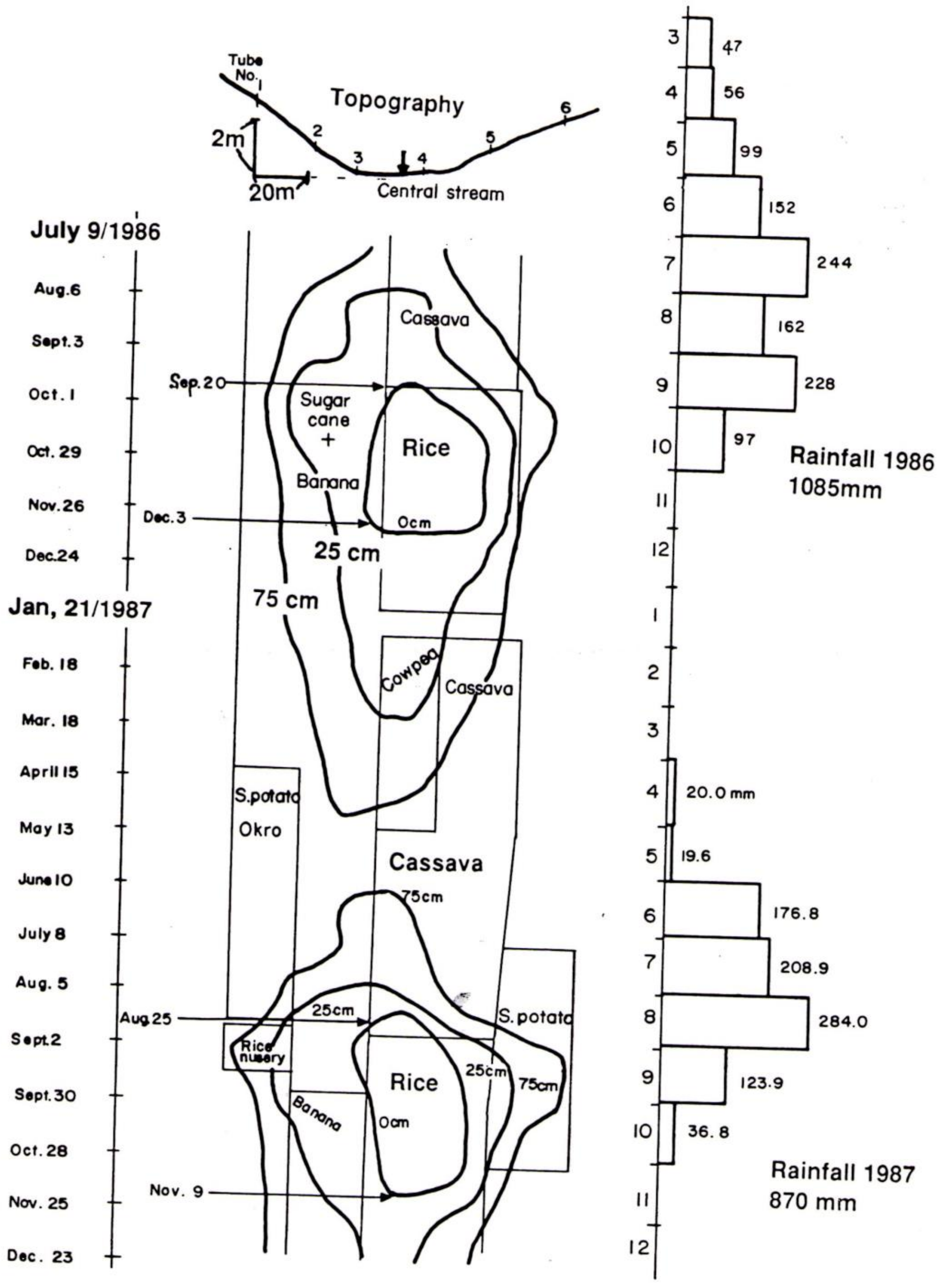

Figure 7.2. Groundwater depth (cm) dynamics and land use pattern along the transect 8 at Gara, Bida, Nigeria: relatively dry site

