INVITED PAPERS

CONSTRAINTS AND OPPORTUNITIES FOR RICE CROPPING IN WEST AFRICA'S INLAND VALLEY LOWLANDS

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ABSTRACT

Determinants for use of lowlands for rice cropping and investment in water control measures were determined through surveys in 179 villages and major cities in central Côte d'Ivoire. Results indicate that market access and population pressure are driving forces for lowland use. Major determinants for investment in water control measures were land ownership, distance to major cities and the number of immigrants active in the lowlands. Possibilities to improve rice productivity and profitability along a water control gradient from rainfed to irrigated lowland were investigated in the same region. Average farmer yield in the rainfed area was 3.9 t ha^{-1} and in the irrigated area 4.1 t ha^{-1}. Rainfed yields were close to irrigated yields, despite much lower input use. We attributed this to poor soil fertility levels at the irrigated site. Improved soil fertility and weed management resulted in a 1 t ha^{-1} yield gain over farmer practice, in both rainfed and irrigated systems. Such improvements were not associated with higher risk and highly profitable, with value/cost ratios > 5 in the rainfed lowlands and without additional costs in the irrigated lowlands. Our research suggests that providing farmers with information on best-bet management of available resources is critical.

Introduction

The lowland ecology in West and Central Africa has great potential for rice production development in the sub-region. Mainly sheltered in inland valley bottoms, there is a potential of 30 to 50 million hectares in West and Central Africa alone that can be targeted for dissemination of improved rice production technologies. About 10 to 25% of inland valley lowlands are being used (mainly for rice), and without water control measures, rice yields are usually low, i.e. about 1 t ha^{-1} (Andriesse et al., 1995). Potential yield, limited by solar radiation and temperature only has been estimated at 7 to 8 t ha^{-1} in the savannah and humid forest ecologies (Becker et al., 2001). There is, therefore, great potential for expansion of the lowland area used for rice, and for improving yields, as the yield gap between actual and potential yields is very large.

Inland valley lowlands have usually relatively fertile soils. They are generally considered as robust, in contrast to the more fragile uplands. The single most important biophysical constraint to lowland development is lack of water control. With improved water management, intensification becomes possible, i.e. it may no longer be too risky for farmers to use external inputs, such as fertilizer. Increased use of inputs and improved input use efficiency may lead to higher and more sustainable rice yields. Better water control may also open up possibilities for diversification, such as aquaculture, or growing other crops, like vegetables in the dry season on residual moisture, or using irrigation water from a shallow groundwater table. Water control measures may range from simple bunding to more sophisticated control measures based on dams or stream derivation. Other important biophysical constraints, next to water control, are weed infestation, poorly adapted rice cultivars, iron toxicity, and pest and disease infestation levels (e.g. Jamin and Andriesse, 1993).

Important socio-economic factors are: organizational problems at the village level, access to capital and labour, land tenure, access to input and output markets, human health concerns, socio-cultural perceptions related to inland valley use, lack of agricultural machinery for land preparation and harvesting, and competition with other activities. (E.g. Lidon and Legoupil, 1995 and Jamin and Andriesse, 1993).

Wopereis et al. (1999) and Donovan et al. (1999) showed that sub-optimal soil fertility and weed management in irrigated systems in the Sahel and the Sudano-savanna region of West Africa resulted in average losses of 70% of applied nitrogen (N), and, therefore, large yield losses. They also identified N as the most limiting nutrient to rice growth in irrigated lowlands, before phosphorus (P) and potassium (K). Häfele et al. (2000) demonstrated that with improved soil fertility and weed management an average yield gain of 2 t ha^{-1} could be obtained in irrigated systems in Mauritania and Senegal, resulting in an increase in net revenues of 40 to 85% to farmers' practice. Wopereis et al. (2000) used the term integrated crop management to indicate the need to provide farmers with crop management options (baskets of choices), adapted to their needs, from land preparation to harvest and post-harvest activities. They proposed a complete 'integrated crop management basket' for irrigated systems in the Sahel. Similar work is needed for rainfed and irrigated lowlands in the savanna and humid forest zones.

Rice farmers in irrigated lowlands in the savanna and humid forest zones are usually given 'blanket fertilizer recommendations'; i.e. often a combination of 100 kg urea ha^{-1} applied in two equal splits and 200 kg NPK composite basal fertilizer ha^{-1}. Blanket recommendations are questionable, as best-bet soil fertility management will depend on many factors, such as native soil fertility, target yield, potential yield, farmer crop management, and fertilizer and paddy prices (Häfele et al., 2001). Knowledge to develop more site-specific recommendations is usually not available. However, the current blanket recommendation of 100 kg urea ha^{-1} and 200 kg NPK composite fertilizer ha^{-1} seems not to give enough emphasis to N. We hypothesized that a recommendation of 200 kg urea ha^{-1} and 100 kg NPK ha^{-1} would be more appropriate, and cheaper, as NPK fertilizer is usually more expensive than urea.

