

TECHNICAL EFFICIENCY OF RICE PRODUCTION AT THE TONO IRRIGATION SCHEME IN NORTHERN GHANA

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ABSTRACT

Aim: To investigate the determinants of technical efficiency of rice farmers at Tono Irrigation Project

Study Design: Cross sectional

Place and Duration: The Kassena-Nankana District of Upper East Region of Ghana in the 2005/2006 cropping season

Methodology: We used one-step estimation of the Cobb-Douglas Stochastic Frontier Model

Results: The technical efficiency estimates ranged from 35.2% to 99.5% with a mean value of 80.7%. The factors that determined farmers' technical efficiency included land, education and the adoption of seeds as well as chemical fertilizers.

Conclusion: The sustainability of the farmers' high efficiency will be dependent on the continuous support they receive in the areas of input supply and education, among others.

Key words: Input Supply, Rice, Technical Efficiency, Tono Irrigation Scheme,

1. INTRODUCTION

Ironically, while we approach the deadline for the Millennium development goals (MDGs), the number of food insecure people in Africa is increasing (FAO, 2006). The FAO (2006) stresses that the continent accounts for 50 percent of the 12 million children under five, who suffer chronic hunger. This is because food production falls short of demand, implying that per capita food production is on the decline. One of the reasons that explain the precarious situation with respect to food supply in Africa is the fact that the region missed out of the Green revolution. The Green revolution combined improved seeds, inorganic fertilizers, plant protection products and irrigation, resulting in significant increases in food supply, especially in Asia (Bationo and Waswa, 2011)). Notable among the crops that the revolution targeted, is rice, which is now an important staple for almost every nation.

The cereal has become so important that at its 21st session in 2006, the International Centre for rice (IRC) chose as its theme “Rice is life” (FAO, 2006). The FAO (2006) reveals that rice supplies consumers with more calories than other staples. Against this backdrop the organization suggests that it should be an important staple for many poor people, who may not be able to buy a variety of food crops in order to get the needed calories. It is along these lines that stakeholders think that Africa could benefit a lot from this crop. Unfortunately, while at the world level, rice supply is, at least, enough to cover consumption, in Sub-Saharan Africa, supply falls short of demand, resulting in rice import bills of about 1 billion US Dollars annually in the region (FAO, 2006). Africa produces less than two-thirds (rice) of what Vietnam produces (Gurdev and Gary, 1991).

Rice is an important food crop in Ghana and its consumption is growing, particularly among urban dwellers. The strategic nature of rice has long drawn the attention of policy makers who view promoting domestic production as a means of reducing dependency on imports and generating employment and income for rice growers (Randolph, 1995). Even though rice output in Ghana rose from 391,000 tones in 2009 to 492,000 tones in 2010, with its corresponding increase in yield per hectare of 2.4 tons/ha to 2.71 tons/ha, this is still low compared with 6.7tons/ha in Vietnam. Whereas Ghana's rice output stood at only

142,000 tones in 2005, Vietnam produced as much as 32 million tones of rice in the same year. As a result of advanced technology, Vietnam's rice cultivation has been rising at an average of 700,000 tones per year in the past five years (FAO, 2006).

In 2005, the agricultural policy of the government was to modernize agricultural and encourage agro-based industry. Also, under the US Millennium Challenge Account (MCA) Aid Package, the theme for the Ghana's programme was "Reducing Poverty through Agricultural Transformation." The specific objectives were to increase productivity as well as competitiveness of agricultural products in regional and international markets (ISSER, 2007).

Northern Ghana accounts for the bulk of the total rice production in the country. For instance, before irrigation projects gradually transformed the Accra coastal plain into a major area of rice production, the Northern region alone accounted for an average of 63% of rice production between 1977 and 1987. Similarly, in 1998, the three Northern Regions together produced about 67% of the total rice produced in the country. The Upper East Region was the largest producer of rice in the whole country in 1998 contributing about 46% of the total rice produced. It is believed that the region can produce rice to feed the whole country if serious attention is paid to improve upon the efficiency of rice farmers in the region.

