

西アフリカ稲作の拡大、集約化、持続性：
コートジボワールとガーナの天水低湿地稲作の例¹

**Expansion, Intensification, and Sustainability of Rice Production in West Africa:
The Case of Rainfed Lowland Rice in Côte d'Ivoire and Ghana¹**

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要 約

西アフリカ諸国の政府は、増大するコメの需要に対処するためにコメを増産しようとしている。同地域でコメの生産拡大に大きなポテンシャルを持つのは、内陸にある低湿地 (inland valley lowlands) である。そこで、コートジボワールのブアケ市とガーナのクマシ市という内陸にある 2 つの大きな商業都市の周辺で、低湿地稲作に関する大規模な調査を実施した。本稿は、その調査の結果に基づき、低湿地における稲作の面的拡大、生産技術の集約化、生産の持続性、それぞれに影響する要因を明らかにする。調査では、まず少なくとも 1 ヶ所は領域内に低湿地のある村を無作為に選んだ。その結果、ブアケ市周辺地域では 157 ヶ村、クマシ市周辺地域では 60 ヶ村が選ばれた。調査対象村落にある低湿地の数は、合計するとブアケ市周辺地域で 317 ヶ所、クマシ市周辺地域で 60 ヶ所にのぼる。

ブアケ市周辺地域の低湿地のうち約 83% では、今までに少なくとも 1 回は稲作が行われたことがあり、約 37% では調査時にも稲が栽培されていた。一方、クマシ市周辺では、それぞれ約 85% と約 57% である。多変量解析の結果によると、ブアケ市周辺地域において低湿地稲作の実施確率を高める要因は、市場への近接度と人口圧であった。しかし、クマシ市周辺地域ではそれらは有意な影響を持たず、その代わり移民の数が稲作実施の確率を高めている。

水管理は、低湿地における稲作の集約化に非常に重要な技術である。しかし、クマシ市周辺地域の低湿地では、稲作はもっぱら天水に依存しており水管理技術は採用されていない。一方、ブアケ市周辺地域では、都市の近くに立地する低湿地ほど畦や水路を構築して水管理を実施する傾向にある。分析の結果、畦や水路の構築を促進する要因は、市場への近接度と移民の数であることが判明した。また、水路のある低湿地では放棄されずに稲作が持続している。

ブアケ市周辺地域で多数派を占める民族はバウレ、クマシ市周辺地域ではアシャンティである。両者ともアカン語族に属するため、文化や慣習については共通点が多い。両民族にとってコメは伝統的な作物ではないため、ブアケ市周辺とクマシ市周辺の両地域で稲作に従事しているのは、たいてい北部のサバナ地帯から来た移民である。移民が低湿地で稲作をする理由は、移住する以前に低湿地稲作の経験があること、移民には畑地が配分されない場合があることなどがある。このように両地域では類似性が高いが、稲作技術とりわけ水管理技術の採用は両地域で異なっている。ブアケ市周辺地域の方が土地の相対価格が高いこと、ブアケ市周辺地域では過去に政府や国際援助機関により技術普及が行われたことが理由であると考えられる。とりわけ、今回の分析対象からは除いてあるが、ブアケ市周辺地域内で実施された灌漑水田プロジェクトから技術が周辺地域に拡散した可能性が高い。一方、クマシ市周辺地域の土地所有制度は、移民が土地に長期的な投資をすることを妨げている可能性がある。

キーワード: 内陸低湿地、コメ、集約化、土地制度、移民

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Expansion, Intensification, and Sustainability of Rice Production in West Africa: The Case of Rainfed Lowland Rice in Côte d'Ivoire and Ghana

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Abstract

Governments of West African countries try to enhance rice production to cope with the increasing demand. Inland valley lowlands constitute a huge potential for rice production. Based on large-scale field surveys around two big inland markets in Côte d'Ivoire (Bouaké) and Ghana (Kumasi), this paper explores factors affecting the expansion, intensification and sustainability of lowland rice production. We randomly selected villages that have one or more lowlands within the village territory. The number of villages selected was 157 around Bouaké and 60 around Kumasi. We identified 317 lowlands in the Bouaké sample villages and 188 lowlands in the Kumasi sample villages.

About 83% of Bouaké lowlands were used at least once for rice cultivation, and 37% of total lowlands were under rice cultivation at the time of study. Corresponding figures for Kumasi were 85% and 57%. Multiple regression analyses revealed that market accessibility and population pressure increased the probability of lowland utilization in the Bouaké area, whereas they had no significant effect in the Kumasi area. In the Kumasi area, on the other hand, immigrant population positively influenced the use of lowlands.

Water control is an important technology for intensification of lowland rice production. In the Kumasi area rice cultivation is purely rainfed, but lowlands located closer to Bouaké tend to be equipped with bunds and canals. Bund and canal construction was found to be influenced positively by market accessibility and number of immigrants. The adoption of water control technologies enhanced the sustainability of lowland rice cultivation.

Dominant ethnic groups are Baoulé in Bouaké and Ashanti in Kumasi, both of which belong to the Akan language group that shares similar cultural heritage. For them rice is not a traditional crop. Usually, migrants from the Savanna zone are cultivating rice in lowlands because they are familiar with lowland rice production and they are sometimes not allowed to use upland fields. Hence we would attribute the differences in rice cultivation methods to the higher relative price of land in the Bouaké area as well as past governmental and/or foreign intervention. Particularly modern irrigation projects around Bouaké (which are excluded from our analyses) may have had spill-over effects of technologies. In addition, we hypothesize that the land tenure systems in the Kumasi area are discouraging migrant tenant cultivators to make a long-term investment in lowlands.

Keywords: inland valley lowlands, rice, intensification, land tenure, immigrants

1. Introduction

Demand for rice in West Africa has been growing since the 1970s not only due to population growth, but also because of a shift in diet away from traditional coarse grains caused by a number of factors such as urbanization (Lançon and Erenstein, 2002). Rice production in this region has grown fast relative to other cereals, but the gap between regional supply and demand for rice is steadily

increasing. As a result rice imports reached an average of 2.6 million tons in the early 1990s (WARDA, 1997). This has raised concern about the future food security in this region and policymakers are taking measures to enhance rice production.

Rice production can be increased by area expansion and/or intensification, i.e. increase in yield per unit area. Rainfed lowland ecology, one

of the five important rice production ecologies in West Africa,¹ is considered to have relatively high potential for both expansion and intensification. The lowland ecology occupies an estimated 20 million to 50 million hectares in West Africa, but only 10 to 25% of the lowland area is under cultivation (WARDA, 1998). Moreover, due to lack of water control, current rice yield in rainfed lowlands is 1.4 tons per hectare on average. Because potential yield is estimated to be 2.5 – 5.0 tons per hectare, potential for intensification is enormous (WARDA, 1999).

In spite of the huge potential for expansion and intensification of West Africa's rainfed lowland ecology, past studies have been limited to describing a few cases and no quantitative analysis on a representative sample has been done. In order to fill this gap and to generalize the observations to formulate policies, we have conducted surveys on lowlands randomly sampled from a large area and constructed a representative data set. Based on this data set, this paper is to identify quantitatively factors that determine the use of lowlands for rice cultivation (i.e. expansion), the adoption of water control technologies (i.e. intensification), and the continuation of lowland rice cultivation (i.e. sustainability).

2. Methods

2.1 Study Sites in Côte d'Ivoire and Ghana

It is generally believed that market access influences the intensification of rainfed lowland rice production. Hence, we selected two large inland cities in West Africa for the study sites in order to examine the effect of market access. The cities are Bouaké in the Bandama Valley region of Côte d'Ivoire and Kumasi in the Ashanti region of Ghana. They are the second largest cities in each country with a population of 333,000 in 1988 and 385,000 in 1984 respectively. Both cities have a large, regional market where locally produced rice as well as imported rice is being traded. Although both cities are not prohibitively far from coastal port cities, local rice should have advantage in terms of transportation costs over imported rice. In 2001 local rice sold at 250 to 300 FCFA/kg and imported rice sold at 250 to 600 FCFA/kg in Bouaké's retail market. Corresponding figures were 2600 to 3200 cedis/kg and 2600 to 6000 cedis/kg in Kumasi's retail market (according to our own survey). Because the exchange rate between FCFA and cedi

was about 1 FCFA = 10 cedis in the same period, nominal rice prices were almost equivalent in the two inland markets. Note that the price of locally produced rice was the same as the lowest price of imported rice in those markets.

With respect to agro-ecology, Bouaké is situated in the transitional zone between the humid forest and the savanna zones and its annual rainfall is about 1000mm on average. Kumasi, on the other hand, is in the humid forest zone with an average of 1400mm annual rainfall. Annual rainfall pattern is bimodal in both areas, but the period of the rainy season is longer in the Kumasi area. In both areas rice is mainly produced in lowlands during the rainy season without modern irrigation technologies, that is, in rainfed lowland ecology. Upland rice is rarely cultivated. Instead uplands are used for yam, maize, and cassava, which are traditional staple foods. Rice cultivation in lowlands was introduced in these areas relatively recently.