A first objective of the work reported here was to obtain information on the distribution and use of lowlands, and their diversity in terms of water control technologies as well as land ownership in central Cote d'Ivoire. A second objective was to investigate the magnitude of the yield gain that can be obtained by improving soil fertility and weed management in farmers' fields in inland valley lowlands with different degrees of water control.

Materials and methods

Village survey

We selected 11 out of 19 districts 'sous-prefectures' in the Bandama valley region in central Côte d'Ivoire: i.e. Botro, Bouaké, Brobo, Diabo, Djébonoua, Katiola, Sakassou, Béoumi, Bodokro, Dabakala and Boniérédougou. We randomly selected 179 villages from a total of 857 villages (i.e. about 20%) occurring in this region. From December 1999 to May 2000, we visited all sample villages and obtained information on lowland use, ownership, water control methods, and general information, such as presence of dispensary, school, water pumps etc. We will refer to lowlands in or near villages as rural or village lowlands. A large number of lowlands located in capital cities of each district were also included in the survey. We will refer to these lowlands as urban lowlands. More details can be found in Sakurai (2001).

Field trials

Field trials were conducted in rainfed and irrigated rice growing areas in the district of Bouaké in the Bandama valley region in central Côte d'Ivoire, along the main road from Bouaké to Katiola during the 2000 wet season (July – December). The irrigated rice area that was studied is located near the village of Yebouekro. The irrigation scheme (110 ha) has complete irrigation and drainage facilities and was developed with funding from the government of Japan. Irrigation is by gravity and dam-based. Current recommended fertilizer rate is 100 kg urea ha^{-1} in two splits (one and two months after transplanting) and 200 kg NPK composite fertilizer (10% N, 20% P_2O_5 and 20% K_2O) ha^{-1} as basal.

The rainfed area is located near the village of Bamaro. Fields are bunded, but no good drainage canal system exists, often resulting in severe floods at the start of the wet season. Farmers do not use any fertilizer, and hand weed. Yebouekro and Bamaro are at about 3km distance. Options to improve soil fertility and weed management were discussed with farmers and extension staff from national extension agencies at the onset of the 2000 wet season. For the irrigated area the following treatments were identified:

- TF: farmers' practice
- T1: farmers' practice but new recommended fertilizer management: 200 kg urea ha^{-1} in two splits, i.e. at mid-tillering and panicle initiation, and 100 kg complex NPK fertilizer (10-20-20) as basal.
- T2: farmers' practice but recommended weed management: early application of herbicide at 20 DAT
- T3: new recommended fertilizer and weed management (combining T1 and T2)

For the rainfed area the following treatments were identified:

- TF: farmers' practice
- T1: farmers' practice but new recommended fertilizer management: 100 kg urea ha^{-1} at mid-tillering and panicle initation, in two equal splits
- T2: farmers' practice but recommended weed management: early manual weeding at 27 DAT
- T3: new recommended fertilizer and weed management (combining T1 and T2)

Fields of collaborating farmers were split in two. On one half, the farmer managed his field according to his own itinerary. In the other half, the T1, T2 and T3 treatments were installed. Size of these subplots varied per field, but was at least $100m^2$. At rice maturity 100 m^2 in the cental area of each subplot was harvested and threshed, and grain yield and grain water content determined. In addition, a separate $1m^2$ area was sampled for yield component analysis in each subplot. All grain yield results were corrected to 14% water content. All fields were harvested at physiological maturity, often before farmers harvested their fields themselves. Losses due to late harvesting are, therefore, not included in the data provided here. In the irrigated area, farmers were asked not to apply fertilizer on part (5m x 5m) of their fields. These so-called 'T0 plots' were harvested at rice maturity as well, and used as a proxy for soil fertility status. Soil samples were taken (10 composite samples in each subplot) before the start of the season for analysis of pH, and plant available N, P and K.

Farmers were interviewed throughout the growing season about the management practices employed on the farms within the study. Observations included field size, use of basal fertilizer, timing of crop management interventions, as well as the dosage and cost of inputs, services, and labour and paddy price. Partial budget techniques (Crawford and Kamuanga, 1991) were used to compare the treatments in terms of their costs and returns.