Against this backdrop, Governments over the years have attempted to boost rice production locally. One of such is the establishment of several irrigation projects including the Vea, Afife, Kpong, Tanoso, Ashaiman, Tono, Dawhenya, Weija, Bontanga, and Aveyime among others

1.1 The Tono Irrigation Project

The Tono irrigation project was constructed by the Ghana government through a state company known as the Irrigation Company of the Upper Region (ICOUR). The construction of the dam began in 1975 and was not completed until 1985 (ICOUR, 1995). The Tono irrigation Project was proposed as part of Nkrumah's agricultural development policies to "provide the north with a large share of the national development fund than ever had been the case during the colonial administration." The government of

Ghana funded the project with loans obtained from the Canadian and British governments. The project consists of an embankment across the Tono River to form a 2,490-hectare reservoir capable of providing about 37 million cubic meters of water for irrigation purpose. The gross project area is about 3,860 hectares. However, the area developed for irrigation is about 2,490 hectares. The catchment area is 650 km². The maximum surface area is 1,860 hectares and a maximum storage capacity of 93x10⁶ m³. The live storage is about 83x10⁶ m³ with a dead storage of 10x10⁶ m³. The crest length is 3,471 meters. The length of the main canals is about 42 kilometres. The length of road is 120 kilometres. It has an altitude of 160 meters. The project is demarcated into 24 zones, and belongs to eight villages along the periphery of the irrigated land behind the main land. The villages include Biu, Bonia, Wuru, Yagbania, Yigbwania, Korania, Gaani, and Chuchuliga. Appendices 1 is the map of Ghana showing the Upper East region, while Appendix 2 is a layout of the Tono Irrigation project showing the communities.

Tono rice farmers enjoy some assistance from ICOUR in the form of buying on credit, inputs such as fertilizers, seeds and pesticides, and paying back after harvest. Also, farm machinery like tractors, combine harvesters and other farm implements are usually leased to farmers for a fee. Apart from these, there are advantages such as fairly flat and gentle sloping lands and abundant labour supply usually during the dry season when there is no rain-fed agricultural activities. The soils are also typical of the savannah ochrosols, quite conducive for the cultivation of rice.

However, as we know, despite the fact that these facilities are available to almost all the farmers, it is not every farmer who will necessarily take advantage and manage his or her farm well for maximum output. Efficiency is dependent on farm and farmer characteristics, which obviously vary across farm-firms. Thus, the objective of this study was to find out how the differences in farmers' socio economic indicators as well as management practices affect the efficiency levels in the Tono Irrigation sites.

2. MATERIALS AND METHODS

2.1 Stochastic frontier production function

Technical efficiency” is defined as the ability to achieve a higher level of output, given similar levels of inputs. In order to estimate and analyze the technical efficiency of rice farmers, the Stochastic Frontier Analysis (SFA) is used. The stochastic frontier approach, unlike the other parametric frontier measures, makes allowance for stochastic errors due to measurement errors. The stochastic frontier model decomposes the error term into a two-sided random error that captures the random effects outside the control of the firm (farmer) and the one-sided inefficiency component. The level of technical efficiency (TE) is measured by the distance a particular firm is from the production frontier. Thus, a firm that sits on the production frontier is said to be technically efficient. TE is measured as a ratio of actual to potential output (Aigner, Lovell, and Schmidt 1977; Meeusen and Van den Broeck 1977). In analyzing farm level data where measurement errors are substantial and weather is likely to have a significant effect, the stochastic frontier method is usually recommended (Coelli 1995).

