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Full Length Research Paper

Agronomic and socio-economic constraints to high yield of upland rice in Tanzania

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A field survey was conducted in March 2009 in upland rice growing agro-ecosystem of four districts in Tanzania namely Ulanga, Kyela, Morogoro and Korogwe to investigate the agronomic and socio-economic factors which influence rice productivity and suitability of these areas for NERICA cultivation so as to increase rice productivity. Questionnaire was used to gather primary information from ten farmers from each district. Secondary information was obtained from district agricultural offices and weather data from Tanzania Meteorological Agency. A composite soil sample was collected from upland rice fields of sampled farmers and analyzed for complete soil fertility. The findings showed that rice is the most important crop in all areas as both food and cash crop. However, rice yield is as low as 1 tha^{-1}. Low yields are attributed to diseases and pests, poor inputs, insufficient water, poor soil fertility, short supply of fertilizers and use of low yielding traditional varieties, among other factors. The soils are potentially low in nitrogen and phosphorus and therefore N and P fertilization is recommended. Rainfall and temperature pattern is adequate for NERICA cultivation which gives higher yields compared to traditional upland varieties under stress-prone environments such as poor soil fertility, disease and pests and moisture stress which characterize the upland agro-ecosystem.

Key words: NERICA, adaptability, soil fertility, upland rice agro-ecosystems, productivity.

INTRODUCTION

Rice (*Oryza sativa* L.) is the second widely cultivated cereal food crop in Tanzania after maize. The crop is grown in three agro-ecosystem namely rainfed lowland (74%), rainfed upland (20%) and irrigated lowland (6%) (Kanyeka, 1994). Drastic shift of consumers' preference both in urban and rural areas from conventional foods to rice coupled with rapid urbanization has resulted into a simultaneous increase in annual per capita consumption of rice in Tanzania to about 25 - 30 kg/year (Kibanda, 2008).

These changes in consumption habits have led to a growing gap between the demand and supply of rice which has to be filled by imports. In its effort to increasing rice productivity, Rice Research Program in Tanzania has engaged in New Rice for Africa (NERICA) research since 2002. NERICA which is inter-specific hybrid between the local African rice (*Oryza glaberrima* Steud.) and the exotic Asian rice (*O. sativa* L) incorporates both the high yielding ability of *O. sativa* and the resistance of *O. glaberrima* to major constraints such as diseases, drought and low soil fertility and they mature up to 30 - 50 days earlier than other upland varieties.

These attributes make them have yield advantage over their *O. glaberrima* and *O. sativa* parents through superior weed competitiveness, drought tolerance and pest or disease resistance (WARDA, 2004). Currently seven upland NERICA genotypes are under multi-location trials in various places of Tanzania, a prerequisite for their official release. . These are NERICA 1, NERICA 2, NERICA 3, NERICA 4, NERICA 6, NERICA 7 and WAB 450-12-2-BL1-DV4. Results of the on-station trials showed that these varieties yield an average of 4.6 t/ha, with WAB 450-12-2-BL1-DV4 recording the highest (5.6 t/ha) compared to local check Lunyuki which yield an average of 3.6 t/ha (Kibanda, AICAD Nairobi Kenya, unpublished).

Upland rice growing areas of Tanzania receives bimodal rainfall with short, low intensity rains commonly known as *vuli* starting from October to December and long heavy rains (*masika*) from March to May. Short rains