Results and discussion

Village survey

Out of the 179 villages surveyed, 152 (i.e. about 85%) had one or more lowlands. A total of 101 villages used the lowlands for cultivation during the 1999WS, and 84 of the villages grew rice. Most of the other villages produced vegetables. Out of the 152 villages with lowlands, 121 villages had grown rice in the past. Since only 84 villages grew rice in the 1999WS, this means that almost one fourth of the villages had stopped growing rice.

We divided the 152 villages with lowlands into two groups: one group contained the villages that used lowlands for cultivation and the other one contained the villages that did not use lowlands for cultivation. Table 1 gives average characteristics of both groups. We found that villages cultivating lowlands are located closer to the capital city of the district, are more populated and have more immigrants. In addition, dispensaries were established earlier in villages using lowlands than in villages not using lowlands. These results suggest that developed and populated villages tend to use lowlands, possibly due to scarcity of upland areas.

The total number of lowlands within reach of the 152 lowlands was 285 (Table 2). Of these 285 lowlands, 127 were used for rice in the 1999WS, and 37 were used for vegetable production.

Table 1 Characteristics of sampled villages.

	All the villages with lowlands	Villages using lowlands	Villages not using lowlands	Significantly different or not[2]
No. of villages	152	101	51	n.a.
Village location				
Distance to SP (km)	15.1	13.9	17.4	1.83*
Travelling time to SP (min)	53.1	50.4	58.4	1.02
Walk to SP (%)	44.7	45.5	43.1	0.08
Distance to Bouaké (km)	44.1	45.0	42.1	0.61
Population				
Village population as of 1988	394	430	321	2.15**
Village of Baoulé (%)	79.6	81.2	76.5	0.46
Number of immigrants	14.1	19.0	4.3	2.05**
Village facilities				
Primary school (%)	51.3	54.5	45.1	1.19
Years since primary school	14.2	15.4	12	1.11
Dispensary (%)	13.2	14.9	9.8	0.76
Years since dispensary	1.25	1.6	0.6	1.65*
Hand pump (%)[1]	82.9	78.2	92.2	4.64**
Years since first hand pump	14.9	14.5	15.6	0.57
No. Of functioning hand pumps	1.19	1.2	1.18	0.35
Public water supply by SODECI (%)	7.9	9.9	3.9	1.66
Market (%)	11.2	11.9	9.8	0.15
Market days in a week (1-7)	1.8	1.7	2.1	1.32
No. Of shops	1.4	1.6	1.1	1.22

[1]If SODECI is operating in the village, this variable is zero even if there exist hand pumps.
[2]When two means are compared, the numbers in this column are t-statistics and when two proportions are compared, the numbers in these columns are Pearson's Chi-square statistics. ** and * indicate significance levels of 5% and 10% respectively

Table 2 Land use, ownership and water control methods used in urban and village lowlands in the Bandama region in central Cote d'Ivoire.

Variable	Urban lowlands		Village lowlands	
	No.	% (of total number of lowlands sampled)	No.	% (of total number of lowlands sampled)
Total number of lowlands sampled	73	100	285	100
Land use				
Lowlands used for rice in 1999WS	72	99	127	45
Lowlands used for rice in 1999WS or in the past	72	99	224	79
Lowlands used for vegetables in 1999WS	64	88	37	14
Ownership				
Owned by government	15	21	0	0
Owned by village or village chief	0	0	117	41
Owned by individuals	53	73	149	52
Owned by absentees	7	10	21	7
Water control for rice				
Bunding	63	86	61	27[1]
Canals	38	52	58	26[1]
Tanks	3	4	16	7[1]
Modern dam	8	11	10	5[1]

[1]Percentage is calculated per number of lowlands used for rice in 1999WS or in the past

As many as 224 lowlands were used for rice in the past, indicating that rice cropping is being abandoned. Farmers blamed this on lack of water and increasing problems with weeds, possibly due to water scarcity. In contrast, almost all urban lowlands produced rice, and most of them produced vegetables as well. None of the sample urban lowlands had been abandoned for rice cropping. This seems to indicate that other factors contributed to the abandonment of rice cropping in the village lowlands as well, such as access to markets, opportunity for cash income from vegetable production and off-farm activities, factors that are mostly lacking in rural villages.

Land is usually not a private property in sub-Saharan Africa, and hence there are few real 'land owners'. We use 'land owners' in our analysis to indicate who controls the use of lowlands. Ownership of the lowlands can be largely classified into four types of land ownership: local government, village or village chief, individuals living in the village or town, and individuals living outside the village or town (absentee owners). In our survey, more than 50% of rural lowland was owned by individual persons living in the village, and about 30% of the lowlands were owned by the village or village chief. In the urban lowlands, local government authorities owned about 20%, the remainder was mostly owned by individuals living in the city.