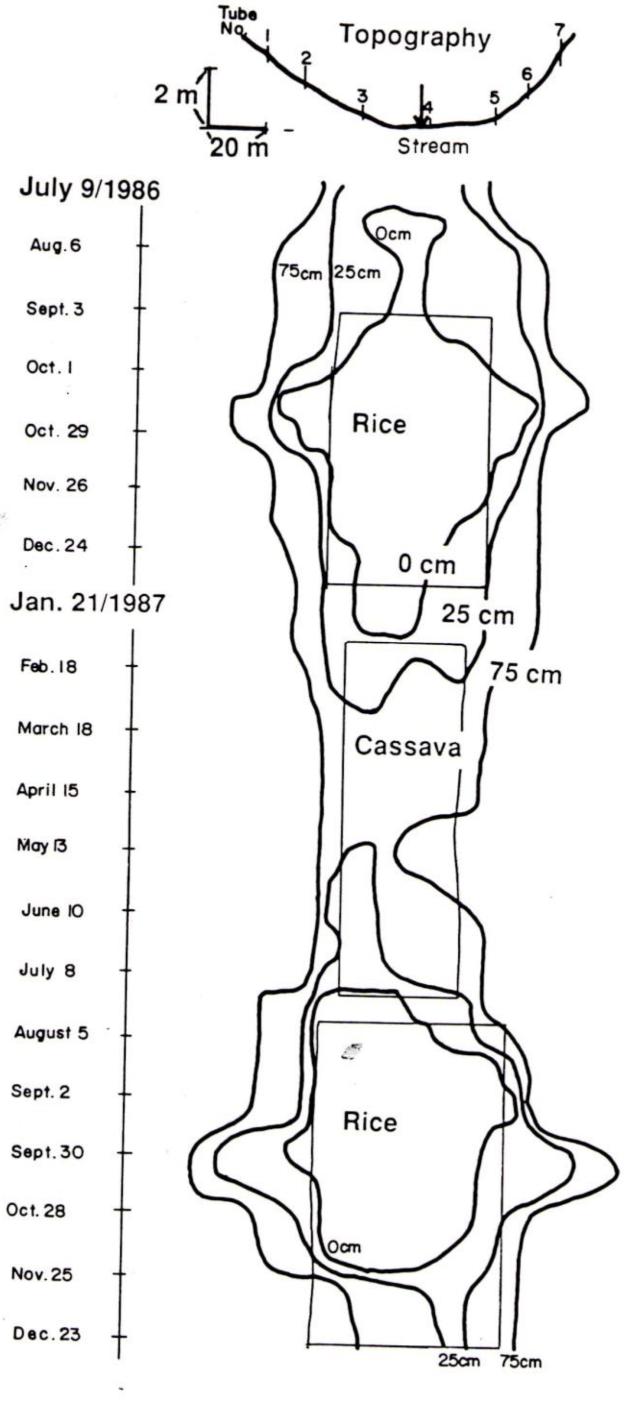

Figure 7.3. Groundwater depth (cm) dynamics and land use pattern along transect 3 in Gara, Bida, Nigeria: relatively moist site