Forsund, Lovell, and Schmidt (1980) argue that inefficiency is typically related to factors that are associated with farm management practices. Such factors include education, farm size, quality of seed, labour cost, experience, sex, etc. Education, which is directly related to management skills, has received adequate attention in the efficiency literature (Weir 1999; Binam et al. 2003). The results of the impact of education on TE are mixed, with some studies showing positive impact (Kalirajan and Shand 1986; Bravo-Ureta and Pinheiro 1997) and others showing a negative impact (Kalirajan 1984, 1991; Bravo-Ureta and Evenson 1994). Education increases the household’s ability to utilize existing technologies and attain higher efficiency levels (Battese and Coelli 1995). Schooling or the level of education of a farmer helps the farmer in the use of production information leading to increased yield. In traditional agriculture, it enhances their decision making ability mainly by increasing their ability to better allocate existing farm resources. TE is expected to increase with age as the farmer gains experience, but at a decreasing rate as the farmer becomes elderly. Gender of the household head is expected to have significant effects on TE. Farms managed by men are expected to attain higher TE than those managed by women. Men have more access to resources and information which increases production efficiency.

The stochastic model is given as

$$Y_i = f(X_i\beta)\exp(V_i - U_i) \dots\dots\dots 1$$

Where Y_i is the output of the i th farmer; X_i is a $(1 \times K)$ vector of farm inputs; β is a $(1 \times K)$ vector of parameters to be estimated; while V_i measure the random variation in output (Y_i) due to factors outside the control of the farm, U_i are factors within the control of the farm responsible for its inefficiency, V is assumed to be identically and independently distributed as $N(0, \sigma_v^2)$ and independent of U_i which is distributed as a truncated normal (at zero) of the $N(0, \sigma_u^2)$ distributions. U_i is independently, but not identically distributed.

The composed error term, ε_i is defined as

$$\varepsilon_i = V_i - U_i \dots\dots\dots 2$$

Therefore, the Technical Efficiency (TE) of a firm is defined as, $TE = \exp(-U_i)$

$$TE = \frac{Y_i^*}{Y_i} = \frac{f(X_i\beta)\exp(V_i - U_i)}{f(X_i\beta)\exp(V_i)} = \exp(U_i) \dots\dots\dots 3$$

We also adapt the model proposed by Battese and Coelli (1995), in which the Technical Inefficiency, TI effects are defined by:

$$U_i = Z_i\delta + w_i \dots\dots\dots 4$$

Where Z_i is a $(1 \times m)$ vector of explanatory variables associated with the TI effects; δ is a $(m \times 1)$ vector of unknown parameters to be estimated; and w_i is an unobservable random variable. The parameters indicate the impacts of variables in Z on TE. A negative value suggests a positive influence on TE and vice versa.

2.2 Empirical model

In terms of the functional form of the Stochastic Frontier Model, the two commonly used are Cobb Douglas and the Translog. The main advantage of the latter is that it is flexible, which implies that it does

not impose assumptions about constant elasticity of production nor elasticities of substitutions between inputs. Also, it can cause multicollinearity problems (a case in point is Dawson et al, 1991). The Cobb Douglas functional form however is not only simple but it is self-dual and has been applied widely in agricultural production technologies in many developing countries (Bravo-Ureta and Pinheiro, 1993).

We use the Cobb Douglas Stochastic Frontier Model to determine the relationship between rice output (dependent variable) on one hand and the socioeconomic, institutional and farm-specific factors (explanatory variables) on the other hand as follows:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + V_i - U_i \dots \dots \dots .5$$

Where $\ln$ represents logarithm to base e ; Y is output of rice (in kg); X_1 is land; X_2 is the quantity of seed used for planting; X_3 is quantity of fertilizer in bags of 50kg; and X_4 is the labour cost.

The inefficiency model is also given as follows;

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \varepsilon_i \dots \dots \dots .6$$

Where Z_1 is the age of the farmer; Z_2 is the number of years of farmer in rice cultivation; Z_3 is number of years in school; and Z_5 is farm size; ε_i is the two-sided error term and δ_i is a vector of parameters to be estimated.