2.2 Sampling in Côte d'Ivoire

In Côte d'Ivoire we selected 11 contiguous sub-prefectures around Bouaké. We obtained the village list of the 1988 census for each sub-prefecture from the National Institute of Statistics in Bouaké, and randomly selected 179 from 857 villages in the list. The number of villages sampled in each sub-prefecture was determined so that it would be proportional to the total number of villages in each sub-prefecture (sampling rate was about 21 percent). From December 1999 to May 2001, we visited all the 179 sampled villages several times to collect village level information on lowland use as well as village characteristics by means of group interview of village leaders. Out of the 179 sampled villages, we found that 157 villages had at least one lowland. These 157 villages were used for the analyses in this paper.

2.3 Sampling in Ghana

In Ghana we numbered all the villages within the 60km radius from the center of Kumasi on topographic sheets issued by the Survey Department of Ghana. The total number of villages amounted to 1586. Then 40 villages were randomly drawn from the villages along the highways, and another 40 villages from the villages off the highways. We visited all of them, and confirmed whether there were lowlands in the village area. Forty villages

were deleted because there were no lowlands in the village area. The remaining villages were stratified based on the distance from the center of Kumasi: 10-20km, 20-40km, and 40-60km. Then, we re-sampled another 20 villages so that there were 12 samples from 10-20km stratum, and 24 samples from 20-40km stratum and 40-60km stratum respectively while keeping the numbers of villages on the highways and off the highways equal. This brought the total number of sample villages to 60 (i.e. 30 located along highways and 30 located off highways).² We conducted group interviews with the village leaders to obtain information on the village and its lowland areas from September to December 2000.

2.4 Data

Table 1 summarizes the variables that we constructed from the survey data. The number of immigrants is a critical variable in this study because it creates population pressure particularly on lowlands (i.e. effective population pressure) and also because the immigrants are considered to have brought lowland rice cultivation in the study sites. But since we could not obtain reliable information with respect to the number of immigrants, we used proxy variables: the ratio of male to female population in the case of Côte d'Ivoire and a dummy variable indicating whether a village is producing cocoa or not in the case of Ghana. In the Kumasi area, cocoa farms have been the main providers of job opportunities for immigrants. In the Bouaké area there is no such dominating industry, but it is obvious that villages with labor demanding industry have more males than females due to influx of male labor force, while villages without such industry loose males because of their temporal departure for other regions such as cocoa and/or timber zones in Côte d'Ivoire.

Because the use of lowland is affected by cultural background, we use dummy variables for ethnic group. The majority is Baoulé in the Bouaké area and Ashanti in the Kumasi area. Both belong to the Akan language group, and share similar cultural heritage. In the Kumasi area 56 of 60 sample villages are Ashanti villages. In the Bouaké area, there are enough villages that belong to other ethnic groups than Baoulé, such as Tagbana, Djimini, and Dioula. Therefore, in addition to the dummy variable for Baoulé, one for Tagbana was created. Ashanti, Baoulé and Tagbana people generally do not have a tradition to cultivate lowlands.

Whether the village was established by people from within the region (i.e. the Bandama Valley region in Côte d'Ivoire or the Ashanti region in Ghana) or by people from outside the region captures some characteristics of the village. In general, an old village has its origins outside the region because its founders migrated from other regions several hundreds years ago. Since then, new villages have been established by separation from the original villages. Therefore, relatively new villages have their origin within the region. Such new villages sometimes do not have enough uplands and consequently tend to cultivate in marginal lands, i.e. lowlands.

With respect to market accessibility, we use direct distance between the village and the capital cities, which does not depend on infrastructure development and does not change over time. The mode, cost, and time of transportation may be better indicators for current market access, but we do not use them because they depend on infrastructure development and cannot reflect accessibility in the past.

3. Statistical Analyses

3.1 Use of Lowlands

Of the 179 sample villages, 157 villages have access to lowlands in the Bouaké area, while 40 villages of the 80 villages investigated have access to lowlands in the Kumasi area. The share of villages with lowlands in all sample villages was much higher in the Bouaké area than in the Kumasi area. The total number of lowlands accessible from the 157 villages was 317 in the Bouaké area and it was 188 in the sampled 60 villages in the Kumasi area, suggesting that the average number of lowlands per village with lowlands was greater in the latter than the former. However, if we include villages without access to lowlands, the average number of lowlands per village becomes 1.8 in the Bouaké area and 1.6 in the Kumasi area.³ This means that the average number of lowlands per village does not differ much between the two study sites, but the distribution of lowlands is more skewed in the Kumasi area.

Table 2 compares the use of lowlands in the rainy season between the two sites. In the Bouaké area more than half of the all sample lowlands are

Table 1 Variables Constructed for Regression Analyses

Variables	Unit	Description
Village Level Variables		
Village population	1000	1988 and 1998 census (Côte d'Ivoire). 1984 census and our own survey as of 2000 (Ghana)
Immigrant indicators		
Ratio of male to female	%	Male population divided by female population in the village multiplied by 100. 1988 and 1998 census data are used (Côte d'Ivoire only)
Cocoa producing village	dummy	If the village produces cocoa, the value is 1 (Ghana only)
Dominant ethnic group		
Akan	dummy	If the dominant ethnic group in the village is Baoulé (Côte d'Ivoire) or Ashanti (Ghana), the value is 1
Tagbana	dummy	If the dominant ethnic group in the village is Tagbana, the value is 1 (Côte d'Ivoire only)
Origin of the village	dummy	If the ancestors came from outside the region (the Bandama Valley region in Côte d'Ivoire or the Ashanti region in Ghana), the value is 1
Hamlets of ethnic minorities	dummy	If ethnic minorities form hamlets in the village, the value is 1
Education at village level		
Existence of primary school	dummy	If a primary school had been established in the village as of 1980, the value is 1
Years since the establishment	years	Number of years since the establishment of the first primary school in the village
Access to the Markets		
Regional capital	km	Distance to the village from Bouaké in Côte d'Ivoire and Kumasi in Ghana
Sub-prefectural capital	km	Distance from the sub-prefectural capital to the village. There are 11 sub-prefectural capitals (Côte d'Ivoire only)
Village along a highway	dummy	If the village is located along a highway, the value is 1. There are 6 highways from Kumasi (Ghana only)
Lowland Level Variables		
Access to the village	km	Distance from the lowland to the village center
Acreage of lowland area	100m ²	Estimated acreage of lowland area (Côte d'Ivoire only)
Water source		
Permanent stream	dummy	If the water source is a permanent stream, the value is 1 (Côte d'Ivoire only)
Seasonal stream	dummy	If the water source is a seasonal stream, the value is 1 (Côte d'Ivoire only)

Table 2 Current Lowland Use in Rainy Season (% of number of lowland)

	No use	Rice	Vegetables	Maize	Tree Plantation	Rice + Vegetable	Rice + Maize	Rice + Tree Plantation
Bouaké area	59.3	36.6	13.3	0.6	1.9	9.8	0.3	0.3
Kumasi area	18.3	56.6	11.8	11.7	59.0	3.5	4.4	39.0

Total number of lowlands is 317 in the Bouaké area and 188 in the Kumasi area. The percentages do not add up to 100% for each sites because of multiple use. In the case of the Kumasi area, the original figures obtained from the survey data are corrected based on the weight of each sampling stratum shown in footnote 2.

Table 3 Current Lowland Use in Dry Season (% of number of lowland)

	No use	Rice	Vegetable	Maize	Tree Plantation	Rice + Vegetable	Rice + Maize	Rice + Tree Plantation
Bouaké area	88.6	4.1	7.3	0.9	1.9	0	0.3	0
Kumasi area	6.4	0	71.1	57.3	59.0	0	0	0

Total number of lowlands is 317 in the Bouaké area and 188 in the Kumasi area. The percentages do not add up to 100% for each sites because of multiple use. In the case of the Kumasi area, the original figures obtained from the survey data are corrected based on the weight of each sampling stratum shown in footnote 2.

Table 4 Expansion and Reduction of Rice Cultivation (% of number of lowland)

	Rice has never been cultivated	Rice was cultivated in the past	Average years passed since last rice cultivation	Rice is currently cultivated (i.e. at the time of this study)
Bouaké area	17.4	46.0	15.5 years	36.6
Kumasi area	14.6	28.5	12.7 years	56.6

Total number of lowlands is 317 in the Bouaké area and 188 in the Kumasi area. In the case of the Kumasi area, the original figures obtained from the survey data are corrected based on the weight of each sampling stratum shown in footnote 2.

not currently utilized (i.e. at the time of study), and rice cultivation is the single dominant use in the rainy season. On the other hand, in the Kumasi area more than 80 percent of the lowlands are currently utilized: the major crop in the rainy season is rice while tree plantation is the major perennial use of lowlands. Palm trees were planted in almost all the cases of tree plantation, and teak and cocoa trees were observed in a few cases. In about 40 percent of the lowlands both rice and trees were grown. Rice is sometimes intercropped with trees while they are still small, but otherwise rice and trees are planted separately. In the Bouaké area, palm, teak, and cocoa trees are planted mainly on uplands.

In the dry season, no rice is grown at both sites except for a few lowlands equipped with modern irrigation facilities in the Bouaké area as shown in Table 3. In the Kumasi area the second rainy

season in the bimodal rainfall pattern, or so-called minor season, is considered part of the dry season. Hence, most of the lowlands profit from the additional rainfall to grow vegetables and maize in the dry season. This does not mean that rice in the rainy season and vegetables and maize in the dry season are cropped on the same plot in a rotation. Rather, those crops usually occupy different plots within the same lowland. On the other hand, since the Bouaké area has less rainfall, almost 90 percent of the lowlands are not cropped during the dry season.

