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ALTERNATIVE LAND USES IN SEMI-ARID TROPICS: A CASE STUDY OF THE WAMI PLAINS, MVOMERO DISTRICT, TANZANIA

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Abstract

A study covering an area of 358 km^2 was conducted at Wami Plains in Mvomero district, Tanzania to assess the suitability of land for various land use types with emphasis on smallholder low input rainfed maize, rice and extensive grazing. Expert knowledge captured in ALES computer programme was used to carry out physical and economic land suitability classification with respect to three major land utilisation types. Decision trees to assess the potentials and constraints of the land for the three land utilisation types were developed in ALES programme. Physical and economic land suitability classification and ALES predicted yields and gross margins are presented. The results indicate that about 90% of the area is physically moderately suitable and economically highly suitable for extensive grazing. Only about 43% is both physically and economically suitable for maize production and about 57% is either marginally suitable or not suitable for maize production. On the other hand about 57% of the studied area is marginally suitable for rice production while 43% is not both physically and economically suitable for this LUT. The most limiting factors for the production of the three studied LUTs are poor soil fertility, poor soil drainage conditions, tsetse flies and ticks infestation and soil erosion hazards. From this study it is also concluded that extensive grazing is economically more profitable in the area compared to the production of maize and rice. Basing on the current farmers observed and predicted yields there are high possibilities for obtaining higher yields from livestock under improved management levels. Maize production is recommended as the second important LUT in the area provided that soil fertility problems and poor drainage conditions are improved. Rice production is economically the third land utilisation type. Higher rice yields could be obtained if farmers were able to invest more on fertiliser use. This forms a strong base in favour of high investment in the area given the potential marketing possibilities in the expanding cities and towns in Tanzania and in East Africa.

Key words: *Land suitability assessment, Automated Land Evaluation System (ALES), rice, maize, extensive grazing, Wami plains, Tanzania*

Introduction

The plains in Tanzania occupy about 70% of the total area. These plains are characterised by low rainfall, unfavourable climatic conditions and poor soil conditions (Kileo, 2000). Major land use systems in these plains include subsistence cultivation of food crops and extensive grazing. There are very few commercial farmers who are investing in rice cultivation in these plains. There have been prolonged land use conflicts among land users in these plains that has led to protracted land disputes. To avoid such land use conflicts, it is urged that the villages must be surveyed, and sustainable land use plans determined and enforced, taking into account the reasonable needs of the various community members in a given area.

Low food production and the prolonged land use conflicts in Tanzania are contributed to a large extent by poor land use planning (Msanya *et al.*, 1999), inadequate research and lack of information on different agro-ecological zones (Kimaro, 1989), poor crop husbandry and management, growing of crops in marginal areas, unreliable rainfall, poor soil fertility, and different forms land degradation (Kimaro, 2003).

Studies on the potentials and constraints of lands in the plains of Tanzania are scarce. This has lead to inappropriate land use, inefficient exploitation and management of natural resources, destruction of the land resources and protracted land use disputes. Formulation of land use planning in lowland areas require knowledge of the potentials and constraints of the various land units and production potentials of each of them for a set of relevant land use types. There is therefore, a need to carry out land evaluation studies in the plains to explore agricultural potentiality for various uses. This information will be useful to the land users and developers as well as decision-makers.

Computer-based land evaluation system (ALES) (Rossiter and Van Wambeke, 1989; 1994) which has been used extensively in Tanzania coupled with expert knowledge (Kimaro, 1989; Kimaro and Kips, 1991; Kileo, 2000 and Kimaro *et al.*, 2001; 2003) offers possibilities for a wide range of applications especially when quick results are required hence a very useful land evaluation tool for land use planning (Van Lanen, 1991; Rossiter, 1995; 1996). In this study expert model developed within ALES programme (Kimaro *et al.*, 2001) was used to evaluate the potentials and constraints of the Wami plains in Mvomero district for physical and agro-economic suitability for smallholder rainfed agriculture and extensive grazing. ALES program is favoured because is capable of quickly process large amount of natural resource database for decision-making on land use and management and timely generation of information required by potential investors.

Materials and Methods

The study area is located between 37°30′00″ and 37°38′6.7″E and 6°30′ and 6°41′3.3″S at an elevation range of 380 and 600 m.a.s.l. The mean annual rainfall ranges between 768 mm to 1036 mm. April is the wettest month with a mean rainfall of 204 mm. Mean annual temperature varies from 21.2°C to 26.0°C with July being the coldest month and December the hottest.