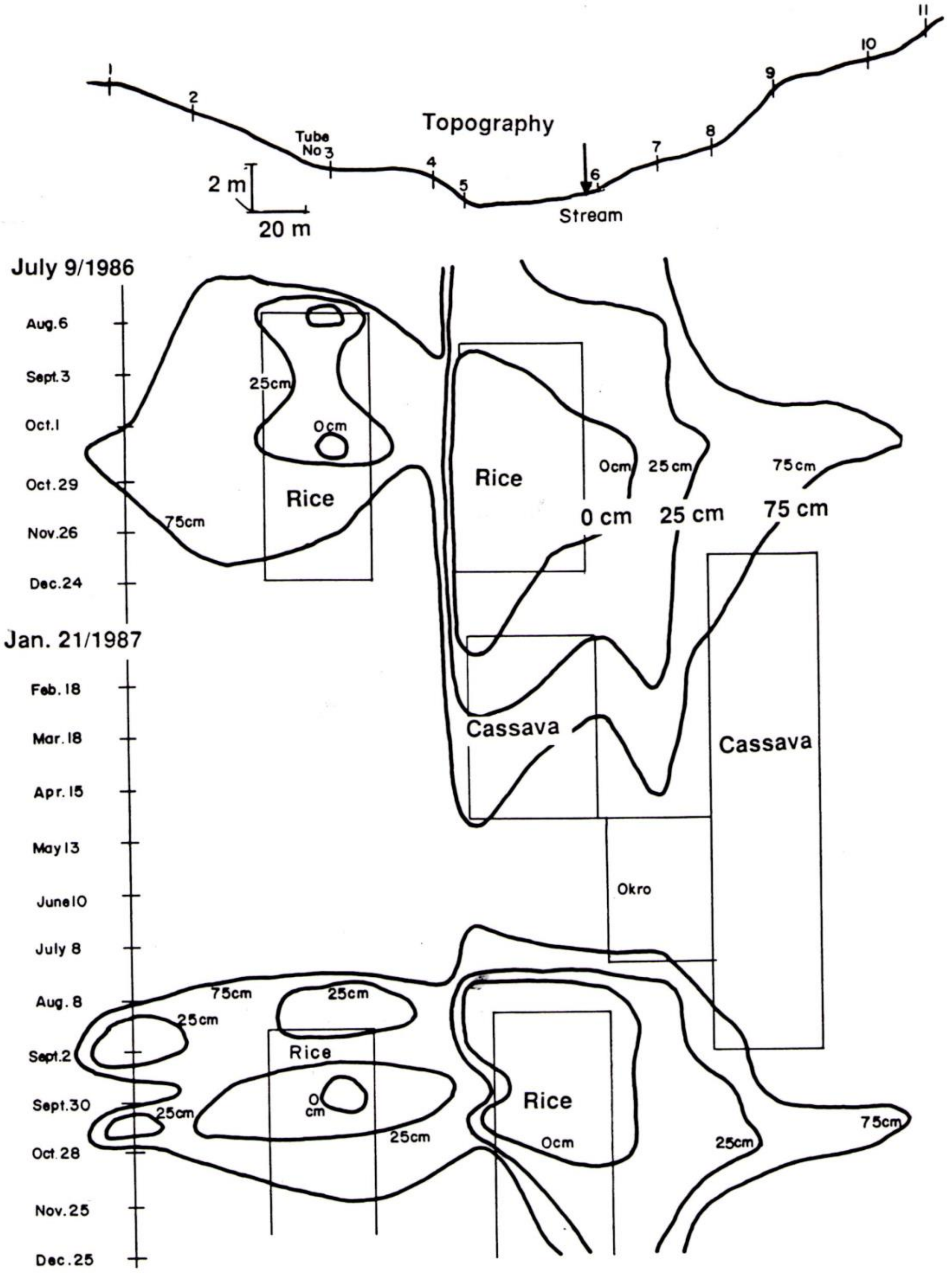

Figure 7.4. Groundwater depth (cm) dynamics and land use pattern along the transect 13 in Gara, Bida, Nigeria: (seepage flow)

Table 7.14. Selected physicochemical nature of soils along the toposequence at transect 7 in Gara, sampled on 15 January 1987, harvesting time

Selected properties	Depth (cm)	B-1 upper (Fringe)	B-1 lower	B-3 (Bottom)	B-5	E-1 (Fringe)	E-3	E-5 (Bottom)	E-7
Clay (%)	0-5	6	8	16	21	8	12	16	22
	10-20	6	8	16	21	8	10	20	20
	20-30	6	9	24	10	6	8	25	10
	40-50	5	6	6	8	6	7	9	10
CEC (me/100 g)	0-5	1.3	1.6	3.1	3.8	1.4	1.8	3.3	3.8
	10-20	0.9	1.3	3.5	3.8	1.4	1.8	3.3	3.8
	20-30	0.8	1.0	4.3	1.7	0.6	1.2	4.4	1.6
	40-50	0.6	0.9	0.8	0.8	0.6	0.8	1.4	2.0
Exchangeable Ca (me/100 g)	0-5	0.81	0.86	1.65	1.87	0.83	0.77	1.56	1.56
	10-20	0.37	0.64	1.11	1.50	0.60	0.44	1.10	1.26
	20-30	0.43	0.56	0.83	0.58	0.36	0.33	1.69	0.47
	40-50	0.36	0.48	0.33	0.36	0.36	0.22	0.42	0.40
Exchangeable K (me/100 g)	0-5	0.10	0.07	0.11	0.11	0.08	0.08	0.23	0.23
	10-20	0.04	0.05	0.09	0.08	0.09	0.05	0.08	0.12
	20-30	0.04	0.03	0.07	0.04	0.04	0.05	0.08	0.06
	40-50	0.03	0.03	0.04	0.03	0.06	0.04	0.04	0.08
Organic carbon (%)	0-5	0.29	0.54	1.54	1.37	0.46	0.97	1.43	1.18
	10-20	0.29	0.54	1.54	1.37	0.46	0.97	1.43	1.18
	20-30	0.05	0.30	1.13	0.29	0.10	0.17	0.89	0.32
	40-50	0.06	0.08	0.253	0.25	0.07	0.07	0.16	0.15
Total nitrogen (%)	0-5	0.012	0.032	0.129	0.112	0.034	0.065	0.102	0.095
	10-20	0.011	0.027	0.087	0.087	0.007	0.030	0.054	0.053
	20-30	0.023	0.022	0.087	0.023	0.014	0.014	0.085	0.022
	40-50	0.037	0.029	0.017	0.011	0.029	0.011	0.014	0.018
Available P (Bray No. 1) (ppm)	0-5	5.7	7.4	6.6	7.2	3.0	1.4	2.7	5.4
	0-20	3.8	8.1	4.7	2.9	2.4	1.5	2.2	3.3
	40-50	5.1	5.1	5.9	8.4	2.7	6.2	4.9	5.1

Notes: B-1 = Improved paddy (upper and lower fringe); B-3 = Improved paddy (middle valley bottom); B-5 = Improved paddy (lower valley bottom); E-1 = Farmer's paddy (upper fringe); E-3 = Farmer's paddy (middle fringe) ;E-5 = Farmer's paddy (upper valley bottom); E-7 = Farmer's paddy (lower valley bottom).