Equations 5 and 6 are estimated by Maximum Likelihood, using the computer program, FRONTIER version 4.1 (Coelli, 1996) by Battese and Coelli's (1993, 1995) one-step/simultaneous estimation procedure. The Maximum Likelihood estimation yields consistent estimators for β, δ, γ and σ_z^2 .

$$\gamma = \sigma^2 / \sigma_z^2 \quad \text{and} \quad \sigma_z^2 = \sigma_v^2 / \sigma^2$$

The study was carried out at the Tono Irrigation Project located in the Kassena-Nankana District of Upper East Region of Ghana. The project is managed by Irrigation Company of Upper Region Ltd. (ICOUR). ICOUR is a state owned enterprise established to promote the production of food crops by small scale farmers within an organized and managed irrigation scheme.

About 2,490 hectares of land is irrigated with water from the 2½ mile long dam which serves seven villages in the Kassena Nankana District. The popular food and cash crops cultivated at the project area

are rice, soya bean, pepper and tomato. The dam allows for all year round farming and about 3000 small-scale farmers cultivate on ICOUR's developed land.

3. RESULTS

3.1 Socio-economic indicators of respondents

Out of the 85 farmers interviewed, approximately 54% and 46% were males and females respectively. The highest percentage of the respondents fell within the 36-45 age-group (32%), followed by the 26-35 (26%) and 46-55 (25%) age-groups. The lowest percentage was recorded by those above age 55years (7%), followed by those between 18 and 25 years old (9%). In terms of education, while 24% had formal education up to Primary 6, 23% did not have any formal education. The same percentage (23) went up to the secondary school level while 21% attended Junior Secondary School. Only 9% of them attained tertiary education. The average farm size was 0.99 hectares.

The parameters and related statistical test results obtained from the estimation of the stochastic frontier model (equations 5 & 6) are presented in Table 1 below. From the table, land, seed and fertilizer were significant at 1%, 5% and 1% respectively in determining output, and for that matter efficiency. All of them also maintained their expected signs. However, even though labour maintained its expected sign it was not significant. The technical efficiency estimates ranged from 35.2% to 99.5% with a mean value of 80.7%, which is comparable with other similar studies (Seidu, 2008, Bhasin (2002). The estimated gamma (γ) parameter of 0.99 in the study area indicates that 99% of the total variation in rice output is due to technical inefficiency. This can also be interpreted to mean that the differences between actual (observed) and frontier output are dominated by technical inefficiency (i.e. factors within the control of the farmers rather than outside their control). The result suggests that 99% of the variation in output among rice farmers is due to differences in technical efficiency while 1% of the variation is due to random shocks outside the farmers' control (Dawson and Lingard, 1989).

3.2 The sources of inefficiency

The sources of inefficiency are discussed using the estimated (δ) coefficients associated with the inefficiency effects in Table 1 below. Variables with negative coefficients have negative relations with inefficiency. The opposite is the case for variables with positive coefficients. The determinants of inefficiency include sex and the level of education of rice farmers.

Farmers' number of years of schooling (education variable) is negative and significant at 10%. This means that farmers with more years of formal education tended to be more technically efficient or were less technically inefficient. Similarly, the negative and significant (at 1%) coefficient of the sex variable also means that male farmers were more technically efficient (or less technically inefficient) than their female counterparts.

Table 1: Maximum Likelihood Estimation Results of the Stochastic Frontier Model

Variable	Parameter	Coefficient	Standard error	T-ratio
Constant	β_0	1.63	0.67	2.43**
Land	β_1	0.47	0.09	5.26***
Seed	β_2	0.37	0.15	2.46**
Fertilizer	β_3	0.09	0.03	2.88**
Labour cost	β_4	0.04	0.03	1.35
Inefficiency				
Constant	δ_0	0.21	0.94	0.22
Sex	δ_1	-0.04	0.07	-5.60***
Age	δ_2	0.04	0.06	0.70
Education	δ_3	-0.03	0.01	-2.15**
Experience	δ_4	-0.00	0.01	-0.13
Farm size	δ_5	-0.04	0.04	-1.00
Sigma squared	σ_v^2	0.07	0.04	2.03**
Gamma	γ	1.0	0.00	4502.20***
Mean efficiency		0.81	-	-