Semi-detailed soil survey was carried out at a scale of 1:50,000 using the results of aerial photo interpretation for the identification of landforms and dominant soils in the study area. Both free survey and transect observations were used to collect data on landforms, land use and soils (Dent and Young, 1981; FAO, 1990). An area of 358 km^2 was surveyed at an intensity of 2 observations per 1 km^2. In each transect, soils were described and studied using soil augering and minipits to a depth of 50 cm. Profile pits were dug to a depth of 2 metres or to lithic / paralithic contact whichever was shallower. A portable Global Positioning System Receiver (model GARMIN 12XL) was used for geo-referencing the observation sites in the study area. Soil samples for both physical and chemical determinations were collected and analysed according to the standard procedures and guidelines as outlined in Klute (1986), McLean, (1986), National Soil Service (1990) and Sparks (1996). Soils were classified up to level-3 of the FAO classification system (WRB) (FAO *et al.*, 1998)

Table 1 presents the major landscape units, dominant soils and the main soil properties used as input data in the ALES model. Four major landforms were identified and studied. The undulating plains have Rhodi-Profondic Lixisols, Hypereutri-Ferralic Cambisols and Hypereutri-

Mollic Fluvisols as the dominant soils. These soils are shallow to deep sandy clay loams to sandy loam textured. The dominant soils on the flat plains with red soils are Chromi-Profondic Lixisols. These soils are very deep sandy clay loams to clay textured. Flat plains with sand soils are dominated by Calcari-Mollic Fluvisols. The soils are very deep with sandy clay loam topsoils and clay textured subsoils. On the valleys and depressions, Hypocalci-Endosodic Calcisols and Endosodi-Pellic Vertisols are dominant. These soils are deep to very deep, stratified sandy clay loams to clay textured.

Thirty-four representative farmers were interviewed using semi-structured questionnaires coupled with Participatory Rural Appraisal (PRA) techniques to obtain information on major land utilisation types and socio-economic data for screening by ALES.

Three major land utilisation types (LUTs) i.e. smallholder low input rainfed maize, smallholder low input rainfed rice and extensive grazing were identified and studied. Most farmers produce crops on very small pieces of land (0-1 ha) while few farmers have about 7-17 ha for crop production. Production is characterised by low capital investment, low level of education and technical knowledge and without application of fertilisers. The agronomic database i.e. farmers reported yields and gross margins for the major identified land utilisation types is given on Table 2.

The suitability of the Morogoro plains for smallholder low input rainfed maize, smallholder low input rainfed rice and extensive grazing was assessed using ALES programme basing on the land qualities (LQs) or land use requirements (LURs) which were considered most relevant for the LUTs. These are moisture availability, nutrient availability, nutrient retention capacity, soil erosion hazard, temperature regime, soil wetness, incidence of pests and diseases (tsetse & ticks), availability of drinking water and accessibility of animals to grazing lands (i.e. bush coverage). LURs are composed of certain land characteristics (LCs). For example the LUR "Nutrient retension capacity" is composed of the LCs "apparent CEC, sum of basic cations and percentage base saturation". In ALES, the interrelations of LCs to rate LURs are established in the form of decision trees. These are structured representations of the reasoning process (expert knowledge) needed to reach decisions. Class limits in the decision trees for the selected LUTs were mainly based on literature sources, PRA and field observations. LURs were rated using severity levels as follows: (1) no limitation, (2) moderate limitation, (3) severe limitation and (4) very severe limitation.

In this study both physical and economic suitability rating of the dominant soils and further landform units were determined using decision trees severity levels constructed in ALES computer programme. The rating followed the Liebig's law of minimum (Rossiter and Van Wambeke, 1989), by which the most limiting LUR determines the suitability class. Four

Table 1: Landscape units, dominant soils and selected soil properties in the study area

Landform units	Dominant soil units	Slope (%)	Depth (cm)	Text. class	pH	OM %	TN %	Avail. P (mg/kg)	BS %	CEC cmol(+)/kg	ESP %
Undulating plains	Rhodi-Profondic Lixisols	2-3	Shallow to moderately deep	SCL-SC	6.2	2.24	0.13	1.5	53	17	1.21
	Hypereutri-Ferralic Cambisols	2-3	Moderately deep	SL	6.8	1.03	0.06	6.8	97	3.8	2.63
Flat plains (red soils)	Chromi-Profondic Lixisols	0.5-1	Very deep	SCL-C	6.5	1.57	0.06	2.23	82	8.3	2.65
Flat plains (sand soils)	Calcari-Mollic Fluvisols	0.5	Very deep	SCL-C	6.2	1.22	0.04	2.29	81	4.84	3.15
Valleys and depressions	Endosodi-Pellic Vertisols	0.5-1	Deep to very deep	SC-C	7.7	1.36	0.08	0.96	97	21.2	3.95

