Climate Change and Agricultural Planning Beyond the 21st Century: A Case Study of Morogoro District

J.P. Hella[1] *and F.T Kamuzora*[2]

1 Department of Agricultural Economics and Agribusiness
Sokoine University of Agriculture, Morogoro
2 Institute of Development Management, Mzumbe

Abstract

The agricultural systems that have been built over the past few decades have contributed greatly to the alleviation of hunger and raising living standard. The systems have saved its purpose up to the point. As we turn toward the 21st Century, reports on localized or general crop failure due to drought and other climate episodes especially in Sub-Saharan Africa are on the increase. The question is; are we facing climate changes?

Using historical data from two meteorological stations in Morogoro District and 16 other stations randomly selected from all over the country, this paper attempts to assess the magnitude of climate changes and variability with special reference to rainfall and temperature. Results indicate that there is no evidence to indicate a major change for the above mentioned climate attributes at 0.01 level of significance. However, seasonal and annual variabilities for the same are predominant. The study recommends that joint efforts among planners, researchers and farmers is required if the objective of achieving sustainable agriculture and economic development in the 21st Century is to be achieved.

Key words: *Climate, change, rainfall, temperature, agriculture, environment, droughts, sustainability.*

1 Background information

1.1 The role of climate in economic development

Climate has been a neglected factor in the world affair (Hare *et al.*, 1985). This is mainly due to the fact that , to many, climate is still a vague idea without much need to worry as long as it performs reliably. However, from the 1970s most national economies particularly those in Sub-Saharan Africa were continuously being shaken by extreme climates mainly those caused by rainfall variability (Mzengeza, 1996; Kasasse, 1992 and Ngana, 1993).

Human societies, plants and animals adopt themselves to ordinary annual rhythms of climate, which are called seasons. Mzengeza (1992) and Hare (1985) explained what really happen when there is a failure to expected seasonal changes. These changes caused by either permanent or cyclic variability has often led to discomfort and economic losses (Kasasse, 1992; and Ngana, 1993). On the other hand, Mahita (1984), Ngana (1993), Mascarenhas (1968) and Jackson (1977) underscored the effect of unexpected climate change to frequently observed localized or generalized famine in these countries.

In Tanzania, agriculture account for more than 50% of the country's Gross National Product (GDP), about 75% of the export earnings and provide employment to about 84% of the population (Mashinga, 1996; Kashuliza and Ngaillo, 1993 and Msambichaka, *et al.*; 1983). Unfortunately due to slow transition to irrigated agriculture which account for less than 2% of total cultivated land (Ashimogo, 1995), Tanzania's agriculture greatly depends on climatic situation which varies enormously within a country and across the years.

Rainfall is therefore a very important source of water for crop production (Kasasse, 1992; Ngana, 1993); and in the case of Tanzania where the rate of transition to irrigated agriculture is limited, small rainfall variability has caused a far reaching effect (Simwanza, 1996). Since the late 1960s, it was evident that, one reason for the observed dismal agricultural performance in Tanzania is, to a greater extent, attributed to drought (Mascarenhas, 1968). However, to date nothing significant has been done to arrest the situation except for a few policy directives in the 1970s following a devastating drought of 1973 (URT, 1993).

As 20th Century closes, report on famine and localized food shortage caused by drought and rainfall variability is frequent in some areas or occasionally through out the country in some years (Majira, May 1997; Kasasse 1992; Ngana, 1993, 1990, 1991; Mahita 1984; and Mascarenhas, 1968; and Perry and Kates, 1972). With an increasing need for food and export crops, the task of maximizing and stabilizing agricultural output becomes an issue requiring commitment of every individual. Thus as the 21st Century approches, strategic decision in planning agricultural systems to cope with ever increasing climatic changes and variability is inevitable

2 Nature and magnitude of the problem

The slow development of agriculture in Tanzania is attributed to many factors but erratic and unreliable rainfall has been singled out as the most outstanding obstacle to agricultural production (Ngana, 1993; Hatibu and Simalenga, 1993; and Kasasse 1992; Msambichaka *et al.*, 1983; Perry and Kates, 1972 and Mascarenhas 1968). In recent years news on climate changes have been reported in Tanzania and elsewhere in the World (UNCED, 1992). While it is generally agreed that environmental factors like rainfall variability, temperature, solar radiation etc., are non-alterable the development of science have made them amenable to improvement through management practices like design of irrigation schemes, choice of farming pattern and land use, selection of cropping varieties, animal breeding and choice of farm machinery. These have successfully been used as intervention strategies in case of environmental uncertainties (Mzengeza, 1994).