Water control is the key factor to increase yield and reduce risk in lowlands. In our village sample, 224 lowlands were used for rice in the past. Out of them, only 10 lowlands are irrigated by water stored behind modern dams. We found tanks (water storage behind small dams constructed by villagers) in 19 lowlands. Canals and bunds were the most important technologies to control water and were constructed more often in urban than in rural lowlands. Our results imply that rice production in urban lowlands is more intensified than in village lowlands.

We determined what drives adoption of canals and bunding using probit regression models. Regression results revealed (Table 3) that canals are more frequently constructed in lowlands owned by absentee landlords, located closer to Bouaké and situated in non-Baoulé villages. Bunds are more frequently constructed in lowlands owned by absentee landlords and situated in non-Baoulé villages. Bunding was also positively correlated with the number of immigrants. Hence we can conclude that the type of land ownership does affect investment in water control technologies in lowlands. Individualized ownership by absentee landlords encouraged investment, while other types of ownership discouraged it.

Land ownership of urban lowlands can largely be classified into two types: ownership by local government authorities and individual ownership. The regression analysis showed (Table 4) that local government ownership is a significant positive factor associated with canal construction. In addition, migrant rice farmers construct canals more often than local rice farmers. No driving factor was found for bund construction in urban lowlands. This is probably due to the fact that most (55 out of 64) urban lowlands have bunds, regardless of ownership and other characteristics.

Field experiments
Farmers' practice (TF) in the irrigated system resulted in an average rice grain yield of 4.1 t ha^{-1}.

Table 3 Determinants of water control technologies in 213 village lowlands, of which 43 have canals and 49 are equipped with bunds.[1)]

	Canals	Bunds
Independent Variables		
Land Ownership		
Village	Not significant	Negative ***
Village Chief	Negative ***	Negative ***
Individual Villagers	Negative ***	Negative ***
Absentees	Positive **	Positive ***
Lowland Characteristics		
Distance from Village (km)	Not significant	Not significant
Size of Lowland (ha)	Not significant	Not significant
Village Location		
Distance to Bouaké (km)	Negative ***	Not significant
Population		
Village Population	Not significant	Not significant
Baoulé village	Negative ***	Negative ***
Number of Immigrants	Not significant	Positive **
Village Facilities		
Years since Primary School	Not significant	Positive *
Market	Not significant	Not significant

1) Probit model is used for the estimation of coefficients. ***, ** and * indicate significance levels 1%, 5% and 10% respectively.

Table 4 Determinants of water control technologies in 64 urban lowlands, of which 31 have canals and 55 are equipped with bunds.[1)]

	Canals	Bunds
Independent Variables		
Land Ownership		
City Government	Positive **	Not significant
Individuals	Not significant	Not significant
Lowland Characteristics		
Distance from City Centre (km)	Not significant	Not significant
Size of Lowland (ha)	Not significant	Not significant
Utilization Rate (%)	Not significant	Not significant
Migrant farmers	Positive **	Not significant
Number of rice farmers	Not significant	Not significant

1) Probit model is used to explain the two variables (canals and bunds). ** indicates significance level 5%.

Exact crop management practices followed by farmers have not yet been compiled. Yields were, however, very variable and ranged from 2.1 t ha^{-1} to 7.7 t ha^{-1}. Grain yield was increased on average by 0.7 t ha^{-1} by applying the new recommended fertilizer rates (T1). Our recommended weed management practice (T2) did not result in a significant yield gain; average yield was even slightly lower than farmers' practice. Improving both soil fertility and weed management (T3) resulted in an average yield gain of 1.1 t ha^{-1}. The coefficient of variation for T3 was considerably lower than for farmers' practice, indicating that with the recommended practice higher and more stable yields were obtained.

Farmers' practice (TF) in the rainfed system resulted in an average grain yield of 3.9 t ha^{-1}. Exact crop management practices followed by farmers have not yet been compiled. Yields varied from 2 t ha^{-1} to 6.5 t ha^{-1}. Grain yield was increased on average by an average 0.6 t ha^{-1} by applying the new fertilizer management strategy (T1). The new weed management strategy (T2) did result in a slight but not significant yield gain of 0.2 t ha^{-1}. Improving both soil fertility and weed management (T3) resulted in an average yield gain of 0.9 t ha^{-1}.

Yield variability in the rainfed system was considerably lower than in the irrigated system. This is surprising, especially because fields in the rainfed system were severely damaged in the early growth stages by flooding and case worms. Rice fields recovered, however, very well. The large variability in the irrigated system may be due to the large variability in sowing dates, and resulting spikelet sterility due to cold for late sowing dates. Sowing dates ranged from mid-July to early October among the 16 sample farmers in the irrigated area. This aspect will be investigated in more detail as soon as the yield components of the different subplots have been analyzed.