Table 7.14 shows the physicochemical nature of rice soils at transect 7 in Gara. Fringe soils are low in clay and effective cation exchange capacity and have poor chemical fertility. Although the top 20-30 cm of valley bottom soils have enough clay and, therefore, relatively high CEC and chemical fertility, the subsoils are sandy and poor. Some parts of valley bottoms in Gara, as well as in Anfani and in Gadza valley, have a very thin layer of top soil— and there are waste lands that no longer have any clay layer at all. Most inland valleys are now characterized as highly degraded soils due to erosion and leaching of soil nutrients.

T. Wakatsuki

Sampling positions of B-1, B-3, B-5, E-1, E-3, E-5 and E-7 are shown at the Table 4-3 of 1986 Annual report, page 86, and Fig.6 of the next page 86.

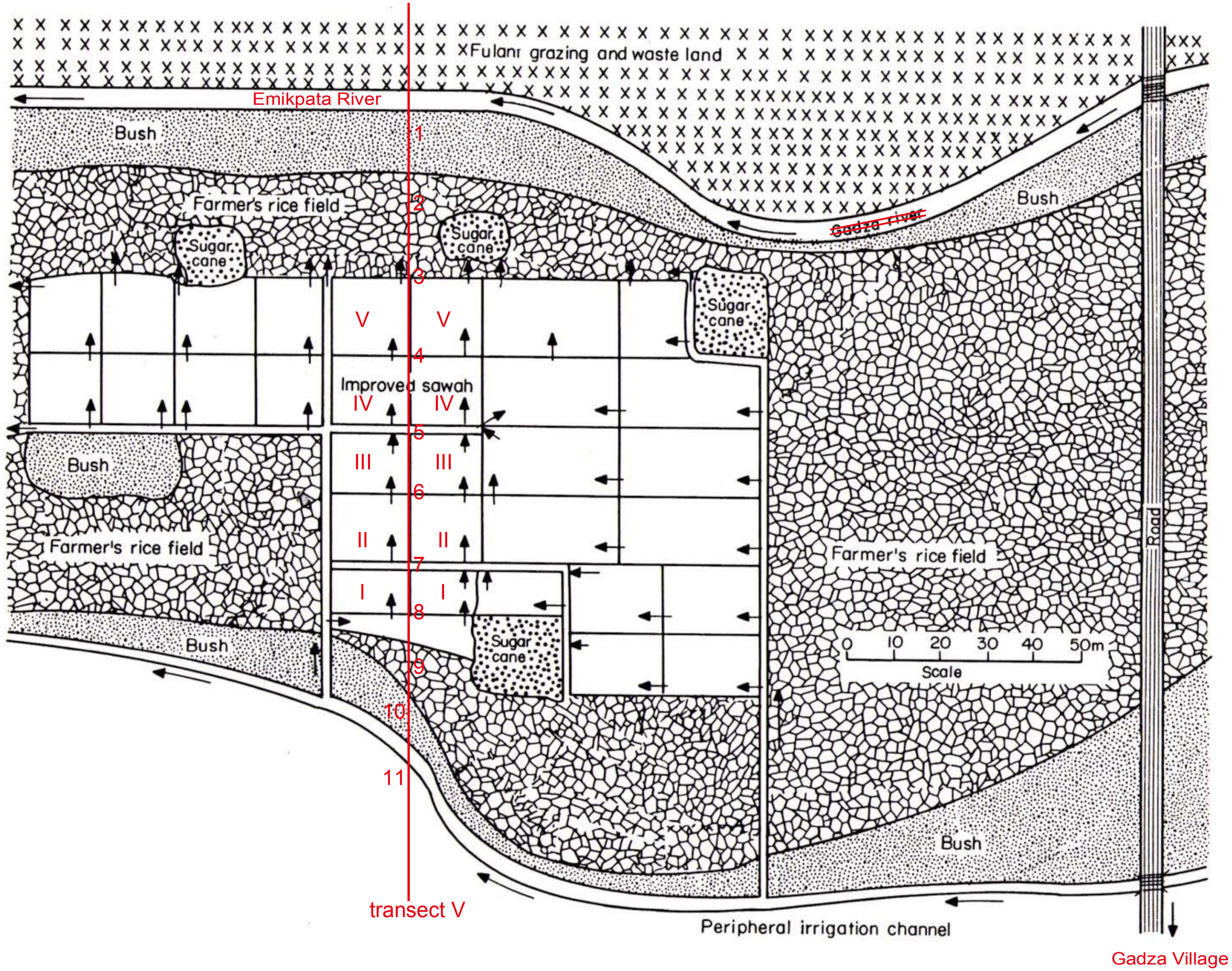

Figure 7.5. Sketch of farmers' rice fields and improved paddy (*sawah*) at Gadza, Bida, Nigeria, November 1987

Note: Rice yields of various varieties in the Sawah plots at I, II, III, IV and V are shown in Table 6 of the paper presented at the 2nd WAFSRN (West Africa Farming System Research Network) symposium by T. Wakatsuki et al. entitled "Sawah for Sustainable Rice Farming in Inland Valley Swamps, IVSs in West Africa," 28th Augus~ 1st September 1989, Accra, Ghana. Top 10 cm soil characteristics of the I~ V as well as ground water dynamics along the transect V above are shown in Table 7 and Fig. 7 respectively of the same paper above. The data are shown in Wakatsuki et al. WAFSRN paper in 1989.

Before Sawah development on 12th of August 1987. View from the position of 4 of transect V of Figure 7.5.

Bund repairing of sawah plot III. Photographed at the plot IV bund (the same position of 4), 1st of October 1987.

Philippine made turtle power tiller assisted sawah plot puddling and leveling of the sawah plot I , 2nd September 1987.

Photographed at the position of 9 of the Fig 7.5. One month before harvest, 9th of December 1987

Photographs of various satges of Sawah system development shown in Figure 7.5