Log likelihood		19.2	-	-
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***, significant at 1% ** significant at 5% * significant at 10%

4. DISCUSSION

4.1 High technical efficiency and possible reasons

As shown earlier the average technical efficiency of Tono rice farmers in this present study is very high (81%). Also, we found the estimated gamma (γ) parameter to be as high as of 0.99, which suggests that 99% of the inefficiency of the farmers is due to factors within the control of the farmers; only 1% was as a result of factors outside the control of farmers. From theory, factors outside the control of farmers include drought, floods or bushfires. The high average efficiency and gamma parameter in this present study do not come as a surprise, considering the intensive nature of the farming that goes on at Tono. Unlike rain-fed agriculture which is exposed to the vagaries of the weather, farming at the Tono Dam is a dry season one, where farmers do not only have water supply (from the dam), but do also have supply of inputs such as fertilizer, seeds, and pesticides, sometimes on credit. Farm machinery like tractors, combine harvesters and other farm implements are also usually available for hiring. However, since these inputs are generally for sale, the quantities that would be bought by the individual farmers depend on their financial statuses and the expected returns, among others. For policy formulation, it is important to note that agricultural intensification, made possible by the availability of irrigation water and the timely supply of other inputs, goes a long way to reduce farmers' dependence on natural factors, resulting in high technical efficiency.

From the results presented, the four main variables that emerged as the determinants of technical efficiency in rice production in the study area were land, seed, fertilizer and education. These may be targeted for specific policy formulation. The "Supply of the right agricultural inputs in adequate quantities and at affordable price is key to overcoming the problem of low productivity in Ghana's agriculture" (ISSER, 2007). With respect to land, the average plot size in the Tono irrigation site is 0.99 hectares, which is likely to reduce with time, as a result of population pressures. The situation will be worse for women, considering the fact that they are already disadvantaged.

Not only should more land be brought under irrigation, women farmers, should particularly be targeted. ISSER (2010) recognizes that improvement of irrigation systems is one of the most important areas that need heavy investment in the country to ensure all-year round production. This facilitates full employment of the other factors of agricultural production, especially labour. In Ghana, the policy objective for irrigation development is to raise productivity of irrigation water from 30% to 80% within a decade, starting from 2007 (MoFA, 2007). Consequently, by the end of 2010, there had been a first phase rehabilitation of the Tono dam, making available 1,874 hectares of land for cultivation. This was aside the rehabilitation of 70 dams in the three northern regions within that same period (ISSER, 2010).

With respect to seed, ISSER (2005) notes that during the 2005 farming season, 20 farmers and 18 seed inspectors were trained in hybrid seed maize production while 2.5 hectares of Nerica (New rice for Africa) was harvested as seed base to be distributed to farmers for planting. In addition, about 9.2 tonnes of (other) rice seed were produced and distributed to farmers. However, these were woefully inadequate. Consequently, at the beginning of 2007 the government's plans were to develop and crop about 500 hectares of valley bottom sites for the production of 2,500 tonnes of rice under the Inland Valley Development Project. In addition, the Nerica Rice Dissemination Project planned to produce 200 tonnes of certified seed rice and further contract the production of 150 tonnes of certified seeds during the off-season. Furthermore, in order to facilitate technology dissemination in Nerica rice cultivation, 2400 farmers were to be mobilized for training. ISSER (2010) also reports that the Savannah Agricultural Research Institute (SARI) and Crop Research Institute (CRI) have developed and approved the release of four improved seed varieties.