3.2 Expansion of Rice Cultivation

Lowland without water control can be classified as “marginal land” because the profitability of lowland rice production may not be as high as crop production on uplands such as maize considering

high labor input for lowland rice production.⁴ Therefore, with respect to the expansion of lowland rice cultivation, **hypothesis 1** is that population pressure reduces the availability of upland, and hence induces the utilization of lowlands, and **hypothesis 2** is that immigrants who are often not allowed to use uplands tend to cultivate lowlands.

As shown in Table 4, there are several lowlands that have never been used for rice cultivation, and the share of such lowlands is 17.4% in the Bouaké area and 14.6% in the Kumasi area. By analyzing factors that distinguish lowlands utilized at least once for rice cultivation and those never utilized, we can identify the determinants of the expansion of lowland rice cultivation. Hence, a binary dummy variable for “utilized lowland” is used as the dependent variable: lowlands utilized at least once take the value of 1, while lowlands never utilized take the value of 0. Note that the explanatory variables used in the regressions are either time

invariant (e.g. distance to the regional capital) or predetermined in the past (e.g. existence of a primary school as of 1980) because in the analyses on the expansion we are concerned with decisions made in the past.

Table 5 presents the regression results. Village population had a positive, significant effect in the Bouaké area, and cocoa production, proxy for immigrants, had a positive, significant effect in the Kumasi area. Therefore, hypothesis 1 is supported in the Bouaké area, while hypothesis 2 is supported in the Kumasi area. Distance from Bouaké had a negative effect, which suggests that lowland rice cultivation has been disseminated from the capital, either informally or formally through extension agency, and/or market access may have promoted the expansion of rice cultivation. But in the Kumasi area distance to Kumasi had no significant effect.

Table 5 Determinants of Utilization of Lowlands for Rice Cultivation¹

Explanatory Variables	Bouaké	Kumasi
Village Level Variables		
Village population as of 1988 / 1984	++	0
Immigrant indicators		
Ratio of male to female population as of 1988	0	na
Cocoa producing village	na	+++
Dominant ethnic group in the village		
Akan	--	na
Tagbana	--	na
Origin of the village is outside	0	++
Ethnic minorities live in hamlets	--	0
Existence of primary school as of 1980	0	0
Location of the village		
Distance to regional capital	-	0
Distance to sub-prefectural capital	0	na
Village on highways	na	0
Lowland Level Variables		
Distance from village center	+	0
Acreage of lowland area	0	na
Water Source		
Permanent stream	0	na
Seasonal stream	0	na
Constant	+++	0
Pseudo R squared	0.16	
Total number of sample lowlands	304 ²	187 ³
Number of lowlands ever utilized for rice cultivation	249	158
Fraction of correct predictions	0.85	0.84

+ (-), ++ (- -), and +++ (- - -) indicate that the coefficient is estimated to be positive (negative) at significance level 10%, 5%, and 1% respectively. 0 indicates the coefficient is not statistically significant at the 10% level.

¹ Dependent variable is binary dummy, whose value is unity if the lowland was utilized for rice cultivation at the time of this study or in the past, and zero otherwise. Probit model was used to estimate the coefficients, but only signs of coefficients are presented in the table. Regression results are available from the author upon request.

² Thirteen lowlands with modern dam irrigation facilities are excluded from the 317 lowlands identified.

³ Total number of sample lowlands in Ghana is 188, but one lowland was dropped due to missing information.

3.3 Intensification of Rice Cultivation

The single most important biophysical constraint to lowland development is lack of water control. Therefore, water control is the critical intensification technology for lowland rice production. In addition, with improved water management, subsequent intensification becomes possible, i.e. it may no longer be too risky for farmers to use external inputs, such as fertilizer. Based on this consideration, we focused on the adoption of water control technologies at lowland level as an indicator of intensification of rice cultivation in lowlands. In the Bouaké area a significant number of lowlands were equipped with bunds and canals. But we found no lowland with water control technologies in the Kumasi area.

Table 6 shows that, in the Bouaké area, 13 lowlands, or 4.1%, of 317 total sample lowlands are equipped with modern dam irrigation facilities with canals and bunds. Except for these lowlands, rice is grown under rainfed conditions. Of all sample lowlands, about 71% have no water control technologies (Table 6). Bunds are more frequently adopted than canals, implying that in some cases farmers create bunds without canals. If we take into account only lowlands under cultivation, the share of lowlands without water control becomes 43% of 129 lowlands. This means that lowlands without water control technologies tend to be abandoned more frequently than those with water control technologies. On the other hand, lowlands with modern irrigation facilities have not been abandoned, though the irrigation is not necessarily fully functioning.

According to Boserup (1965), population pressure causes intensification of agricultural production. In the same line, the induced innovation theory predicts that intensification should be induced by high price of land relative to that of labor (Hayami and Ruttan, 1985). Therefore, **hypothesis 3** is that higher population induces intensification, if the population increases demand for lowlands as well as supply of labor force. Note that this is the case where land is scarce and consequently population pressure cannot cause an expansion but rather induce an intensification. On the other hand, because water control technologies are not indigenous in the study sites, they may have been disseminated from the cities. In addition, market accessibility increases profitability of rice production and consequently enhances the probability of the technology adoption. Hence,

hypothesis 4 is that the distance from the markets has a negative effect on technology adoption.

Table 7 shows the results of Probit analyses on the determinants of the adoption of water control technologies in the Bouaké area. The regressions are done for bunds and water supply canals simultaneously by bivariate Probit method since the adoption of these technologies should be correlated. In fact, 37 of the lowlands have both bunds and water supply canals. First, the ratio of male population has a positive significant effect on both bunds and canals. Since this is an indicator of immigrant population, the results support the hypothesis 3. On the other hand, village population has no significant effect on the adoption of bunds and canals. This suggests that intensification is induced not simply by increased population, but rather by increased lowland users and labor force, or “effective population pressure” as indicated by the ratio male to female population. Second, the distance to capital cities reduces the probability of the adoption of water control technologies, as expected. That is, hypothesis 4 is supported.

3.4 Economic Sustainability of Rice Cultivation

As shown in Table 4, the share of lowlands never utilized for rice cultivation is higher in the Bouaké area than in the Kumasi area, but the difference is not so large as that for rice cultivation at the time of study (‘current cultivation’). This indicates that in about 85% of the lowlands, rice cultivation has been attempted in both sites but rice cultivation was more frequently abandoned in the Bouaké area. Table 4 also shows that the average number of years since rice was cultivated last is greater in the Bouaké area than in the Kumasi area (15.5 years and 12.7 years respectively), but they do not differ very much. With respect to sustainability, this study concerns sustainability at lowland level, not at plot level. In the Kumasi area, plot level sustainability of lowland rice cultivation is not an issue, since most farmers are practicing shifting rice cultivation with several years of fallow. The issue we are concerned with here is continuous use of lowlands for rice cultivation. This is more like economic sustainability because it depends on profitability of rice production. Based on this definition, sustainability of rice cultivation at lowland level is measured by (1) current use of lowland for rice cultivation, and (2) the number of years since rice

Table 6 Adoption of Water Control Technologies (% of number of lowland)

	Modern dam irrigation	Rainfed lowlands (without modern irrigation)				
		No water control technologies	Bunds	Supply canal	Drain canal	Bunds + both canals
Bouaké area All the lowlands	4.1	70.7	23.3	13.6	6.6	3.8
Bouaké area Lowlands under rice cultivation	10.1	43.4	45.0	27.9	11.6	7.0
Kumasi area	0	100	0	0	0	0

Total number of lowlands is 317 in the Bouaké area and 188 in the Kumasi area. Number of lowlands currently under rice cultivation is 129 in the Bouaké area. The percentages do not add up to 100% because of adoption of several technologies.

Table 7 Determinants of Adoption of Water Control Technologies in the Bouaké area¹

Explanatory Variables	Bunds	Canals
Village Level Variables		
Village population as of 1988	0	0
Immigrant indicators		
Ratio of male to female population as of 1988	++	++
Dominant ethnic group in the village		
Akan	---	---
Tagbana	0	0
Origin of the village is outside	0	0
Ethnic minorities live in hamlets	0	+++
Existence of primary school as of 1980	+	0
Access to the village		
Distance to regional capital	0	--
Distance to sub-prefectural capital	---	---
Lowland Level Variables		
Distance from village center to lowland	0	0
Acreage of lowland area	0	0
Water Source		
Permanent stream	+	0
Seasonal stream	+++	+++
Constant	0	0
Correlation in the residuals		++
Pseudo R squared ³	0.13	0.23
Number of lowlands ever utilized for rice cultivation	249 ²	249 ²
Number of lowlands with water control technologies	74	43
Fraction of correct predictions ³	0.73	0.86

+ (-), ++ (- -), and +++ (- - -) indicate that the coefficient is estimated to be positive (negative) at significance level 10%, 5%, and 1% respectively. 0 indicates the coefficient is not statistically significant at the 10% level.

¹ Dependent variable is binary dummy, whose value is unity if the lowland has adopted water control technologies (bunds and water supply canals), and zero otherwise. Bivariate Probit model is used to estimate the coefficients, but only signs of coefficients are presented in the table. Regression results are available from the author upon request.

² Thirteen lowlands irrigated by modern dam irrigation are excluded from the analyses.