Photographs of various stages of Sawah system development shown in Figure 7.5（All photographs were taken during August to December 1987 and added for supplementary information on 29 April 2014 by T. Wakatsuki)

Table 6. Rice yields of various varieties in the improved SAWAH in toposequence along the transect V in Gadza valley, August 1987 ~ January 1988.

Entry designation	yields (ton/ha) at a various toposequence Fring-I	II	III	IV	V-Bottom	Mean
ITA230	4.7	3.6	5.7	6.4	7.6	5.6
ITA306	4.9	4.1	4.3	6.6	7.5	5.4
ITA312	3.0	5.5	5.3	6.9	6.9	5.5
Tox3109-75-4-1	3.3	4.2	5.4	6.2	5.6	4.9
Tox3114-10-1-1	2.6	3.8	2.8	4.7	4.5	3.7
Tox3118-2-E2-2	5.0	5.0	5.5	11.2?	6.6	6.7
Tox3118-6-E2-3	3.3	6.3	4.7	7.6	7.1	5.8
Tox3118-47-1-1	3.0	5.3	5.2	5.8	6.0	5.1
Tox3118-78-2-1	3.0	6.4	5.6	5.6	6.5	5.4
Tox3133-56-1-3	2.1	5.3	3.4	6.7	6.2	4.7
ITA308	2.7	5.9	6.9	4.8	5.0	5.1
Manbeshi (local check)	2.1	4.9	4.3	4.8	6.2	4.5
Mean	3.3	5.0	4.9	6.4	6.3	5.1

(Wakatsuki et al. "Sawah for Sustainable Rice Farming in Inland Valley Swamps, IVSs, in West Africa, 2nd WAFSRN symposium, 28th August~ 1st September, 1989, Accra, Ghana.)

Supplementary soil data in relation to Table 6 above and Figure 7.5 in page 188 as well as Figure 7 in next page

Top 10cm Soil Characteristics of Toposequence Trials at Gadza IVS. Sampled at September, 1987, just before transplanting of rice.

Topo-sequence	pH	Org-C (%)	Total N (%)	Bray 1-P ppm	Exchangeable Catins Ca (me / 100g soil)	Mg	Mn	K	Na	Total Acidity	effective CEC	Sand (%)	Silt (%)	Clay (%)
I, Fringe	5.5	0.17	0.015	0.9	0.47	0.16	0.01	0.06	0.09	0.220	1.01	94	4	3
II	5.5	0.54	0.046	4.8	0.86	0.27	0.04	0.09	0.12	0.190	1.57	81	14	5
III	5.1	1.16	0.066	1.2	1.27	0.46	0.07	0.14	0.01	0.257	2.21	66	28	7
IV	5.0	0.93	0.068	1.1	1.02	0.41	0.06	0.10	0.13	0.270	1.99	72	12	17
V, Bottom	5.0	0.72	0.056	1.2	1.13	0.43	0.06	0.10	0.11	0.257	2.09	72	12	17

(Data are cited from chapter 6, page 398 Table 6-5, "Restoration of Ecological Environment and Rural Life of Savannah Zone of West Africa(In Japanese: Nishi-Afurika Sabanna No Seitai Kankyo No Shufuku To Nouson No Saisei)," edited by Hirose and Wakatsuki, 1997, Norin Tokei Kyokai, Tokyo, Japan.)