SCL = Sandy clay loam, SL = Sandy loam, LS = Loamy sand, SC = Sandy clay, C = Clay, TN = Total nitrogen, OM = Organic matter, BS = Base saturation, CEC = Cation exchange capacity

Table 2: Farmers reported yields and Gross margins in the study area

Landform units	Dominant soil units	Number of respondents	Farmers reported yields (Land utilisation types)				Farmers reported gross margins (Land utilisation types)			
			Maize (kg/ha)	Rice (kg/ha)	Extensive grazing Meat (kg/farmer /yr)	Extensive grazing Milk (litres/ farmer/yr)	Maize (TAS/ha)	Rice (TAS/ha)	Extensive grazing Meat (TAS/farme r/yr)	Extensive grazing Milk (TAS/far mer/yr)
Undulating plains	*Rhodi-Profondic Lixisols*	4	1,900	1,100	2,700	23,000	130,000	85,000	350,000	260,000
	Hypereutri-Ferralic Cambisols	4	2,900	1,500	2,700	23,000	230,000	145,000	350,000	260,000
Flat plains (red soils)	*Chromi-Profondic Lixisols*	6	2,300	1,200	2,600	27,000	170,000	100,000	300,000	340,000
Flat plains (sand soils)	*Calcari-Mollic Fluvisols*	6	1,600	900	2,600	29,000	100,000	55,000	300,000	380,000
Valleys and depressions	*Endosodi-Pellic Vertisols*	4	1,200	1,700	2,500	26,00	60,000	175,000	250,000	320,000

TAS = Tanzanian Shilling, US$ = 1,049 TAS physical suitability classes were defined as follows: (1) good potential, (2) moderate potential, (3) poor potential and (4) very poor potential. ALES was used to predict yields on the basis of limiting yield factors.

Results and Discussion

ALES physical suitability classification of the study area for the three studied land utilisation types is shown in Table 3. About 90 % of the study area was found to have moderate potential for extensive grazing with yield predictions of 2,240 kg/farmer/year and 23,200 litres/farmer/year for meat and milk respectively. Biological hazards, bush coverage in some areas, climatic conditions and drinking water availability are slightly limiting factors for this LUT. Generally the study area is classified as having poor to very poor potential for rice production with yield predictions ranging between zero and 800 kg/ha. Soil fertility, temperature regime and soil wetness are the most limiting factors. Flat plains with red soils and most parts of undulating plains have moderate potential for maize production with yield predictions of 2,400 kg/ha. Soil erosion, soil fertility and duration of flooding are slightly limiting factors. Flat plains with sandy soils and some parts of valleys and depressions have poor potential for maize production with yield predictions of 1,200 kg/ha. Soil fertility and oxygen availability to roots are the most limiting factors. The rest of valleys and depressions were classified to have very poor potentials for maize production with zero yield predictions. Poor drainage conditions are the most limiting factors for this LUT. Some parts of the undulating plains have very poor potentials for rice production with zero yield predictions.

ALES predicted gross margins and economic suitability classification are summarised in Table 4. Most parts of the study area were rated as highly suitable (S1) for extensive grazing with predicted gross margins of 361,000 TAS/farmer/year. Most parts of the undulating plains are moderately suitable (S2) for maize with predicted gross margins of 185,000 TAS/ha while very small proportion of this landform unit is classified as economically not suitable (n1) for rice production with zero predicted gross margins. Valleys and depression and small parts of undulating plains and flat plains with red soils are marginally suitable (S3) for rice production with predicted gross margins of 70,000 TAS/ha while the larger part being economically not suitable (n1) for this LUT with zero predicted gross margins. Flat plains and some parts of valleys and depressions are moderately (S2) and marginally (S3) suitable for maize production with predicted gross margins of 185,000 TAS/ha and 92,000 TAS/ha respectively. The rest of the valleys and depressions are economically not suitable (n1) for this LUT with zero predicted gross margins.