³ Based on single-equation Probit estimation.

was last cultivated in the lowland. For the first measure, a binary dummy variable is created with a value of 1 for lowlands currently under rice cultivation, and a value of 0 for lowlands where rice was grown at least once in the past but where rice cultivation was abandoned, i.e. where rice was not grown at the time of study. By the second measure, if rice was present at the time of study, the number of years is 0. If rice has been abandoned, the more years have passed since rice was cultivated last, the less sustainable cultivation will be. Hence, this measures rather “non-sustainability.” Note that even if rice is not cultivated in a lowland at the time of study, it does not mean that the lowland was abandoned permanently. But it would be reasonable to assume that the longer the period of non-utilization since the last rice cultivation, the closer to permanent abandonment, although we cannot foresee when they will resume rice cultivation. Therefore, we will use the two kinds of indicator of sustainability.

We assume that when rice cultivation was attempted, the decision was rational and hence the rice cultivation was expected to be profitable at least in the short run. But after a while, rice cultivation was abandoned due to some changes in the economic environment that made rice production unprofitable. There could be two reasons for this: one is a lower rice price, and the other is a higher labor cost. The lower rice price might be due to lower import price reflecting the lower world price and/or lower price of local rice due to successful irrigation projects. The higher labor cost could be a result of stagnation of population growth in the village or migration. Hence, with respect to sustainability of lowland rice cultivation, we postulate the following hypotheses: **hypothesis 5** is that distance from the market has a negative effect on sustainability because high transportation costs make it impossible for local rainfed lowland rice to compete with cheap rice in the market; **hypothesis 6** is that immigrants have a positive effect on sustainability because they supply cheap labor force; and **hypothesis 7** is that lowlands with water control technologies are more sustainable because of higher efficiency.⁵

Table 8 presents the results of Probit regressions to explain the sustainability measured by the current use, and Table 9 presents the results of Tobit regressions to explain the “non-sustainability” measured by years since the last rice cultivation. First, the distance to the markets has no significant effect in the Kumasi area, but it has unexpected

signs in the Bouaké area. Hence, hypothesis 5 is rejected. Second, in the Bouaké area village population increases the sustainability measured by current use as shown in Table 8, but the male to female ratio has no significant effect on sustainability as shown in Tables 8 and 9. On the other hand, in the Kumasi area, lowland rice cultivation in cocoa producing villages tends to be more sustainable in both measures. The results support hypothesis 6 for the Kumasi area, but the support is partial for the Bouaké area. Third, in the Bouaké area the adoption of bunds and canals increases the probability of sustainable rice cultivation in lowlands, which renders a support to hypothesis 7. As already shown in Table 7, the adoption is significantly influenced by access to the market and male population, but those variables do not appear to have significant effect in Tables 8 and 9. Therefore, market access and effective population pressure enhance the sustainability of rice cultivation, but their effects may not be direct, but rather through the investment in water control technologies. In sum, sustainability of lowland rice cultivation depends on water control technologies which are affected by male population and market access in the Bouaké area, while it depends on migrant population for cocoa plantation in Kumasi area which has no relationship with the distance to market.

4. Discussions

We found that in both Bouaké and Kumasi areas, rice cultivation was attempted in more than 80% of the total lowlands in the past. The expansion was induced by population pressure. But the sustainability of lowland rice cultivation differs in the two sites. In the Bouaké area some of the lowlands have adopted water control technologies, and rice cultivation in such lowlands tends to be more sustainable than those without water control. As a result, a number of lowlands that failed to adopt water control technologies have been abandoned. On the other hand, in the Kumasi area, no lowland has adopted water control technologies, and sustainability does not depend on the technologies. Surprisingly, however, more lowlands are under sustained utilization in the Kumasi area than in the Bouaké area. That is, while in the Kumasi area lowland rice cultivation is more extended and more sustainable, in the Bouaké area lowland rice cultivation is more concentrated to lowlands with water control technologies.

Table 8 Determinants of Sustainability of Rice Cultivation (current use of lowland)¹

Explanatory Variables	Bouaké	Kumasi
Village Level Variables		
Village population as of 1998 / 2000	+++	0
Immigrant indicators		
Ratio of male to female population as of 1998	0	na
Cocoa producing village	na	++
Dominant ethnic group in the village		
Akan	+++	na
Tagbana	+++	na
Origin of the village is outside	0	--
Ethnic minorities live in hamlets	0	0
Number of years since establishment of primary school	0	++
Access to the village		
Distance to regional capital	0	0
Distance to sub-prefectural capital	+	na
Village on highways	na	0
Lowland Level Variables		
Water control technologies in lowland		
Bunds	+++	na
Canals (for water supply)	+++	na
Distance from village center to lowland	0	0
Acreage of lowland area	++	na
Water source		
Permanent stream	0	na
Seasonal stream	0	na
Constant	---	--
Pseudo R squared	0.35	0.10
Number of lowlands ever utilized for rice cultivation	249 ²	158
Number of lowlands currently being cultivated	103	97
Fraction of correct predictions	0.79	0.65

+ (-), ++ (- -), and +++ (- - -) indicate that the coefficient is estimated to be positive (negative) at significance level 10%, 5%, and 1% respectively. 0 indicates the coefficient is not statistically significant at the 10% level.

¹ Dependent variable is a binary dummy, whose value is unity if the lowland is currently being utilized for rice cultivation (i.e. at the time of this study), and zero otherwise. Probit model is used to estimate the coefficients, but only signs of coefficients are presented in the table. Regression results are available from the author upon request.

² Thirteen lowlands irrigated by modern dam irrigation are excluded from the analyses.

Thus, the first question is why lowland rice cultivation in the Kumasi area is more sustainable than that in the Bouaké area. As Table 5 shows, lowland rice cultivation in the Kumasi area does not depend on the distance to Kumasi, the regional market. This does not mean that the rice production in the Kumasi area is only for self-consumption. Rather, most of their production is sold in the market. But most of the transaction takes place at the millers in local towns (Furuya and Sakurai (2005) and Sakurai, Furuya, and Futakuchi (2006)). Rice producers bring paddy to local millers and mill the paddy. Then, they sell the milled rice to rice traders who come to purchase milled rice. They resell it in the bigger market like Kumasi. The number of millers has increased in recent years according to our own survey on millers.

It implies that milled rice transaction at local millers is profitable for producers, millers, and traders. On the other hand, in the Bouaké area, lowland rice production depends on the distance to the city market. This indicates that transportation cost is too high for rice producers in remote areas. Current output/input price ratio suggests that the price of rice might be so high in the Kumasi area that it gives a good incentive for producers. As mentioned above, the retail price of milled local rice in the Bouaké market is about 250 – 300 FCFA/kg, and that in the Kumasi market is about 2600 – 3200 cedis/kg. On the other hand, standard daily wage for agricultural labor is 1000 FCFA/day in the Bouaké area and 6000 cedis/day in the Kumasi area. Hence, 1 kg of milled rice costs 0.25 – 0.30 day work and 0.43 – 0.53 day work respectively. That

Table 9 Determinants of Non-Sustainability of Rice Cultivation (number of years of fallow)¹

Explanatory Variables	Bouaké	Kumasi
Village Level Variables		
Village population as of 1998 / 2000	0	0
Immigrant indicators		
Ratio of male to female population as of 1998	0	na
Cocoa producing village	na	--
Dominant ethnic group in the village		
Akan	---	na
Tagbana	---	na
Origin of the village is outside	0	0
Ethnic minorities live in hamlets	0	0
Number of years since establishment of primary school	0	0
Access to the village		
Distance to regional capital	---	0
Distance to sub-prefectural capital	0	na
Village on highways	na	0
Lowland Level Variables		
Water control technologies in lowland		
Bunds	---	na
Canals (for water supply)	---	na
Distance from village center to lowland	0	0
Acreage of lowland area	0	na
Water source		
Permanent stream	0	na
Seasonal stream	0	na
Constant	+++	0
Pseudo R squared	0.07	0.05
Number of lowlands ever utilized for rice cultivation	247 ²	145 ³
Number of lowlands currently NOT being cultivated	144	45

+ (-), ++ (- -), and +++ (- - -) indicate that the coefficient is estimated to be positive (negative) at significance level 10%, 5%, and 1% respectively. 0 indicates the coefficient is not statistically significant at the 10% level.

¹ Dependent variable is number of years since last rice cultivation. If a lowland is currently cultivated to rice, the number of years is zero, otherwise it is a positive number. Tobit model is used to estimate the coefficients to take into account the significant number of cases of zero in the dependent variable. Only signs of coefficients are presented in the table. Regression results are available from the author upon request.

² Two lowlands are dropped from 249 lowlands due to missing information. Thirteen lowlands irrigated by modern dam irrigation are excluded from the analysis.

³ Thirteen lowlands are dropped from 158 lowlands due to missing information.

is, rice is more expensive in the Kumasi area. Because labor is the major input for rice production, this high price of rice can explain why lowland rice production in the Kumasi area is more sustainable at this moment.

As for intensification, even though the “non-intensive” system in the Kumasi area may be profitable enough, it does not explain why lowland rice cultivation in the Kumasi area has not been intensified at all. Some intensification will bring a larger harvest, which is likely to result in a larger profit under higher price of rice. We may have three explanations, which are not mutually exclusive, for “non-intensification” in the Kumasi area.⁶

First, intensification is, as already discussed, affected by the relative factor price. Average rental cost of one hectare of lowland is 41,000 FCFA (standard deviation is 20,000) in the Bouaké area and 177,000 cedis (standard deviation is 144,000) in the Kumasi area according to our own survey. Although the standard deviations are very large, the ratio of rental cost to daily wage is 41 days/ha and 30 days/ha respectively. This implies that the extensive land use continues in the Kumasi area because land is relatively cheap. This is consistent with our casual observation in the Kumasi area where lowlands are so abundant that cultivators are still able to shift their plot every year.