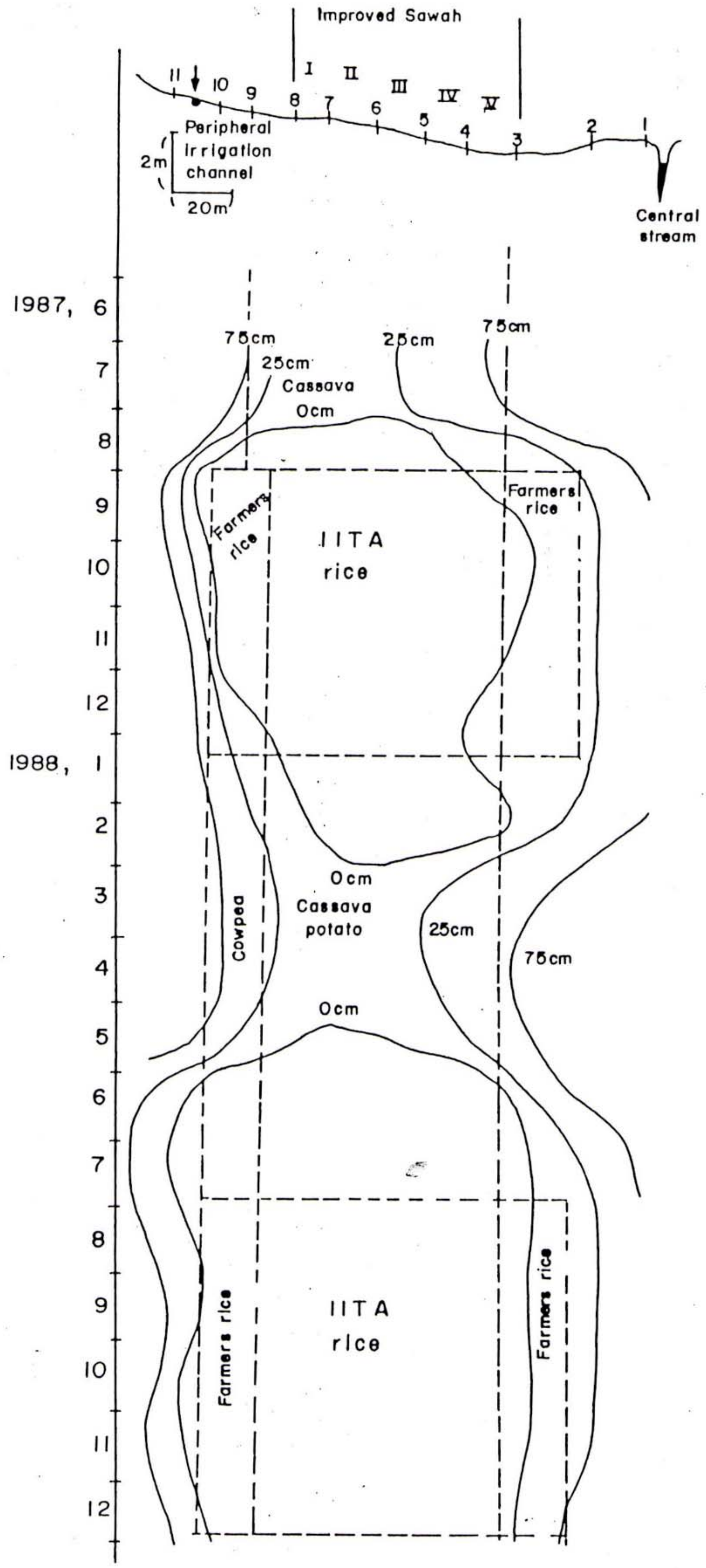

Figure 7. Ground water depth (cm) dynamics and land use pattern along the transect V in Gadza valley, On-farm research site for the effect of the Sawah, Fabourable IVS.

(Wakatsuki et al. "Sawah for Sustainable Rice Farming in Inland Valley Swamps, IVSs, in West Africa, 2nd WAFSRN symposium, 28th August~ 1st September, 1989, Accra, Ghana.)