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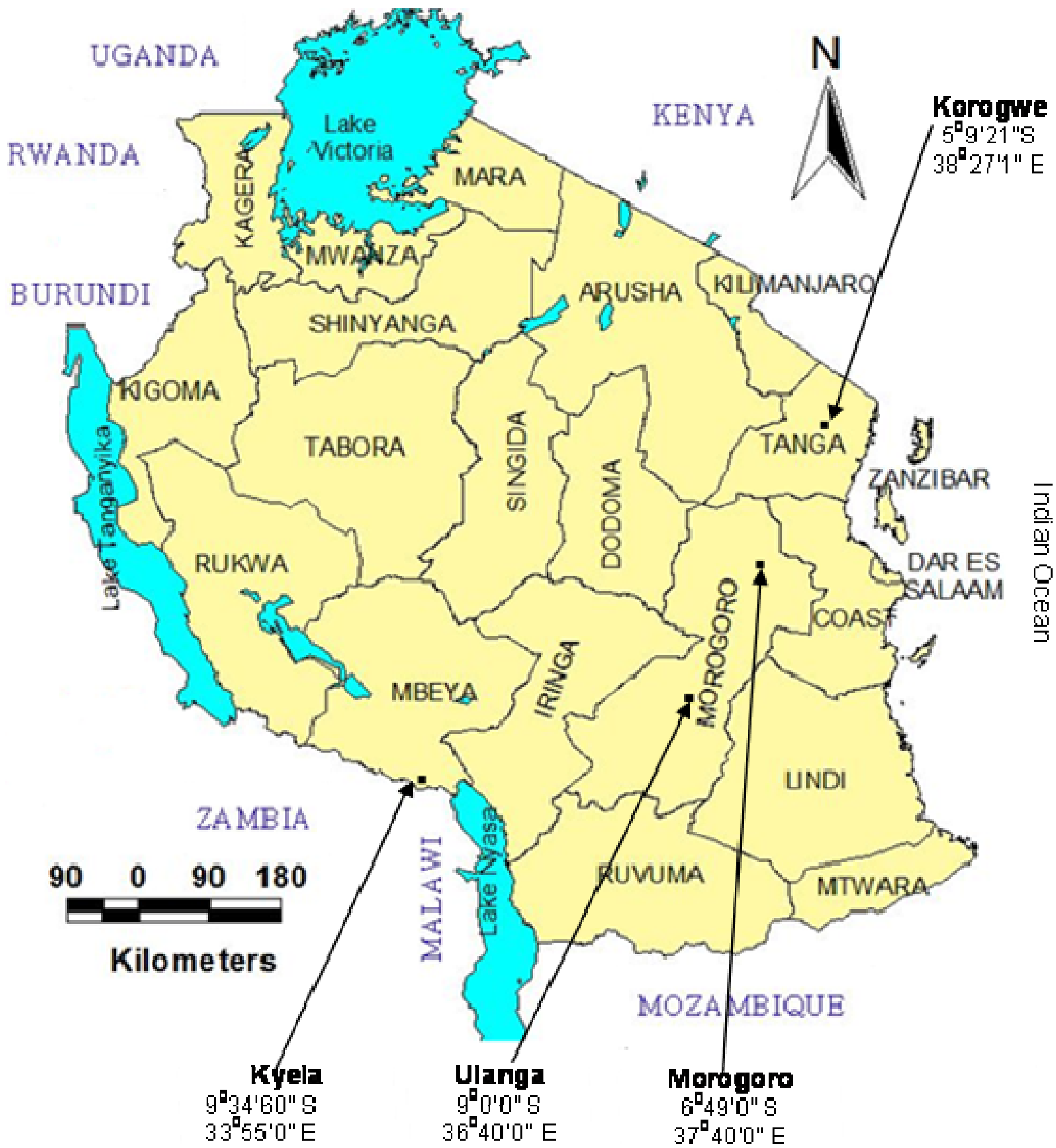

Figure 1. Map of Tanzania showing regions and location of study areas by districts as indicated by arrows.

are utilized for production of short duration crops or cultivars while rice depends on heavy rains. Temperature is highest from October to March while June to September is the coolest period. NERICAs thrive well at low rainfall, a minimum of 20 mm per week, well-distributed during the three months of growing season (Tsuboi, AICAD, Nairobi Kenya, unpublished). However, information with regards to agronomic and socio-economic factors influencing upland rice productivity and NERICA adaptation in Tanzania is meagre.

In this study, we sought to determine the agronomic, socio-economic and environmental factors influencing rice production and suitability of the upland rice agro-agro-ecosystem for growing upland NERICA rice in order to increase productivity of the upland rice in Tanzania.

MATERIALS AND METHODS

Sampling procedure

Multi-stage and cluster-sampling techniques (IFAD, 2003; FAO, 1997) were used to identify the village samples to ensure good representativeness of rice farming population in the study areas. In the first stage four districts, namely Monogram, Ulanga, Kyela and Korogwe were identified as among the key upland rice producing areas in Tanzania and therefore they were targeted for the study (Figure 1). These areas are also the major focus for the on-going research on upland NERICA adaptability trials.