The relative price can explain why the intensification is sustainable in the Bouaké area, but it does not explain why it was technically possible for them to adopt intensification technologies because water control technologies were not indigenous. Therefore, the second explanation concerns interventions that have taken place in the past. In fact, during the 1970s, massive interventions took place in Côte d'Ivoire through the creation of a state agency for rice development, i.e. SODERIZ (Société de Développement de la Riziculture), as well as foreign aid particularly from Taiwan (Le Roy, 1998; Wakatsuki, 2000). Out of 317 sample lowlands in the Bouaké area, 13 lowlands are irrigated by modern dam irrigation facilities, while in the Kumasi sample there is no dam irrigation site.⁷ Not only water control technologies such as bunds and canals, but also improved rice varieties and transplantation technology are considered to have been spilled-over from the irrigation project sites to rainfed lowlands.

Finally, the third explanation is from the viewpoint of land tenure systems. In the Kumasi area, tenancy contract is usually valid only for one year, and therefore tenant cultivators have to make a new contract every year. This encourages rice cultivators to shift their plots every year, and consequently discourages investment in land to use the same plot continuously. On the other hand, in the Bouaké area, tenancy contract is less strict and hence usually no duration is specified at the time of contract. In this case, investment in water control technologies is safer and could be more encouraged than in the Kumasi area. The difference in land tenure systems in the two sites may be caused by historical factors, particularly by the plantation of cash tree crops such as cocoa and palm in the Kumasi area. Because investment in land by tree planting enhances land ownership rights (Besley, 1995), migrants usually are not allowed to plant trees. Investment in water control technologies may be regarded on a similar footing as tree planting.

5. Conclusions

This paper explores the factors affecting the expansion, intensification, and sustainability of lowland rice production around two large inland markets in Côte d'Ivoire (Bouaké) and Ghana (Kumasi). The analyses reveal that immigrant population is the most significant determinant of the expansion and sustainability of lowland rice

cultivation in the Kumasi area. But no water control technologies have been adopted there: rice cultivation is purely rainfed. On the other hand, in the Bouaké area, the expansion seems to have been driven by population pressure, but the sustainability depends on the adoption of water control technologies. That is, inefficient rice production does not last. Since bund and canal construction is influenced positively by the accessibility to the market and number of immigrants, lowlands located closer to Bouaké tend to have water control technologies.

Comparing the two study sites, we showed that the difference in rice cultivation methods could be attributed to: (1) higher relative price of land in the Bouaké area, (2) past governmental and/or foreign intervention in the Bouaké area, and (3) land tenure systems in the Kumasi area. Modern irrigation projects around Bouaké (which are excluded from our analyses) may have had spill-over effects of technologies. This suggests that, although the relatively high price of land is a necessary condition for intensification, intensification will not take place 'automatically', i.e. it needs a push, through the introduction and dissemination of technologies.

Footnote

¹ The five ecologies for rice cultivation are irrigated lowland, rainfed lowland, rainfed upland, mangrove, and deep-water (Dalton and Guei, 2003).

² The sampling rate for each stratum is summarized in the table at the end. The number of villages along the highways is much lower than that of villages off the highways. But because we assumed *a priori* that whether a village is located along or off the highways should be an important factor affecting market access and consequently lowland rice cultivation, we sampled the two types of villages equally so that we would be able to examine the effect of market access.

³ As noted in the text, half of the 80 villages initially sampled have no accessible lowland. Therefore, assuming that half of the 60 sample villages have access to lowlands, the average number of lowlands is estimated as $188/(60+60)$.

⁴ Lowland rice production is generally considered to be less profitable than upland cropping such as maize. But this needs to be formally verified. We are currently collecting plot level data of

lowland rice and upland maize production so that we will be able to compare their profitability.

⁵ Sakurai (2006) showed that rice production in rainfed lowland is more profitable with partial water control technologies such as supply canals than without them. He used data collected from lowlands in the city of Bouaké where transportation costs to the market can be ignored.

⁶ Because there is no lowland with water control technologies in the Kumasi area, the three explanations cannot be statistically tested, unfortunately.

⁷ In the Kumasi area, we found only one dam-irrigated paddy field developed with Taiwanese aid, but it was not included in our sample.

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Stratum	Along the highways		Off the highways	
	Total number of villages	Number of sample villages	Total number of villages	Number of sample villages
10 – 20 km	35	6 (17.4%)	138	6 (4.3%)
20 – 40 km	114	12 (10.5%)	534	12 (2.2%)
40 – 60 km	106	12 (11.3%)	564	12 (2.1%)
Total	255	30 (11.8%)	1236	30 (2.4%)

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Intensification of Rainfed Lowland Rice Production and Potential Green Revolution

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Rice in West Africa

- Increasing demand
 - 6 % per year since 1973
 - 8 million tons per year recent years
 - because of population growth and urbanization
- Increasing gap between supply-demand
 - production growth: 5.1%
 - Import: 2.8 million tons in 1998
 - heavy burden on trade balances
- How to enhance regional rice production?

Enhancing Rice Production in West Africa

- Area expansion (extensification)
 - Upland is limited since fallow period is required
 - Vast lowland area remains uncultivated
 - 10 – 25% of total area is under cultivation
- Yield increase (intensification)
 - Modern irrigation facilities are too costly
 - Low potential of yield increase in upland ecology
 - There is a room for intensification in lowland ecology
 - Water control technology (canal and bund)
 - High yielding varieties are already available
 - Chemical fertilizer is more effective in lowland

Questions

- What factors influence
 - Area expansion of lowland rice production
 - Intensification of lowland rice production
- Is there potential Green Revolution of rice in West Africa?
 - Water control technologies
 - Rice modern varieties
 - Their impact on rice yield

Water Control Technologies in Rainfed Lowland



Without water control technologies



With bunds and canals

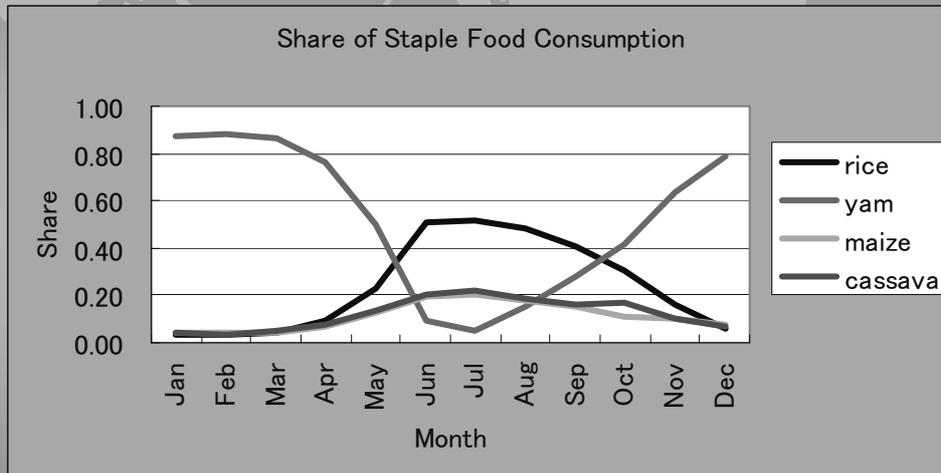
Study Site

- **Bandama Valley region, central Côte d'Ivoire**
- **Transitional zone with 1100 mm precipitation**
 - No cocoa or coffee
 - No cotton
 - Yam is traditional staple food
 - Few upland rice
 - Some lowland rice
 - Irrigation/lowland development project during the 1970s
- **Bouaké, the second largest city, is located**
 - Ideal for looking at the effect of market access
- **179 villages are randomly selected from 11 sub-prefectures (21% of total villages)**