"A major component of production cost in Ghana's agriculture is the cost of inputs which are very high, thus making it difficult for the many poor smallholders who dominate the sector to afford them" (ISSER, 2008, P133). As reported in ISSER (2008) the price of Urea went up by about 11.76% from ₵215,670 (Gh ₵ 21.57) in 2005 to ₵241, 038 (Gh ₵ 24.10) in 2006. The price of NPK-15-15-15 also rose slightly from ₵202, 189 (Gh ₵ 20.22) per 50 kg in 2005 to ₵202,439 (Gh ₵ 20.24) in 2006. However, the price of NPK-

20-20-20 fell from ₵ 204, 158 (Gh ₵ 20.42) per 50 kg in 2005 to 199,186 (Gh ₵ 19.92) in 2006 (The Exchange rate during this period was about 1.50 Gh ₵ to 1.00 US\$). In the case of insecticides and pesticides the prices were lower in 2006, with Actielic and Atrazine falling by as much as 26% and 23% respectively. Against the backdrop of the difficulty associated with the fertilizer subsidization, in 2010, the fertilizer programme was reviewed and a more efficient waybill system introduced to replace the existing coupon system. This was to enhance the delivery of the programme and ensure a more transparent distribution system (ISSER, 2010). Consequently, in 2010 the government subsidized 60,000 metric tonnes of fertilizer at an average cost of Gh₵ 16.00 per bag of 50kg as part of efforts to increase productivity.

The role of education in the development of a country cannot be over-emphasized. Seini (2002) argues that investment in people, especially the poor and women, is key to the accelerated growth and development of Ghana. He stresses that education increases people's ability to understand issues related to the adoption of technology, thereby raising their productivity. Along similar lines Nankani (2007) argues that basic education is critical for small farmers who need to adopt new technologies, seeds and crops. The result for the present study is consistent with the findings by Abdulai and Huffman (2000), Seyoum, et al., (2000) and Seidu (2008). Seyoum, et al., (2000) find that farmers with more education respond more readily to new technology and produce closer to the frontier output. Also, Ajibefun and Daramola (2003) conclude that education is an important policy variable, which can be targeted to improve both technical and allocative efficiency. However, Kalirajan and Shand (1985) argue that even though the number of years of schooling is a productive factor, farmers' education is not necessarily related significantly to their yield achievement. Illiterate farmers, without the training to read and write, can understand a modern production technology as well as their educated counterparts, provided the technology is communicated properly. In Ghana, the implementation of new educational reforms for basic education began in 2007. The main components included teacher upgrading and deployment, attainment of gender parity, the active promotion of science, technology and research; and the incorporation of pre-schools into the basic education system. However, while Nankani (2007) acknowledges that Ghana has made major strides in expanding gross enrolments in primary education, he laments over the relative

neglect of programs of adult literacy that will help current farmers to absorb new methods of agriculture. He concludes that the most important thing to do, if a nation is to have quality education, is to involve local government, communities and parents in the running of schools.

Like our present study, Donkoh (2011), Binam, Gockowski and Nkamleu (2008) find male farmers to be more efficient than their female counterparts. However, Doss and Morris (2001) argue that the reason for lower efficiency on the part of female-headed households is their engagement in non-farm activities more than their male counterparts. In Seidu (2008), the gender variable was not significant. Women continue to produce and manage a large share of goods and services, yet their efforts have often been hidden in the tasks associated with domestic and conjugal roles (Adepoju and Oppong, 1994). Also, Ellis (1993) states that because of the domestic roles (such as cooking, clearing and mending) and the biological roles of child bearing and caring for children, women do not have enough time to perform other tasks adequately. Farmers, especially women can be supported to rely on group assistance as an alternative source of affordable human labour supply.

5. CONCLUSION

The high average technical efficiency level of the farmers at the Tono Irrigation is largely due to the intensification nature of the farming, made possible by the supply of the dam water and other inputs for which they receive support. The sustainability of the high efficiency will be dependent on the continuous support the farmers receive in the areas of input supply and education, among others.