At the district level one respective village from each district (Matombo, Chilombola, Lupembe and Mnyuzi) were purposively selected for sample household's survey. The sample size (N) was determined by using Equation (1) as Wonnacott and Wonnacott (1990) attest.

$$N = \frac{Z^2 p(1-p)}{\Phi^2} \quad (1)$$

Where; N = required sample size, Z = confidence level at 95% (standard value of 1.96), p = estimated proportion of an attribute, which was estimated at 90% due to the fact that about 90% of the rural population in Tanzania are employed in farming activities (Mlambiti, 1998) and Φ = margin of error at 5% (standard value of 0.05). Therefore, using Equation (2), N was determined.

$$N = \frac{Z^2 p(1-p)}{\Phi^2} = \frac{(1.96)^2(0.9)(1-0.9)}{(0.05)^2} = 138.2976 \approx 140 \quad (2)$$

The sample size of one hundred and forty (140) village households was equally distributed between Matombo, Chilombola, Lupembe and Mnyuzi villages accounting for thirty five (35) farming households in each village. Due to time constraint and poor road network, a target of twenty (20) households (representing 57.14% of village sampled population) was expected to participate in the formal interview. Ultimately, responses of ten (10) usable questionnaires from each village making a total of forty (40) households were recorded (representing a response rate of 28.57%) which was satisfactory for this study. The selection of farmers was done in collaboration with village leaders and agricultural extension officers taking into consideration the gender, age of farmer, soil type, farm size and income. The number of farming households per village was 265, 184, 226 and 232 for Chilombola, Matombo, Lupembe and Mnyuzi, respectively.

Household questionnaire was used to gather information on: (1) the village such as number of households in the village, economic activities, social services – health, water and education; (2) household characteristics which include members of the household, their number and relation to the head of the household, the source of land for farming etc; (3) individual farmer and field characteristics - the age, sex, education level, land ownership, types of crops grown, revenue from farming enterprises, available labour and its utilization and constraints to agricultural productivity and (4) individual crops where at least two most important crops grown by each farmer (including rice) were assessed in terms of cropping calendar, agronomic practices applied, yield and contribution of each crop to the well being of the farmer in terms of food and cash.

Soil sampling and analysis

One composite soil sample (0 - 15 cm) from each farmer's upland rice field was obtained and analysed for particle size distribution (hydrometer method) and complete soil fertility which include determination of organic carbon, pH (water), electrical conductivity (Ec), cation exchange capacity (CEC), exchangeable bases (Na, K, Ca and Mg), available phosphorus and total nitrogen.

Soil pH was measured using 1:2.5 soil - water ratio as described by McLean (1982). The available phosphorus was extracted with NH_4F + 0.025N HCl as described by Bray and Kurtz (1945). Phosphorus in the extract was determined colourimetrically after developing blue colour with ascorbic acid as described by Murphy and Rickey (1962). Organic carbon was determined by the wet digestion method of Walkley-Black (Nelson and Sommer, 1982). Total nitrogen was determined by the micro-Kjeldahl digestion and distillation method (Bremner and Mulvaney, 1982). Cation exchange capacity (CEC) was determined by the ammonium acetate saturation method as described by Chapman (1965). Electrical conductivity was determined using EC meter by measuring the resistance of a 1:5 soil - water suspension. Exchangeable K, Na, Ca and Mg in the NH_4OAc filtrate were determined using atomic absorption spectrophotometer (AAS). Particle size distribution was determined by the Bouyoucos Hydrometer method (Bouyoucos, 1962) and textural classes by using USDA textural triangle.

Meteorological data

Weather data (rainfall and maximum and minimum temperature) was obtained from Tanzania Meteorological Agency (TMA). However, temperature data for Kyela, Matombo (Morogoro) and Korogwe are not recorded in these stations but at nearby synoptic stations namely Mbeya, Morogoro-SUA Met and Tanga airport, respectively.

Data analysis

The Statistical Package for Social Sciences (SPSS 13.0) was used to analyse the information from questionnaires. Descriptive statistics were used to compute minimum, maximum and means of various variables. Means for monthly rainfall and maximum and minimum temperature which were used to make graphs were computed by excel. In deriving representative sample statistics, calculation of farmers' average income from crops (Y_{ij}) and livestock (Z_{ij}) was computed by using equation (3) and (4), respectively.

$$Y_{ij} = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{Q_{ij} . P_j^C}{A_j}\right) \quad (3)$$

$$Z_{ij} = \frac{1}{N}\sum_{i=1}^{N}(X_{ij})(P_j^L) \quad (4)$$

Where; Q_{ij} represents yield in kg of crop j for farmer i, X_{ij} is the number of livestock j sold by farmer i, A_j is the size (ha) of field in which crop j is cultivated, N is the sample size, P_j^C and P_j^L refers to the unit price of crop j and livestock j, respectively.