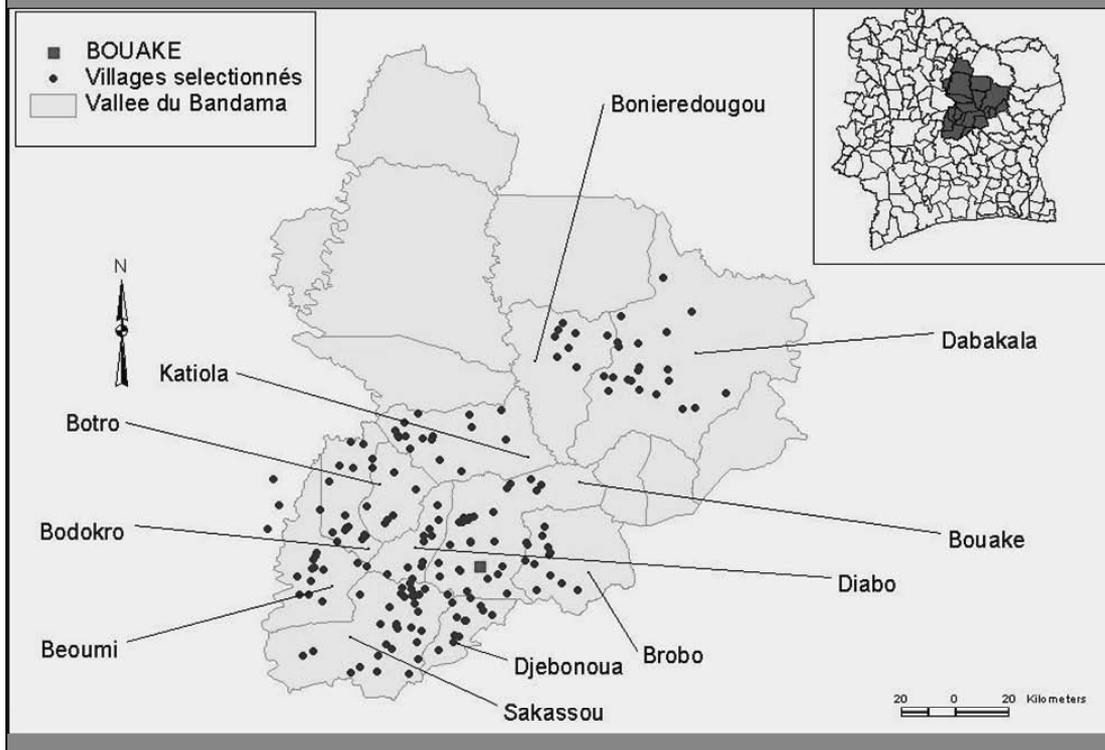
Source: CIA World Factbook

Staple Food in the Surveyed Villages

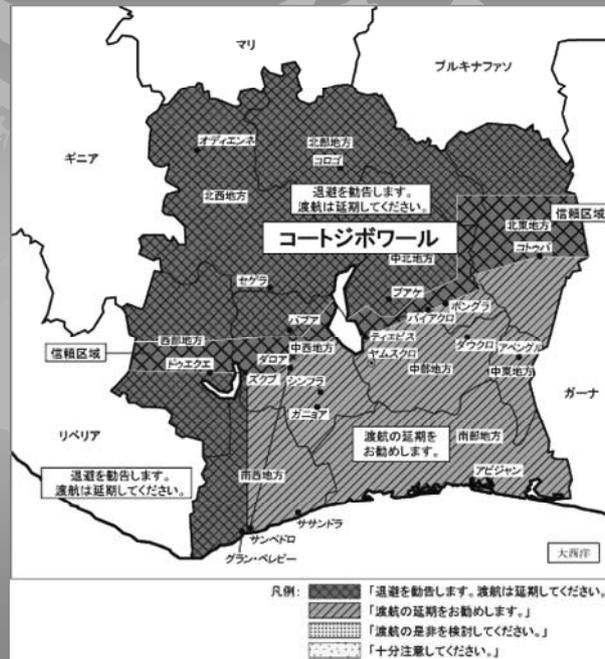


Production of rice is very few or zero in most villages.
 People purchase rice for consumption even in rural villages.

Distribution of Sample Villages



Current Situation



Source: Ministry of Foreign Affairs of Japan

Data Collection

- Village/Lowland survey
 - Randomly sampled 179 villages
 - All the accessible lowlands from the villages (317 lowlands were identified)
- Rice cultivator survey
 - 64 cultivators in the city of Bouaké
 - No difference in terms of market access
 - All the corresponding land owners

Market Access and Prices

	In Bouaké	Average of 179 villages
Distance from Bouaké	0 km	46 km
Sale Price of Paddy	128 F/kg	79 F/kg
Purchase Price of Chemical Fertilizer	240 F/kg	289 F/kg
Paddy/Fertilizer Price Ratio	0.53	0.27

Village/Lowland Survey

- Total number of lowlands: 317
 - With irrigation facilities 13 (excluded)
 - Without irrigation facilities 304

TABLE I
Current Lowland Use at Lowland Level
(% of number of lowland plots)

	No Use	Rice	Vegetables	Maize	Tree Plantation	Rice + Vegetables	Rice + Maize	Rice + Tree Plantation
Rainy season	59.3	36.6	13.3	0.6	1.9	9.8	0.3	0.3
Dry season	88.6	4.1	7.3	0.9	1.9	0.0	0.3	0.0

Notes: 1. Total number of lowland plots is 317.

2. The percentages do not add up to 100% for each season because of multiple use.

- Out of 304 lowlands without irrigation
 - Rice was cultivated at least once 249
 - Determinants of rice cultivation are identified by Probit regression

Determinants of Utilization of Lowland for Rice Production		
Explanatory Variables ²		
<i>Village Level Variables</i>		
Village Population		
Population density	0.01 (0.00)***	Population Density +
Population growth rate	-0.01 (0.08)	
Immigrant indicators		Paddy/Fert. Price +
Percentage of immigrants in total population	0.01 (0.02)	
Percentage of male in female population	-0.02 (0.01)***	Access to city +
Dominant ethnic group in the village		
Baoulé	-1.98 (0.42)***	
Tagbana	-1.20 (0.54)**	
Primary school	0.00 (0.01)	
Market access		
Price ratio of paddy and fertilizer	2.86 (1.27)**	
Distance to sub-prefectural capital	-0.03 (0.01)**	
<i>Lowland Level Variables</i>		
Distance from village center	0.05 (0.04)	
Acreage of lowland area	0.00 (0.00)	
Water Source		
Permanent stream	0.48 (0.38)	
Seasonal stream	0.12 (0.29)	
Constant	3.45 (0.81)***	
Total number of sample lowlands	304 ³	
Number of lowlands ever utilized for rice cultivation	249	
Fraction of correct predictions	0.84	

Table 2

Determinants of Lowland Rice Expansion

- Higher population density leads the use of lowland area for rice cultivation (due to the scarcity of upland area)
- It is not immigrants but population pressure that induces the use of lowland area
- Closeness to city is a positive factor for lowland rice cultivation
 - technology is disseminated from the city
 - favorable output price due to transportation cost

Village/Lowland Survey: Water Control

TABLE 3
Water Control Technologies at Lowland Level
(% of number of lowland plots)

	Modern Dam Irrigation	Rainfed Lowlands (Without Modern Irrigation)				
		No Water Control Technologies	Bunds	Supply Canal	Drain Canal	Bunds + Both Canals
All the lowlands	4.1	70.7	23.3	13.6	6.6	3.8
Lowlands under rice cultivation	10.1	43.4	45.0	27.9	11.6	7.0

Notes: 1. Total number of lowland plots is 317. Number of plots currently under rice cultivation is 129.

2. The percentages do not add up to 100% because of adoption of several technologies.

- Lowlands ever utilized for rice cultivation: 249
 - With bunds: 74 (29.7%)
 - With irrigation canals: 43 (17.3%)
- Determinants of the adoption of water control are identified by Probit regression

Determinants of Adoption of Water Control Technologies

Explanatory Variables	Bunds	Canals
<i>Village Level Variables</i>		
Village Population		
Population density	-0.00 (0.00)	-0.00 (0.00)
Population growth rate	0.01 (0.08)	0.02 (0.12)
Immigrant indicators		
Percentage of immigrants in total population	0.05 (0.04)	0.10 (0.04)**
Percentage of male to female population	0.02 (0.01)***	0.01 (0.01)**
Dominant ethnic group in the village		
Baoulé	-1.09 (0.34)***	-0.69 (0.38)*
Tagbana	-0.31 (0.56)	0.12 (0.78)
Primary school	0.01 (0.01)	0.02 (0.01)*
Market access		
Price ratio of paddy and fertilizer	3.07 (1.17)***	4.50 (1.30)***
Distance to sub-prefectural capital	-0.04 (0.02)***	-0.04 (0.02)*
<i>Lowland Level Variables</i>		
Distance from village center	-0.05 (0.04)	0.02 (0.04)
Acreage of lowland area	0.00 (0.00)	0.01 (0.00)
Water Source		
Permanent stream	0.61 (0.38)	-0.09 (0.55)
Seasonal stream	1.22 (0.36)***	1.90 (0.07)***
Constant	-2.58 (0.78)***	-4.46 (1.03)***
Number of lowlands ever utilized for rice cultivation	249 ³	249 ³
Number of lowlands with water control technologies	74	43
Fraction of correct predictions	0.76	0.87

Male Population +
Paddy/Fert. Price +
Access to city +

Table 4

Determinants of Water Control Technologies

- Immigrants promote water control technologies
 - Effective population pressure
 - Technology is brought by immigrants
- Population density and population growth have no effect on the technology adoption
 - Lowland is not a scarce resource
- Closeness to the city is again a positive factor of the technology adoption

Rice Cultivator Survey in Bouaké: Water Control

- Total number of sample cultivators 64
 - Bunds 62 cultivators
 - Irrigation canals 42 cultivators
 - Much higher adoption rates than in rural areas

TABLE 5
Adoption of Water Control Technologies in Bouaké at Cultivator Level

Modern Dam Irrigation	Rainfed Lowlands (Without Modern Irrigation)				
	No Water Control Technologies	Bunds	Supply Canal	Drain Canal	Bunds + Both Canals
0	3.1	96.9	65.6	59.4	42.2

Notes: 1. Total number of cultivators is 64.

2. The percentages do not add up to 100% because of adoption of several technologies.

Rice Cultivator Survey in Bouaké: Land Ownership and Cultivator's Status

Combinations of Rice Cultivator and Land Owner in Bouaké¹⁾

Status of Rice Cultivators	Type of Land Owners	Indigene (inherited from father)	Indigene (inherited from other than father) ²⁾	Immi grant	Owner/Cultivator			Public or institutional owner ⁴⁾
					Indigene (inherited from father)	Indigene (inherited from other than father) ³⁾	Immi grant	
Immigrants (total 54)		13	19	11	NA	NA	1	10
Indigenes (total 9)		1	4	0	1	2	NA	1

¹⁾ Numbers in the table are the number of rice cultivators that fall in each combination. The number of rice cultivators interviewed is 64, but one has been dropped due to missing information.