The results indicate that most of the land in Morogoro plains i.e. about 90% is physically moderately suitable and economically highly suitable for extensive grazing. About 43% of the study area is both physically and economically suitable for maize production. The remaining area (about 57%) is either marginally suitable or not suitable for maize production for both physical and economic reasons. On the other hand about 57% of the studied area is marginally suitable for rice production while 43% is not both physically and economically suitable for this LUT. The most limiting factors for the production of the three studied LUTs are poor soil fertility, poor soil drainage conditions, tsetse flies and ticks infestation and soil erosion hazards.

Table 3: Maximum attainable yields, ALES predicted yields and physical suitability classification

Landform units	Dominant soil unit	Maximum attainable yields: Land utilisation types				ALES predicted yields: Land utilisation types				physical suitability classification: Land utilisation types		
		Maize (kg/ha)	Rice (kg/ha)	Extensive grazing Meat *	Extensive grazing Milk **	Maize (kg/ha)	Rice (kg/ha)	Extensive grazing Meat *	Extensive grazing Milk **	Maize	Rice	Extensive grazing
Undulating plains	*Lixisols*	3,000	2,000	2,800	29,000	2,400	800	2,240	23,200	2na/e	3na/wt	2ac/bh/cl/m
	Cambisols	3,000	2,000	2,800	29,000	2,400	0	2,240	23,200	2na/nr	4na	2ac/bh/cl
Flat plains (red soils)	*Lixisols*	3,000	2,000	2,800	29,000	2,400	800	2,240	23,200	2na/nr	3na	2ac/bh/cl/dw
Flat plains (sand soils)	*Fluvisols*	3,000	2,000	2,800	29,000	1,200	0	2,240	23,200	3df/na	4na	2ac/bh/cl/dw/m
Valleys and depressions	*Vertisols*	3,000	2,000	2,800	29,000	0	800	1,120	11,600	4df/o	3na	3bh

* = kg/farmer/year, ** = litres/farmer/year, m = moisture availability, na = nutrients availability, nr = nutrients retention, df = duration of flooding, o = oxygen availability to roots, tr = temperature regime, wt = soil wetness, ac = accessibility of animals to grazing lands, bh = biological hazards (tsetse & ticks), cl = climatic conditions, dw = drinking water availability.

Table 4: ALES predicted yields, gross margins and economic suitability classification

Landform units	Dominant soil units	ALES predicted yields – Land utilisation types				ALES predicted gross margins – Land utilisation types			Economic suitability classification – Land utilisation types		
		Maize	Rice	Extensive grazing		Maize	Rice	Extensive grazing	Maize	Rice	Extensive grazing
		(kg/ha)		Meat (kg/farmer /yr)	Milk (litres/ farmer/yr)	(TAS/ha/yr)		(TAS/farmer/yr)			
Undulating plains	*Lixisols*	2,400	800	2,240	23,200	185,000	70,000	361,000	S2	S3	S1
	Cambisols	2,400	0	2,240	23,200	185,000	0	361,000	S2	n1	S1
Flat plains (red soils)	*Lixisols*	2,400	800	2,240	23,200	185,000	70,000	361,000	S2	S3	S1
Flat plains (sand soils)	*Fluvisols*	1,200	0	2,240	23,200	92,000	0	361,000	S3	n1	S1
Valleys and depressions	Vertisols	0	800	1,120	11,600	0	70,000	150,000	n1	S3	S3

TAS = Tanzanian Shilling, 1US$ = 1049/= TAS, S1 = highly suitable, S2 = moderately, S3 = marginally suitable, n1 = not suitable

Conclusions and Recommendations

From this study it is concluded that extensive grazing is economically more profitable in the area compared to the production of maize and rice. Basing on the current farmers' observed and predicted yields; there are high possibilities for obtaining higher yields from livestock under improved management levels. Maize production is recommended as the second economically viable land utilisation type to the farmers living in these areas provided that soil fertility problems and poor drainage conditions are solved. Rice production is the third economically viable land utilisation type. Higher rice yields could be obtained if farmers were able to invest more on fertiliser use. This forms a strong base in favour of high investment in the area given the potential marketing possibilities in the expanding cities and towns in Tanzania and in East Africa.

Although the land characteristics used in this study are broadly defined and are compound in nature, it is clearly demonstrated that the results obtained will be useful in policy development and decision making in land use planning of the study area and others with similar environmental characteristics.

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