RESULTS AND DISCUSSION

Farmers interviewed included 21 and 19 male and female, respectively. Their ages ranged from 31 to 75 with the average of 49 years. Thirty four farmers (16 male and 18 female) completed primary education while six (five male and one female) completed ordinary level of secondary education. The size of the household ranged from 2 to 11 with an average of 5.9 (Table 1). This figure is above the national average of 4.9 (Tanzania National Website, 2003). This is in line with the population growth of Tanzania which according to Population Reference Bureau (2008), is growing at the rate of 2.6% per annum and is projected to 81.5 million by 2050, an increase of 110% of the current 38.7 million peoples. Farming revenue refers to the monetary value of total crop harvested which includes the amount consumed as food and the amount sold based on individual farmer selling price.

Table 1. Demographic and socio-economic characteristics of sampled households.

Description	Minimum	Maximum	Mean	Median
Size of the household (no. of people)	2	11	5.9	6.0
Age of farmers (years)	31	75	49.2	48.5
Land owned and land proportion allocated for rice				
Total land area (ha)	0.40	6.40	2.3	2.2
Size of upland rice field (ha)	0.20	2.40	0.9	0.7
Total rice production and yield of rice per ha				
Total rice production (kg)	40	4,400	1,089	650
Yield of rice (kg/ha)	100	3,833	1,277	1125
Farmers revenue (Tshs)				
Revenue from farming	32,000	2,640,000	755,923	649,000
Revenue from non-farm activities	15,000	1,110,000	148,675	150,000
Total revenue	162,000	2,640,000	904,598	872,500

Notes: US$ 1 is approx.1300 Tanzanian shillings (Tshs) as of March 2009.

Table 2. Contribution of farm and non-farm enterprises to total farmer's revenue (n=40).

Source	Amount (Tshs)	% farm revenue	% Total revenue
Rice	475,125	62.8	52.5
Maize	147,863	19.6	16.3
Sesame	58,725	7.8	6.4
Livestock	43,975	5.8	4.9
Other crops	30,235	4.0	3.4
Total farm revenue	755,923	100.0	83.6
Non - farm revenue	148,675		16.4
Total revenue	904,598		100.0

Importance of farming in household economy

As indicated in Table 2, farming (crops and livestock) and non-farming activities contribute up to about 83.6% and 16.4%, respectively, of the total household revenue in surveyed areas.

The non-farm activities include small scale mining (Morogoro and Ulanga), brick making, labour, petty business such as retail shops, local brewing, food vendor etc. Specifically, farming share to household revenue is highest in Ulanga (95%) and lowest in Korogwe (74%) and vice-versa for the non-farm revenue (Figure 2). Rice, maize and sesame are the major crops cultivated in the survey areas. Other minor crops but of importance include beans, cocoa, groundnuts, cassava and variety of horticultural crops.

Farming practices

The percentage of farmers who use tractors and draught animals for cultivation is 18 and 33%, respectively, while the remaining use hand hoe which is also used for weeding. Regardless of the cultivation tools used, other farming activities are done by traditional tools such as machetes and bush knives or commonly known as *panga* for land preparation, sickles, knives and snail shells for harvesting rice, small hoes for weeding rice fields etc. There is very little use of fertilizers and manures– only 15% and 20% of farmers used fertilizers and manures, respectively. Low use of fertilizer is attributed to low availability and high prices whenever available. Also the few livestock kept produce little manure for use.

Land area available for rice

Figure 3 presents the average total land area owned by each farmer and the portion allocated for rice cultivation in hectares. Kyela farmers allocated more land for rice (62.5%) of total land area, while Korogwe farmers have the least land area for rice (19.2%). Ulanga and Morogoro farmers allocated 36.4 and 36.8%, respectively, of their total land area for rice. The total average area allocated for rice is 39.1%.