Effect of improving the paddy or *sawah* systems

The rudimentary *sawah* system used by farmers was improved at Gadza in 1986 in order to reduce water leakage and level the surface (figure 7.5). The aim was to create a more regular shape and bigger plot size, as well as more bunds. Since the work was done using only traditional tools, the quality of the bund and the degree of leveling were not excellent. However, with subsequent croppings it is expected that this will improve, provided farmers do not destroy established bunds. After improvement of the *sawah*, a Turtle power tiller was used for puddling and leveling. These changes also resulted in improved water management practices. The improved *sawah* decreased the water requirement and increased rice yield considerably, as shown in the 1986 Annual Report.

Table 7.15 shows the dynamics of the physicochemical nature of rice soils in improved *sawah* and in farmers' rice fields in an IVS in Gara. The characteristics of the top 5 cm of soils were compared before and after rice cultivation. Topsoils in the improved *sawah* seemed to accumulate clay during the rice growing period, resulting in higher effective CEC and exchangeable calcium and magnesium. However, the clay content in farmers' rice fields did not tend to increase. Instead soils in farmers' rice fields tended to lose both their silt and their clay fractions. The retention times of water in improved *sawah* were 1 to 2 days at the fringe and 3 to 5 days on bottom land. In farmers' fields retention times were estimated at a few hours only. Thus the clay particles in water in the improved *sawah* had enough time to settle, while soils in farmers' rice fields were more easily eroded by the continuous flow of surface water.

Improved *sawah* systems have been recognized as one of the most sustainable wetland production systems in a wide range of climatic conditions from temperate monsoon to humid tropics in Asia. There are no physical and environmental limitations to the development and management of the *sawah* system in most of West African IVS, as demonstrated in this as well as earlier research by other groups. It is therefore necessary to determine the socioeconomic constraints and devise strategies that would lead to widespread adoption of the system by African farmers.

T. Wakatsuki, M. C. Palada and O. O. Fashola

Costs and returns of improved paddy system in Bida, Nigeria

To construct the partially improved *sawah* (paddy) system described in the previous section would require an estimated 175 to 225 person-days of hired or family labor per hectare. In addition, about 20 person-days would be required every year to maintain the systems. Assuming a 10-year life span for an improved sawah and a discount rate of 20 percent, the present value of the investment is ₦1379 ha^{-1} (table 7.16). A modest yield increase of 0.5 to 1.5 tons ha^{-1} is easily attainable under farmers' crop management conditions. During the first year of improvement it is assumed that yield increase will be zero or minimal, since surface soil will be considerably disturbed. Using the current farm state market price of ₦730 ton^{-1} an internal rate of return (IRR) of 58 percent and a benefit: cost ratio of 2.4 are obtained. This conservatively estimated rate of return is much above the market interest rate, indicating that it would be profitable to invest in small-scale paddy improvement.

If the profitability of paddy improvement is so high, why have farmers not made investments in these improvements? The answer may lie with the past economic policies of the government and local institutional factors. In the past, liberal food import policies and overvaluation of the naira turned the terms of trade against the agricultural sector. For example, re-evaluating the investment at the 1984/85 paddy price of ₦350 ton^{-1}, the IRR is reduced to 27 percent, only a little over the institutional

Table 7.15. Dynamics of physicochemical natures of rice soils in improved sawah and farmers' fields at inland valley, Gara, Bida, Nigeria, 1987