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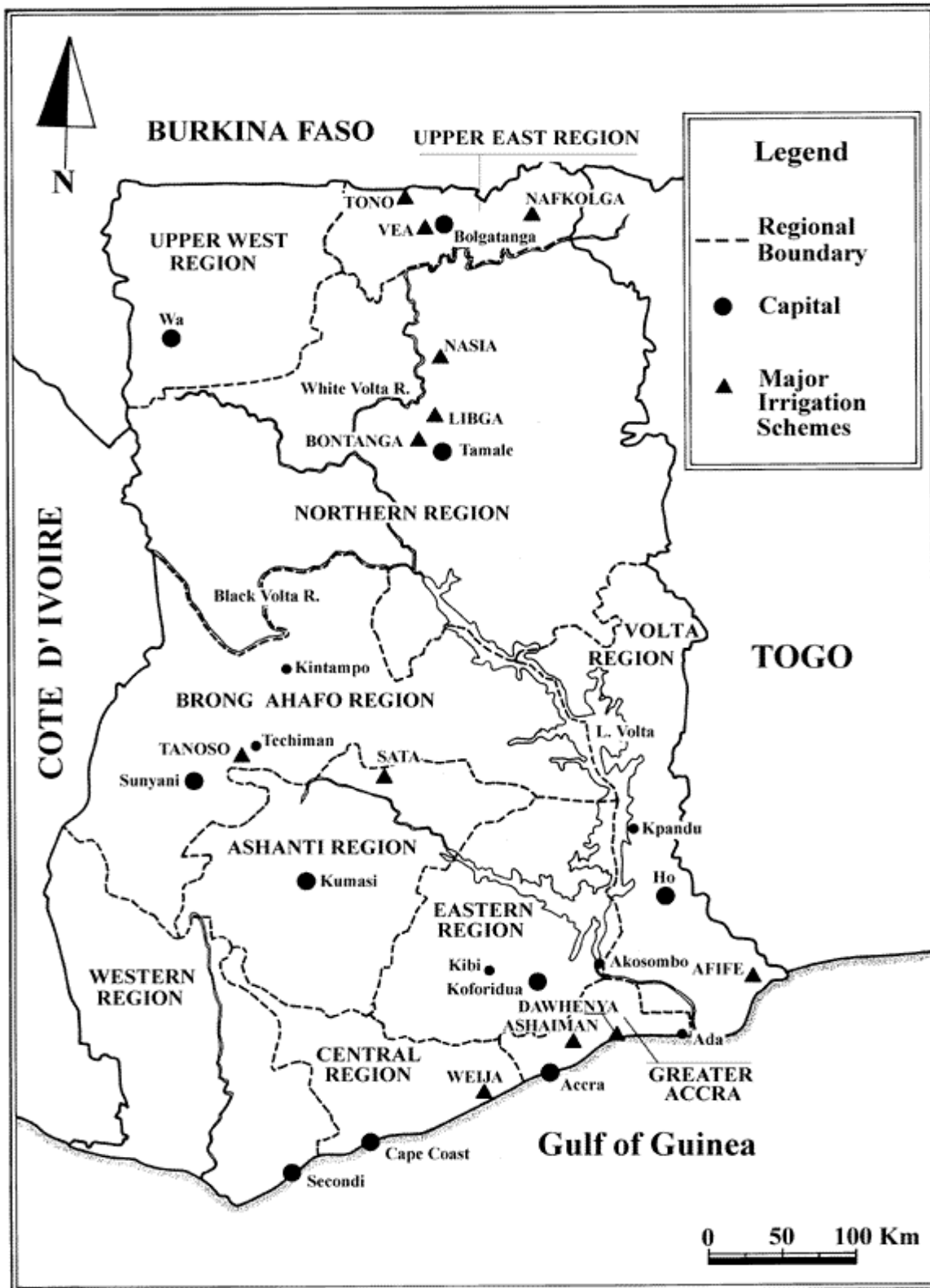
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LIST OF ABBREVIATIONS

FAO	Food and Agriculture Organisation
IRC	International Centre for rice
ISSER	Institute of Statistical, Social and Economic Research
SAF	Stochastic Frontier Analysis
SARI	Savannah Agricultural Research Institute
CRI	Crop Research Institute

Appendix 1: A map of Ghana showing the major irrigation schemes including Ghana



Appendix 2: A Layout of the Tono Irrigation Scheme