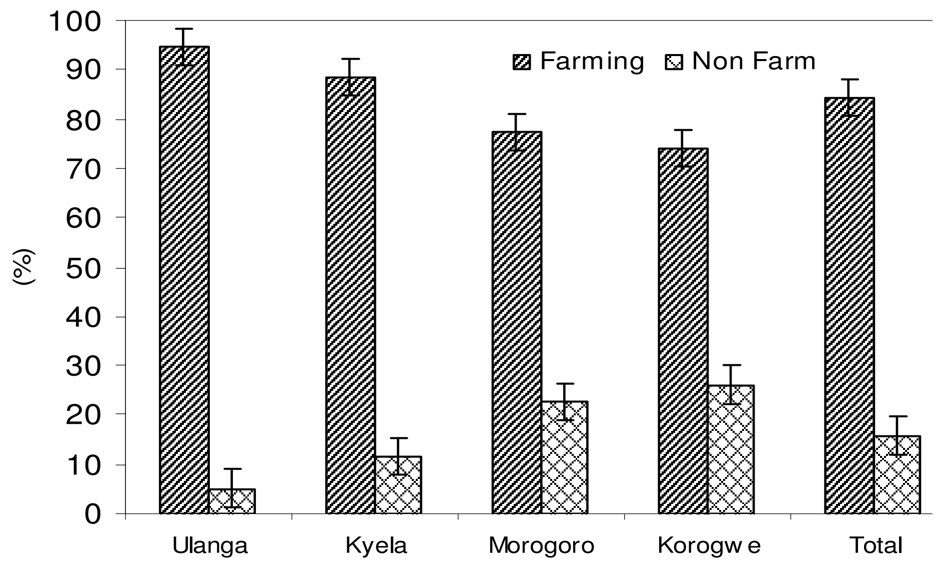

Figure 2. Percentage contribution of farm and non farm revenue to total revenue by location. The data is from ten farmers (n=10) from each location, making a total of 40 farmers. Bars indicate the standard error.

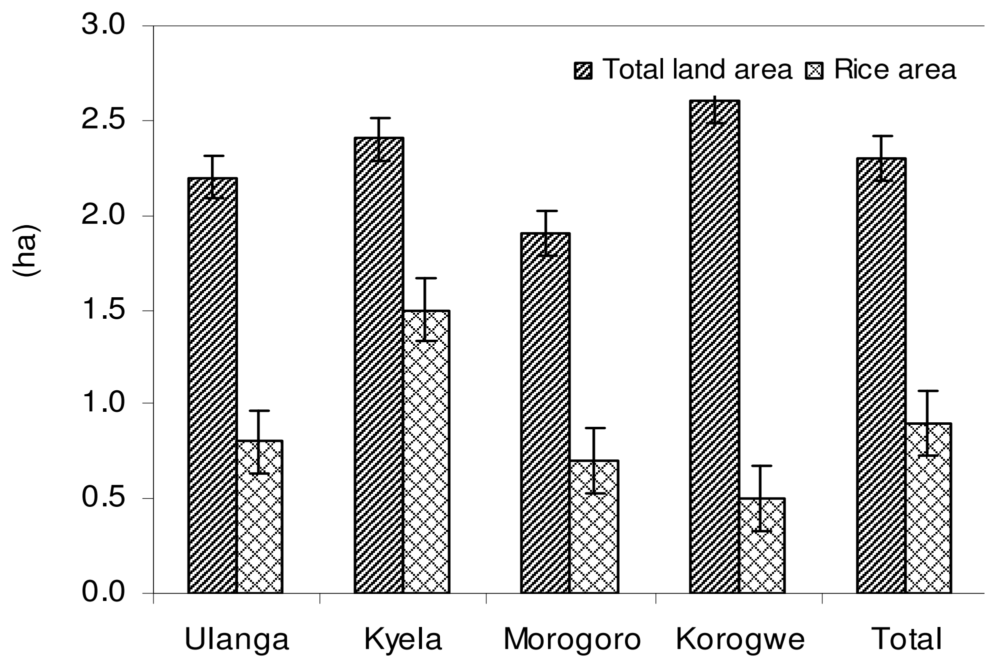

Figure 3. Total field area owned and area allocated for rice farming by each farmer total land area includes the compound area, builings and farm area. Bars indicate the standard error.

Potential of rice in the surveyed areas

Maize followed by rice are the major cereal crops grown for food and cash in Tanzania. However, in the surveyed areas rice is preferred most than maize in that regard (Table 3). As aforementioned, rice is allocated proportionally bigger areas (39%) of the total area available to each farmer. In general it contributes to 59.1% of the total farm income followed by maize (19.0%), sesame (12.9%), livestock (5.2%) and other crops (3.8%). It is only in Korogwe where maize contributes more to the farm income (51.0%) compared to rice (43.8%). Sesame

Table 3. Contribution of various agricultural enterprises to farm revenue by location (%).

Location	n	Rice	Maize	Sesame	Livestock	Others [1]	Total
Ulanga	10	60.0	4.6	23.5	0.6	11.3	100.0
Kyela	10	80.5	10.1		5.5	3.9	100.0
Morogoro	10	51.9	10.4	28.3	9.0	0.4	100.0
Korogwe	10	43.8	51.0		4.3	0.9	100.0
Total	40	59.1	19.0	12.9	5.2	3.8	100.0

[1] Although produced in small quantities, beans, cocoa, groundnuts, cassava and variety of horticultural crops are also a good source of revenue to some farmers.

Table 4 . Total traditional rice production and yield by location.