Sawah system		pH (H_2O)		Org. car-bon	T-N	Exchangeable cations (me/100g)							Avail. P (B-1)	Sand (%)	Silt (%)	Clay (%)
		wet	dry		%	Ca	Mg	K	Na	Mn	Al+H	CEC				
1. Top-soil, 0.5 cm, sampled at September 19, 1986 (transplanting time)																
Impro-)	B-1	5.8	5.1	0.42	0.026	0.53	0.11	0.08	0.01	0.05	0.34	1.12	23.2	82	11	7
ved)	-3	5.8	5.6	1.50	0.108	1.32	0.29	0.19	0.01	0.12	1.23	3.17	13.5	63	20	17
)	-5	6.0	4.4	1.41	0.104	1.37	0.31	0.21	0.03	0.16	1.00	3.08	10.9	66	17	17
Impro-)	C-2	5.6	5.2	0.49	0.050	0.64	0.12	0.17	0.03	0.05	0.33	1.34	53.2	82	8	10
ved)	-4	5.7	4.8	1.43	0.110	1.44	0.33	0.29	0.03	0.14	0.95	3.18	14.9	64	19	17
)	-6	6.3	4.7	1.84	0.136	2.25	0.43	0.39	0.05	0.22	0.81	4.15	9.1	55	23	22
Far-)	E-1	5.7	5.3	0.87	0.034	0.52	0.19	0.11	0.02	0.08	0.52	1.44	17.2	78	14	8
mer's)	-3	5.7	5.0	1.26	0.076	0.80	0.17	0.13	0.02	0.11	1.24	2.47	9.0	68	20	12
rice)	-5	5.4	4.9	1.19	0.088	0.82	0.20	0.14	0.02	0.11	1.48	2.77	5.9	62	20	18
paddy)	-7	6.1	5.1	2.69	0.200	2.10	0.44	0.46	0.07	0.16	1.04	4.27	11.2	52	26	22
II. Top-soil, 0-5cm, sampled at 15 January 1987, harvesting time. Difference between 1 and II, harvesting - (transplanting)																
Impro-)	B-1	-	0.2	0.41	-0.004	0.31	0.13	0.01	0.10	-0.02	-0.14	0.37	-16.6	0	0	0
ved)	-3	-	-0.1	0.04	0.021	0.33	0.13	-0.08	0.08	-0.04	-0.25	0.18	-6.9	1	0	-1
)	-5	-	-0.4	-0.04	0.008	0.50	0.50	-0.10	0.07	-0.07	-0.14	0.69	-3.7	-11	7	4
Impro-)	C-2	-	-0.3	0.07	0.009	0.33	0.2	-0.08	0.07	-0.02	-0.11	0.87	-23.6	-10	8	2
ved)	-4	-	-0.2	-0.05	-0.004	1.06	0.17	-0.14	0.09	-0.12	0.02	1.12	-7.4	1	-6	5
)	-6	-	-0.2	-0.15	0.019	0.07	0.15	-0.18	0.11	-0.08	0.82	0.89	-3.9	-7	2	5
Far-)	E-1	-	0	-0.41	0	0.31	0.09	-0.03	0.09	-0.03	-0.52	-0.09	-14.2	6	-6	0
mer's)	-3	-	0	-0.29	-0.107	-0.03	0.08	-0.05	0.09	-0.06	-0.66	-0.63	-7.6	5	-5	0
rice)	-5	-	-0.1	0.24	0.014	0.74	0.28	0.09	0.13	0.01	-0.74	-0.51	-3.2	2	0	-2
paddy)	-7	-	-0.8	-1.51	-0.110	-0.54	0.01	-0.23	0.05	-0.09	0.34	-0.46	-5.8	11	-11	0

Notes: B-1 = upper and lower fringe; B-3 = middle valley bottom; B-5 = lower valley bottom; C-2 = upper fringe; C-4 = middle fringe; C-6 = lower valley bottom; E-1 = upper fringe; E-3 = middle fringe; E-5 = upper valley bottom; E-7 = lower valley bottom;

Sampling positions of B-1, B-3, B-5, E-1, E-3, E-5 and E-7 are shown at the Table 4-3 of 1986 Annual report, page 86, and Fig.6 of the next page 86.

Table 7.16. Financial analysis of paddy improvement by farmers in Niger State, Nigeria[a]

Year	Investment cost (₦ ha^{-1})	Rice yield increase (t ha^{-1})	Value of rice (₦ ha^{-1})	Net benefits (₦ ha^{-1})	Costs	Present values (₦ ha^{-1})[b] gross benefits	net benefits
1	1000	0	0	0	1000	-1000	-1000
2	100	0.5	365	265	83	304	221
3	100	1.0	730	630	67	491	437
4	100	1.5	1095	995	55	603	576
5	100	1.5	1095	995	45	494	449
6	100	1.5	1095	995	37	405	340
7	100	1.5	1095	995	30	332	333
8	100	1.5	1095	995	25	273	278
9	100	1.5	1095	995	20	223	231
10	100	1.5	1095	995	17	183	193
Total	1900 B: C [c] = 2.4	12.0 IRR [d] = 58%	8760	6860	1379	3308	2058

Notes : [a] Although improved paddies can last indefinitely, benefits and costs are estimated for a 10-year period only since most farmers base their investment decisions on expected returns over a short to medium period. Also a conservative yield increases of 1.5 t ha^{-1} is maintained although yield increases will become larger with the improvement of soil texture and soil fertility over time.

[b] Based on 20% discount rate

[c] B:C = Benefit cost ratio

[d] IRR = Internal rate of return

market interest rate. Thus, it was not attractive enough to invest in paddy improvement, given the high opportunity cost of farm labor and cash capital. Secondly, investment in paddy improvement presupposes permanent land use rights by farmers whereas most rice farmers in Niger State are tenants. It is unlikely that farmers will invest in land which is not theirs when there is no assurance that they can continue to cultivate indefinitely. In fact, making the land more productive may attract absentee landlords back to it, or they may increase the rent.

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