²⁾ Out of 23 cases, 15 are the case of inheritance from an uncle on the mother's side.

³⁾ The two are the case of inheritance from an uncle on the mother's side.

⁴⁾ This includes land owned by city government, land inside a military camp, and land owned by public/private companies.

Rice Cultivator Survey in Bouaké: Land Tenure

- Determinants of the adoption of irrigation canals are identified by Probit regression
 - Market access and population pressure are assumed to be equal in the sample
 - Effect of land tenure security is focused
 - Proxied by
 - Cultivator's status: immigrants or indigenes
 - Type of land ownership in the case of immigrant cultivator
 - Indigenous communal land (inherited from relatives)
 - Indigenous individualized land (inherited from father)
 - Institutional land (public or private firms)
 - Immigrants
 - Immigrants cultivator's land tenure security is low at the beginning
 - If investment enhances the security, the cultivator is willing to invest in land relative to otherwise
 - In the case of communal land and immigrant's land

Determinants of Adoption of Water Control Technologies

Determinants of Water Supply Canals and Modern Varieties at Cultivator Level

Explanatory Variables	Dummy for Cultivators with Water Supply Canals Probit Model
Cultivator's status (dummy variable): Immigrants cultivators	2.78 (1.29)**
Type of landownership (dummy variables): Immigrants-Indigenous communal	0.41 (0.80)
Immigrants-Indigenous individualized	-3.12 (1.14)***
Immigrants-Public/Institutional	-3.25 (1.13)***
Cultivator's characteristics: Age (10^{-2})	0.44 (2.56)
Sex (1 = male, 0 = female)	0.43 (1.00)
Years of schooling	-0.02 (0.07)
Living in own house (= 1, otherwise 0)	-0.64 (0.58)
Years of rice cultivation experience	-0.11 (0.05)**
Plot characteristics: Water source is permanent stream	0.50 (0.99)
Water source is seasonal stream	1.47 (0.71)**
Water source is pond	-0.94 (0.98)
Distance from water source (1,000 m)	-0.06 (0.24)
Walking time from the residence (100 min)	-0.02 (0.01)**
Acreage of the plot (ha)	2.36 (1.87)
Constant	0.65 (1.78)
Fraction of correct prediction	0.84
No. of positive observations	42
No. of observations ¹	63

- Use rights are weak
relative to the case of indigenes
- Less secure

- Ownership is strong
relative to other cases
- Fewer room to enhance the use rights

Table 6

Rice Cultivator Survey in Bouaké: Rice Varieties

TABLE 7
Adoption of Modern Rice Varieties (MV) in Bouaké at Cultivator Level

Traditional Local Varieties	Unknown Varieties (Early MV)	MV (%)				
		Recent MV			Early MV	
		Bouaké 189	WARDA Varieties	Jaya	IR5	Others
0	10.9	68.8	12.5	3.1	1.6	4.7

Notes: 1. Total number of cultivators is 64.

2. The percentages do not add up to 100% because of adoption of several technologies.

- Unknown varieties are classified as early modern varieties (MV) as they were adopted many years ago and have been continuously cultivated without renewal
- Determinants of the adoption of recent modern varieties (MV) are identified by Probit regression

Determinants of Adoption of Rice Modern Varieties

Determinants of Water Supply Canals and Modern Varieties at Cultivator Level

Explanatory Variables	Dummy for Cultivators with "Recent MV" Probit Model	
Cultivator's status (dummy variable): Immigrants cultivators	2.38 (1.47)	Land tenure has no effect
Type of landownership (dummy variables): Immigrants-Indigenous communal	-1.99 (1.37)	
Immigrants-Indigenous individualized	-1.12 (1.30)	
Immigrants-Public/Institutional	-0.72 (1.19)	
Cultivator's characteristics: Age (10 ⁻²)	-1.52 (2.89)	
Sex (1 = male, 0 = female)	3.35 (1.59)**	Male cultivator +
Years of schooling	-0.18 (0.11)	
Living in own house (= 1, otherwise 0)	2.02 (0.97)**	House owner (wealth) +
Years of rice cultivation experience	-0.08 (0.06)	
Plot characteristics: Water source is permanent stream	0.03 (1.13)	
Water source is seasonal stream	-0.80 (1.00)	
Water source is pond	-5.33 (2.21)**	
Distance from water source (1,000 m)	3.16 (1.82)*	
Walking time from the residence (100 min)	0.99 (0.77)	
Acreage of the plot (ha)	4.43 (2.57)*	
Constant	-2.30 (1.88)	
Fraction of correct prediction	0.86	
No. of positive observations	50	
No. of observations ¹	63	

Table 6

Factor Payments by Water Control and Rice Varieties

	With Water Supply Canal		Without Water Supply Canal	
	Recent MV	Early MV	Recent MV	Early MV
Plot Size (ha)	0.35 (0.24)	0.26 (0.15)	0.32 (0.18)	0.30 (0.05)
Yield of Paddy (kg/ha)	3633 (2112)	2896 (1310)	2770 (1340)	2454 (2080)
Variable Input Costs (10 ³ FCFA/ha)				
Seed	17.4 (11.9)	15.0 (6.3)	14.3 (8.5)	12.6 (4.8)
NPK	7.4 (16.6)	0.6 (1.7)	11.5 (18.3)	1.3 (2.5)
Urea	11.5 (18.7)	3.4 (7.9)	10.3 (12.1)	5.0 (10.0)
Herbicide	9.0 (10.5)	1.1 (3.0)	17.8 (16.1)	9.4 (12.0)
Insecticide	2.4 (5.3)	0.4 (1.2)	1.2 (3.6)	1.6 (3.1)
Family Labor	299 (215)	307 (159)	291 (241)	128 (83.3)
Hired Labor	104 (90.9)	86.5 (111)	132 (166)	124 (111)
Total Variable Costs (10 ³ FCFA/ha)	451 (244)	414 (144)	479 (276)	281 (104)
Value of Output (10 ³ FCFA/ha)	454 (264)	362 (164)	346 (168)	307 (260)
Residual (10 ³ FCFA/ha)	3.5 (235)	-52 (124)	-133 (302)	25.2 (218)
Unit Costs (FCFA/kg of paddy)	144 (84.0)	153 (51.2)	220 (188)	123 (70.9)
Number of Cultivators	32	8	17	4

The yields do not differ significantly.
 The uses of chemical fertilizer differ significantly: higher in the case of recent MV
 The residuals are not significantly different from zero.

Table 8

Rice Cultivator Survey in Bouaké: Fertilizer Use and Yield

- 33 out of 64 cultivators use no chemical fertilizer
 - Average use (urea + NPK) for 31 cultivators: 146 kg/ha (SD=138)
 - Average use (urea + NPK) for all cultivators: 69kg/ha (SD=118)
- According to WARDA's on-farm trial under partial water control
 - 100 kg urea per ha is recommended
 - Yield: 2.6 t/ha (SD=1.4) without fertilizer
 - Yield: 3.9 t/ha (SD=0.9) with recommended fertilizer
 - This much fertilizer makes more profit, given the current prices
 - This yield level is quite similar to the results of the Bouaké survey

Effect of Irrigation and Modern Varieties on Fertilizer Use

Effects of Technology Adoption on Fertilizer Use and Yield at Cultivator Level

Explanatory Variables	2SLS Model	
	Chem Fertilizer Use (kg/ha)	
Water supply canals (endogenous)	16.1	(53.0)
Use of recent MVs (endogenous)	53.8	(38.5)
Cultivator's characteristics:		
Age	-2.88	(0.83)***
Sex (1 = male, 0 = female)	48.7	(48.9) *
Years of schooling	-5.04	(2.73)*
Living in own house (= 1, otherwise 0)	116	(39.8)***
Years of rice cultivation experience	1.54	(1.36)
Plot characteristics:		
Water source is permanent stream	-119	(62.5)*
Water source is seasonal stream	-116	(61.1)*
Water source is pond	-179	(79.2)**
Distance from water source (100 m)	-0.30	(0.78)
Acreage of the plot (ha)	-16.6	(49.8)
Constant	166	(64.7)**
R ²	0.41	
No. of observations [†]	63	

Neither irrigation nor modern variety influences the amount of chemical fertilizer use

House owner (wealth) has a positive effect

Table 9

Effect of Irrigation and Modern Varieties on Yield

Effects of Technology Adoption on Fertilizer Use and Yield at Cultivator Level

Explanatory Variables	2SLS Model	
		Yield (kg/ha)
Water supply canals (endogenous)	1340 (730)*	Canal increases yield
Use of recent MVs (endogenous)	201 (1030)	Modern varieties have no significant effect on yield
Cultivator's characteristics:		
Age	-15.3 (21.9)	
Sex (1 = male, 0 = female)	1200 (640)*	
Years of schooling	4.71 (63.1)	
Living in own house (= 1, otherwise 0)	-139 (510)	
Years of rice cultivation experience	51.5 (32.4)	
Plot characteristics:		
Water source is permanent stream	-241 (803)	
Water source is seasonal stream	-1110 (634)*	
Water source is pond	-1330 (941)	
Distance from water source (100 m)	10.9 (17.1)	
Acreage of the plot (ha)	-3550 (1120)***	
Constant	2900 (1060)***	
R^2	0.34	
No. of observations [†]	63	