		Ulanga		Kyela		Morogoro		Korogwe		Total	
		Mean	N	Mean	N	Mean	N	Mean	N	Mean	N
Production (kg)	Below 1000	543	7	620	5	259	8	386	7	432	27
	1000 to 2000	2,000	1	1,750	2	1,200	1	1,350	2	1,567	6
	2001 to 3000	2,800	1	2,550	2	-	-	2,300	1	2,550	4
	3001 to 4000	3,900	1	4,000	1	-	-	-	-	3,950	2
	Above 4000	-	-	-	-	4,400	1	-	-	4,400	1
	Overall	1,250	10	1,570	10	767	10	770	10	1,089	40
Yield (kg/ha)	Below 1000	535	4	594	4	495	9	681	3	511	20
	1000 to 2000	1453	4	1969	6	-	-	1625	6	1608	16
	Above 2000	3413	2	-	-	3668	1	3833	1	3582	4
	Overall	1477	10	1254	10	813	10	1563	10	1277	40

ranked second in Ulanga and Morogoro. Rice cultivation in these areas is therefore of great importance to the household livelihood and the need for its improvement for increased productivity is necessary.

Total production and yield of rice per unit area

On average, farmers in the upland rice agro-ecosystem under study produced a total of 1089 kg of rice per farmer which is equivalent to 1277 kg/ha (Table 4). This falls in the national average of 0.5 to 1.5 ton/ha of upland rice (MAFS, 1998). However, 68% (27 farmers) produced below 1000 kg of rice in total and yield of 50% (20 farmers) was below 1000 kg/ha indicating very low rice yield. Bangu and Wambura (1999) associated poor crop yields in Tanzania to the fact that about 80% of the nation's food is produced by small holder farmers whose farming practices are grossly deficient in such agronomic inputs as timely and proper land preparation, application of adequate organic and inorganic fertilizers, use of good seed, timely and proper weeding and use of pesticides. The data is based on 2008 growing season. Yield figures (kg/ha) exceeding the actual amount produced (kg) is due to conversion from small land areas cultivated which in most cases was below 1 ha.

Rice production constraints and their countermeasures

Each farmer across the surveyed areas was asked to mention the most important problem which singly or in combination with others influenced their agricultural productivity. The problems mentioned were diseases and pests, poor soil fertility, poor tools and wild animals. Others are labour shortage, fertilizer unavailability, unfavourable weather, small field sizes, lack of irrigation systems and poor seed distribution.

Rice yellow mottling caused by rice yellow mottle virus (RYMV) is a devastating disease of rice which is spreading at an alarming rate to almost all rice growing areas of Tanzania, the surveyed areas no exception. The disease causes yield losses of up to 97% if not well managed (Fomba, 1988). Weed infestation significantly reduces rice yield levels due to ineffective weed management done by hand weeding. Mbwaga (2002) reported witch weed striga being a serious problem in Kyela, affecting nearly 3,000 ha of upland rice in at least 5 village areas with some 15% rice areas in the district being severely affected.

Poor soils are a consequence of extensive cultivation without replenishment of nutrients mined by crops. Despite of its higher prices, the unavailability of fertilizer

Table 5. Physicochemical properties of sampled soils.

Area	pH (water)	Texture	TN (%)	OC (%)	P (mg/kg)	K (cmol(+)/100g)	Ca	Mg	Na	CEC	Ec (dS/m)
Ulanga	6.2	SCL	0.17	1.78	2.5	1.96	7.76	1.45	0.06	17.17	0.14
Kyela	4.7	SCL	0.16	1.65	0.5	0.61	1.71	0.40	0.12	19.42	0.06
Morogoro	5.9	SL	0.11	1.33	13.4	0.26	9.17	2.47	0.06	17.18	0.06
Korogwe	5.7	SCL/C	0.19	1.89	8.6	0.77	14.23	9.51	0.54	46.75	0.49

SCL = Sandy clay loam, SL = Sandy loam and C = Clay
These results represent average of ten soil samples collected from each study site.

further complicates the problem, forcing farmers to practice the non environmental friendly shifting cultivation. Damage of crops by wild animals and small field sizes are major concerns in Mahenge (Ulanga) and Matombo (Morogoro) due to proximity of the area to the wildlife habitat and the mountainous terrain, respectively. The most troublesome animals are primate group. In the current season, weather notably rainfall has been unpredictable especially in the eastern zone of Tanzania posing a big threat to farmers whose agriculture solely depends on it.