T0 yields in the irrigated system were on average only 2.6 t ha^{-1}, indicating that soils were relatively poor. This may be due to the land scraping and levelling that was done to install the scheme. Analysis of the soil samples will give a better insight in the differences between soil fertility in the rainfed and the irrigated sites. T0 yields in the irrigated area can be compared with farmers' yields in the rainfed area, where no fertilizer was applied. The difference is a striking 1.3 t ha^{-1}, indicating that Bamaro farmers profit from a much more fertile soil than Yebouekro farmers. Differences in native soil fertility need to be taken into account when giving fertilizer recommendations to farmers. Future research will look into possibilities of using the framework for soil fertility management developed by Häfele et al. (2001) for irrigated systems in the Sahel in the rainfed and irrigated lowlands of the savanna and humid forest zones.

A first rough financial analysis of the T3 treatment compared to the TF treatment revealed that improved soil fertility and weed management in both rainfed and irrigated systems was highly profitable. The cost/benefit ratio for Bamaro (rainfed area) was 5.4, i.e. much higher than the threshold of 1.5 to 2 recommended by Crawford and Kamuanga (1991). Yield gains in the irrigated system with the T3 treatment were obtained without additional costs. Our research suggests that providing farmers with information on best-bet management of available resources is critical.

Table 5 Grain yields (t ha^{-1}, 14% water content) obtained at the experimental sites in Yebouekro (irrigated) and Bamaro (rainfed), Bandama valley, central Côte d'Ivoire. T0: non-fertilizer plots at the irrigated site in Yebouekro. TF: farmers' practice; T1: farmers' practice, but recommended fertilizer management; T2: farmers' practice, but recommended weed management; T3: recommended fertilizer and weed management. Treatments in a row followed by a common letter are not significantly different according to the Duncan Multiple Range Test with $\alpha = 0.05$.

	T0	TF	T1	T2	T3
Rainfed area					
Yield (t ha^{-1})		3.9b	4.5a	4.1b	4.8a
SD (t ha^{-1})		0.9	0.9	0.9	0.9
Irrigated area					
Yield (t ha^{-1})	2.6c	4.1b	4.8a	3.9b	5.2a
SD (t ha^{-1})	1.4	1.6	1.3	1.5	1.1

Table 6 Economic evaluation of improved soil fertility and weed management (T3) using partial budgeting at the irrigated site of Yebouekro and the rainfed site of Bamaro, Bandama valley, Central Côte d'Ivoire. TF: farmers' practice; T3: recommended fertilizer and weed management.

Parameter	TF / T3	Units	Bamaro (rainfed)	Yebeoukro (irrigated)
Season			WS 2000	WS 2000
No. of farmers			16	16
Yield	TF	t ha^{-1}	3.9	4.1
	T3	t ha^{-1}	4.8	5.2
Additional costs[1]		1000CFA ha^{-1}	21	-1
Gross added product[2]		1000CFA ha^{-1}	114	134
Treatment net benefit[3]		1000CFA ha^{-1}	93	135
Value / Cost ratio[4]			5.4	n.d.[5]

[1] Additional costs: cost of the treatment – cost for the non-controlled treatment
[2] Gross added product: paddy price * yield increase – additional costs caused by higher yields
[3] Treatment net benefit: gross added product – additional costs
[4] Value / Cost ratio: gross added product / additional cost
[5] n.d.: not determined, because additional costs are negative

Conclusions

Market access and population pressure were two major factors affecting the use or non-use of lowlands. Individualization of land ownership has taken place in villages with better access to markets and higher population density. For the rural lowlands, individual ownership by absentee landlords encouraged investment. Canals and bunds were more frequently constructed in lowlands owned by absentee landlords, located closer to Bouaké and situated in non-Baoulé villages. Bunds were positively associated with the number of immigrants and level of education at village level. In the urban lowlands, land ownership by local government authorities were shown to be a positive factor for canal construction. In addition, migrant rice farmers are more likely to construct canals. No significant determinant was found for bund construction, probably because most urban lowlands have bunds.

Improved soil fertility and weed management was shown to be highly profitable for both irrigated and rainfed farmers in this region. Yield gains of 1 t ha^{-1} were obtained in both rainfed and irrigated systems. Partial budgeting showed the profitability of the improved management practices. Our research illustrated the importance to develop best-bet integrated crop management recommendations for low, medium and high input lowland systems.

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