Table 9

Summary of Findings

- Rice cultivation in lowland tends to be induced by
 - Population pressure
 - Market access
- Water control technologies are adopted due to
 - Immigrant population
 - Market access
 - Tenure security as well as potential enhancement of security
- Adoption of rice modern varieties is affected by several factors, among which:
 - Relatively wealthy cultivators seem to have adopted them through purchase
- Half of the sample cultivators put no chemical fertilizer
 - If they use, the amount is good enough
 - Relatively wealthy cultivators tend to use chemical fertilizer
- Water control technologies enhance rice yield, while new modern varieties have no effect on rice yield
- Rice production in lowlands is not so profitable even in the city of Bouaké
 - Modern varieties without water control is less profitable than with water control due to lower yield
 - In rural areas it may be less profitable due to lower paddy/fertilizer price ratio

Conclusions

- Despite of potential land tenure problem and liquidity/credit constraints, the average yield in the city of Bouaké is comparable with Asian countries like the Philippines.
- For realizing a Green Revolution, investment in water control technologies in rainfed lowland and further improvement of modern varieties are necessary.
- Although there are vast areas of lowlands in rural area where potential of a Green Revolution exists, poor infrastructure makes rice production less profitable and limits area expansion and intensification.



質疑応答

Question and Answer Session

西アフリカにおける低湿地稲作の集約化と緑の革命の可能性
Intensification of Rainfed Lowland Rice Production and Potential Green Revolution

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司会: 杉本 充邦 Chair person: Mitsukuni Sugimoto

名古屋大学農学国際教育協力研究センター 准教授

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杉本 (司会):

Thank you very much for your presentation. Dr. Sakurai has mentioned about the land tenure problems and how the African people can accelerate the adoption of NERICA varieties. Are there any questions?

小山: 細かい質問で恐縮ですが、移民の役割、移民という要件がかなり技術導入に効いているということでしたが、移民とはどのような定義をされているのでしょうか。移民はいつまで経っても移民なのか、それとも何代か経てば移民ではなくなるのでしょうか、そういう transitional なことを分析されているのではないかという気がするのですが、その辺はいかがでしょうか?

櫻井: 今ブアケ周辺に住んでいる Baoulé の人々は 2~300 年ぐらい前にガーナから来たので移民ですが、彼ら自身はもう地元の人間だと強く意識していて、自分たちの土地であるという権利を主張しています。それに対して誰もクレームする人はいませんから、それはそうなのでしょう。そうするとその土地は Baoulé の土地であるということになっていて、Baoulé がコントロールしているわけです。Baoulé に属さない民族の移民はフランス植民地時代に始まったことでしょうか、せいぜい数世代しか経っていません。民族の定義から言えば、Baoulé でなければいつまで経っても移民は移民です。結婚とか、長く住んでいて Baoulé の言葉がしゃべれるようになるなどして、いつの間にか地元民化する人もいるかもしれません。しかし、いくら長く住んでいても移民の子孫であれば、その土地に対する生得的な権利は生じませんから、そういう意味では移民か移民でないかということは彼ら自身の認識の中でクリアに分かれていると思います。それが一時的なものなのか、それとも未来永劫に続く

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かどうかはわかりませんが、現状の分析をするにあたってはそのような形で十分だと思います。

浅沼: **government** がやっきになっても、まわりの農家がやっきになっても、なかなか広がらないというのが最後の結論のようですが、何が農民にとってインセンティブなのか、櫻井さんの研究のなかから分かることはあるでしょうか？

櫻井 明らかにマーケットに近いところでは技術は普及し、採用されていますし、稲作地も広がっているわけです。今日は稲作の話だけをしましたが、野菜作りなども市場に近い所では非常に拡大しています。これは **government** が普及しているわけではなく自分達でやっているのですから経済的インセンティブは非常に大きいということです。

一方で、技術的な情報が何もなく、低湿地で稲作をすることに関して何もアイデアを持っていない人達を放っておいても勝手に稲作を始めるかという、やはりそういったことはないわけです。そこに経験のある移民が来るとか、今日はあまり強調しませんが **government** の普及員が来るといったきっかけが必要です。コートジボワールでは、**government** がかつて低湿地での稲作を普及させた時代があります。今日の話はそういう活動が 90 年代初めに全部終わってしまって 10 年以上経った状態でどうなっているかという話です。今は 300 いくつかの低湿地のうち 100 いくつか稲作をしていませんが、かつては 200 か所以上で稲作をしていた時期がありました。なぜかという **government** が価格を管理していて米の価格が非常に高かったためです。そのころは稲作の普及も政府が行っていました。その後、構造調整政策のため、価格への介入を止めてしまい、普及もあまりやらなくなったため、低湿地での稲作がどんどん縮小してしまいました。そうすると **government** がやったことは普及にとって全然意味がなかったわけではないけれども、普及させた技術に持続性があるかどうかというところでは経済的な問題が一番大きいのではないかと思います。

飯嶋: 名古屋大学の飯嶋です。細かいことで恐縮ですが、肥料を投入した場合と投入しない場合の収量が非常に違っているのに興味を持ちまして、先ほどのスライドの中で肥料を投入した場合 3.9 トン、投入しない場合 2.6 トンの平均収量が得られるとありましたが、これはおよそ 1.5 倍くらいの収量が出ていることになります。肥料を投入している時は水を与えたりいろいろなことをやっていますので、トータルの利益としてはどれくらいアップしているとみてよろしいでしょうか？

櫻井: これは私がやった試験ではなくて、WARDA の研究者が on farm で行った試験です。同じ partial water control の低湿地でやっていますので、水に関しては条件が

同じで、肥料の違いのみでこれだけ収量の違いが出ているということだと思います。稲作の利潤も計算していきまして、私は数字は覚えていませんが、肥料として 100 キロの尿素を入れてこれだけの収量になったときに、当時の肥料と米の価格に基づいて計算するならば利益は十分高いということになっていました。肥料を入れる労力はたいしたことありませんので、労働時間に関してはほとんど同じで、肥料のコストの違いだけでしょうから、単純に言えば、収量の増えた分を金額に換算して、そこから肥料のコストを引いただけ利益が増えているといえます。

飯嶋： そうしますと、肥料を投入して奨励品種を栽培することで、十分余分の利益はあがると考えてよろしいでしょうか。

櫻井： はい。ただし、これは 1 年だけの試験です。partial water control がどれくらい有効かわかりませんが、降水量の毎年の変動がありますので、肥料を入れても雨が少ない年には駄目になるというリスクもあります。単純に毎年これだけの違いがあるかどうかはわからないと思います。それともう一つには、私が行った別の研究に示しましたがけれども、肥料を買うに際してクレジットなどはありませんので、キャッシュがある人は買えるが無い人は買えません。降水量が多いことが判っていたとしても皆が肥料を買うかという、今の市場経済のメカニズムではなかなかそうはいきません。もちろん、だからといって私は肥料に補助金を出せという議論はあまりしないのですが、補助金ではなくクレジットを供与するにしても、借金をしても早魃になると返せないというリスクがあるので農家も簡単には飛びつきません。

飯嶋： どうもありがとうございました。

杉本(司会)：

ありがとうございました。

Profile

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1985年東京大学理学系研究科動物学専攻修士課程修了。同年4月より、日経BP社(入社時社名、日経マグロウヒル社)に記者として勤務。1989年9月より、退職し、米国ミシガン州立大学大学院に留学、農業経済学を学ぶ。1995年8月、同大学よりPh.D.授与、同年10月、農業総合研究所(農林水産政策研究所の前身)に主任研究官として採用される。1999年1月より国際農林水産業研究センターに出向し、同センターの「アフリカ稲作プロジェクト」に参画した。その一環としてコートジボワールにある西アフリカ稲作開発協会(WARDA - The Africa Rice Center)にエコノミストとして2003年7月まで勤務。2004年4月に農林水産政策研究所に復帰し、国際政策部主任研究官。和光大学経済経営学部教授を経て、現在は一橋大学経済研究所教授。専門は、サブサハラ・アフリカと南アジアの農業技術、天然資源管理、貧困削減にかかわる経済分析。

Academic career

Professor Takeshi Sakurai received his Master degree in Zoology from Graduate School of Science, the University of Tokyo in 1985, and Ph.D. in agricultural economics in August 1995 from Michigan State University, USA.

Professional career

Professor Takeshi Sakurai started his professional career as a staff writer for Nikkei Business Publications, Inc. After obtaining Ph.D., he joined the National Research Institute of Agricultural Economics (the predecessor of PRIMAFF) in October 1995 as a senior economist. In January 1999, he transferred to Japan International Research Center for Agricultural Sciences (JIRCAS) to work for the Africa Rice Project, and worked as an economist at West Africa Rice Development Association (WARDA) in Côte d'Ivoire until July 2003. From April, he returned to PRIMAFF and served as a senior economist for Policy Research Institute until March 2008. Professor of economics and business management, Wako University from April 2008 to March 2009, and he has been a professor of Institute of Economic Research, Hitotsubashi University. His study covers economic analyses on agricultural technologies, natural resource management, and poverty alleviation in sub-Saharan Africa and South Asia.