Labour is in short supply and/or ineffective due to the fact that few family members involved in farming are of advanced age with low succession rate by youth or inability to hire labour and use of poor tools. All these problems lead to poor farming practices and ultimately low productivity. Various interventions are in place to solving these problems. For instance, research on management of RYMV disease has succeeded to release local varieties Mwangaza and Kalalu that have shown resistance to the disease (Kihupi et al., 2004). Soil fertility management has received much attention following the government's subsidy scheme on fertilizers to enable more farmers' access the input. Small-scale irrigation systems, mechanized agriculture and production and distribution of good seed are among the top priorities of the agricultural policy. Extensive research on weed management especially striga (Mbwaga, 2002) and wild rice (Mbapila, 2005) has been successfully conducted.

Physical and chemical properties of soils

The soil pH indicates that soils of Ulanga are slightly acidic, those from Kyela are strongly acidic while Matombo and Korogwe soils are medium acidic (Table 5). Rice grows well in pH range between 4.5 and 6.6 (Van Breeman, 1980). Therefore, soil pH is not a limiting factor with respect to rice production in the surveyed areas.

Soils of Ulanga and Kyela are sandy clay loam in texture while those of Morogoro are mostly sandy loam. In Korogwe, sandy clay loam and clay soils dominate. The higher clay content of Korogwe soils accounts for their higher CEC and hence high fertility. Total nitrogen for all soils is between 0.1 and 1.2% which according to Landon (1991) is low to support the growth of rice. All sampled soils had medium organic carbon according to Baize (1993) ranging from 1.26 to 2.50%. Available phosphorus is low to medium according to EOROCONSULT (1989) who reported that soils with <7, 7-20 and >20 mg/kg P are low, medium and high in available P, respectively. N and P fertilization is therefore necessary for increasing rice production in these areas.

With the exception of Morogoro, the content of K in the soils is above the critical level for deficiency (0.217 cmol(+)/100g) reported by Baize (1993) and therefore K is not a limiting factor with respect to rice cultivation in Kyela, Korogwe and Ulanga upland rice agro-ecosystem. According to Landon (1991), soils with < 4 meq/100g Ca are considered low in calcium. In this regard, Kyela soils are calcium deficient. Soil is said to be deficient of magnesium if its content is below 1.0 cmol (+)/100g (Embleton, 1993). With the exception of Kyela, magnesium is not a constraint to rice production in the surveyed areas. Cation exchange capacity (CEC) ranged from 17.17 in Ulanga to 46.75 cmol (+)/100 g in Korogwe. According to EOROCONSULT (1989) soils with CEC < 6.0, 6.0 to 12.0, 12.1 to 25.0, 25.1 to 40.0 and > 40.0 cmol(+)/100g have very low, low, medium, high and very high CEC, respectively.

Therefore the CEC of the surveyed areas is medium to very high capable of supporting the growth of rice. Soils with electrical conductivity (EC) greater than 4 dS/m are considered saline. All soils from surveyed areas have low EC of between 0.06 and 0.49 dS/m indicating that they are not saline to sufficiently affect the growth of rice.

Weather condition

March to May marks the rainfall peaks in all areas (Figures 4 - 7). However, more annual rainfall is recorded in Kyela (annual mean 2925 mm). In Matombo annual rainfall is 1647 mm and is relatively well distributed compared to other places (Figure 4). Mahenge and Korogwe receive annual mean rainfall of 1728 and 1062 mm, respectively.

The highest temperature is recorded in Korogwe in March (33°C) and the lowest in Kyela in July (6°C).

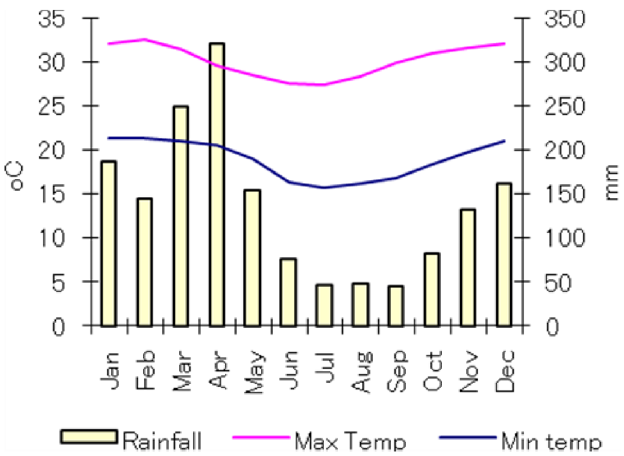

Figure 4. Monthly rainfall and maximum and minimum temperature (Mean of 10 years, 1988-1997) at Matombo Morogoro.

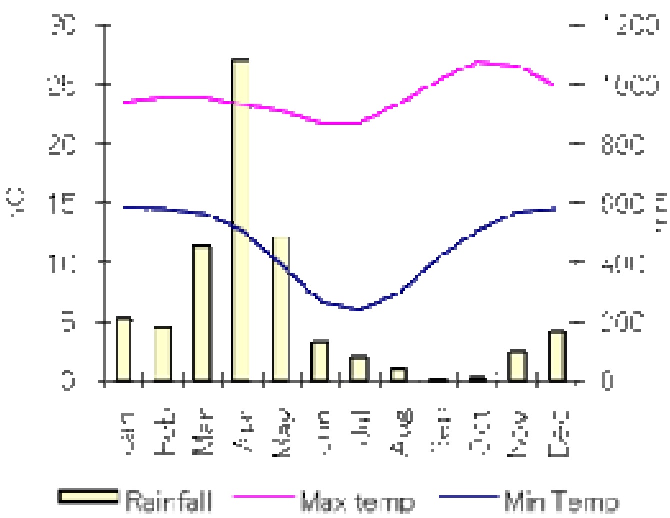

Figure 5. Monthly rainfall and Max and Min temperature (Mean of 20 years, 1989-2008) at Kyela.

Monthly maximum and minimum temperature during rice growing season (January to June) ranges from 21.9°C in Kyela to 33°C in Korogwe and 6.6°C in Kyela to 24.5°C in Korogwe, respectively.

Conclusion

Despite of its importance as both food and cash crop in the surveyed areas in particular, and Tanzania in general, yield levels of upland rice are disappointedly low. The surveyed soils are grossly deficient of N and P - the nutrient elements limiting rice production. Potassium and Calcium are also low in Kyela and Potassium is low in Morogoro. Other yield constraints include use of traditional

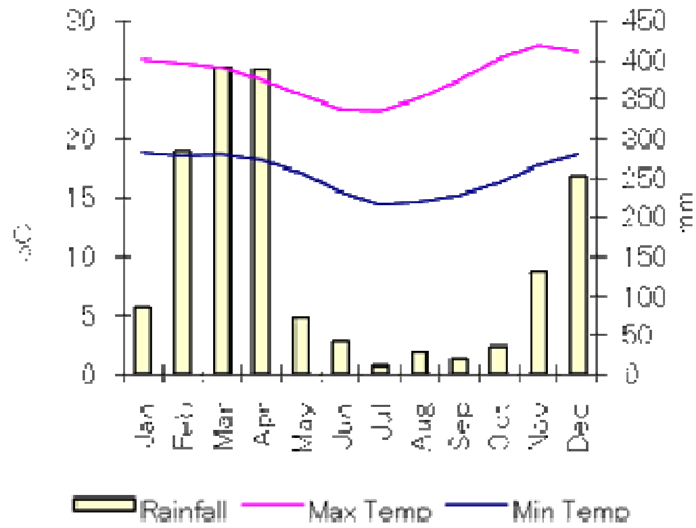

Figure 6. Monthly rainfall and maximum and minimum temperature (Mean of 10 years, 1999-2008) at Mahenge Ulanga.

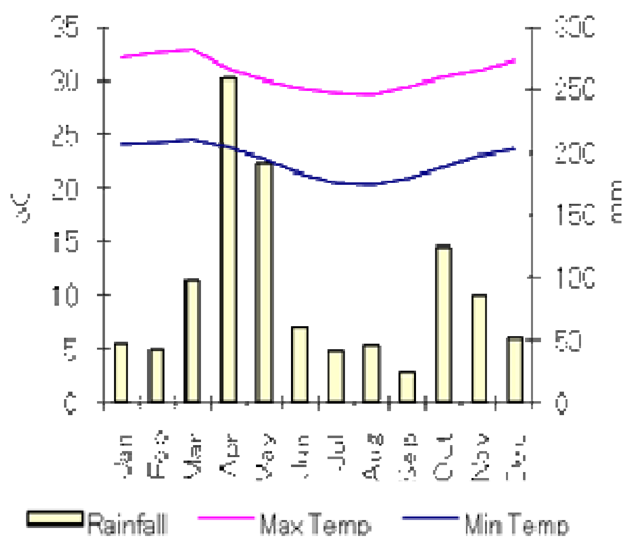

Figure 7. Monthly rainfall and maximum and minimum temperature (Mean of 15 years, 1992-2006) at Korogwe.

low yielding varieties, inadequate fertilizer application, low moisture and diseases and pests. Rainfall and temperature regimes are suitable for upland rice including NERICA which are now being tested in Tanzania and ultimately promoted for cultivation to take advantage of their high yielding potential under diverse production constraints which can not be easily addressed by low-input farmers who dominate the farming community.

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