Studies on climate change in East Africa in general and Tanzania in particular are limited. Christianson and Kikula, (1996) in their work; *"Changing Environments: Research on man-land interrelations in Semi-Arid Tanzania"*; emphasized more on management and society's coping strategy respect to climate change. An attempt to address the issue of climate change and in particular rainfall is addressed in Hulme (1994) who indicated that between 1931 and 1992 amount of rainfall in Eastern Africa has increased by 15%.

Very specific survey on environmental attributes and its variability in Tanzania were conducted since the early 1960s (Msambichaka *et al.*, 1983 and Mascarenhas, 1968). Very recent studies along the same line include Mashinga, (1996); Ngana, (1990, 1991, 1993 and 1996), Hatibu and Simalenga, (1993); and Mahita (1984). However, most of these studies were targeted in the Semi-arid areas of Central Tanzania except for a few (Ngalesoni, 1996; Kasasse, 1992; Jackson, 1977; and Perry and Kate 1972). However, very limited studies have been conducted in the Eastern agro-ecological zone (Ngalesoni, 1996). It is within this background that this study was proposed to examine the climatic attributes in the zone.

3 Objective of the study

The general objective of this study was to assesschanges and variability of climate related variables in the Eastern Zone of Tanzania and subsequently to suggest some production mitigation for sustainable agricultural and economic development.

Specifically the study was thought to;

i) Assess climate change (rainfall and temperature) over a specified time period.

ii) Isolate characteristic cyclic climate variability in the study area.

iii) Relate the changes and variability with productivity in agricultural sector.

iv) Suggest environmental mitigation at farm level that can act as safety margins to ensure stable production across the planning horizons.

This study was further guided by the following hypotheses.

i) There is no significant change of climate related variables over the study period.

ii) There is no significant seasonal climate variability to cause substantial reduction of agricultural production and agro-based economic development.

4 Study area

4.1 Location of the study area

Baseline data for this study was collected in Morogoro District The District covers about 19296 km^2 of which, 19230 km^2 is in Rural and the rest is Urban (IRDP, 1980). The District is divided into 10 divisions; Mvomero, Turiani, Mgeta, Mlali, Kingolwira, Mkuyuni, Ngerengere, Matombo and Mngazi. Data for this study were collected from two meteorological stations; Sokoine University of Agriculture (SUA) and Dakawa Rice Research Centre (DRRC) located in Morogoro municipal and Morogoro Rural District respectively. The latter is about 45 km from Morogoro town along Morogoro - Dodoma highway.

Based on climate the district may be divided into lowland and highland areas. The highlands that lie between 1400-2033 meters above sea level gets between 1000-1800 mm rainfall per annum. In most cases the rainfall is reliable and farming is done throughout the year. The lowlands lie between 400-900 meters above the sea level while the valleys lie between 800-1000 meters. In the latter two systems rain falls for 6 months. Other months are relatively dry. The two meteorological stations are located in this relief zone.

4.2 Type, sources and methods of data collection

Historical monthly climate records were collected at the Sokoine University of Agriculture (SUA) and Dakawa Rice Research Centre (DRRC) meteorological stations. These stations are situated about 550 meter above the sea level. Monthly rainfall (amount and number of rain days) and temperature (mean monthly minimum and maximum) data for the period between 1971 and 1997 were collected. Mean annual rainfall amount and number of rain days from meteorological stations in Kagera, Mara, Arusha, Mwanza, Kilimanjaro, Tabora, Singida, Tabora, Tanga, Dodoma, Dar es Salaam, Iringa, Mtwara and Ruvuma regions were also collected from various documents at Sokoine National Agricultural Library (SNAL). The data cover a period between 1960 and 1990.

4.3 Data analysis

Climatic records and production data collected were organized and analyzed by using computer and statistical software packages including Lotus 1-2-3, Harvard Graphic and SPSS. Specifically some data were analyzed for mean, variance, coefficient of variability, and t-statistics for monthly and annual difference analysis. The use of paired t-test to analyse pre-determined strata of three periods; early 1970s, 1980s and 1990s was also used to establish aspects of climate change over predetermined study periods.

4.4 Farming system of the study area

Agriculture is the main economic activity for people residing in the District. Main crops planted include; maize, rice, beans, pigeon peas, cow peas, sorghum, cotton, banana, sisal and sugarcane. Other crops produced at smaller scale include; sesame, cassava, vegetables and fruits. In the district small holder subsistence farmers who own plots of not more than 3 ha carry out agricultural activities. Further 99% of agriculture production is rain-fed. Irrigation is limited in sugarcane estates. Limited traditional irrigation for vegetable production is practised in hilly areas.

5 Results and discussion

5.1 Rainfall characteristics

5.1.1 Annual mean rainfall variability

Amount of rainfall (mm) per annum is the most used indicator of rainfall pattern among planners. Data collected from four stations indicated that mean rainfall per annum ranged between 562 mm in Dodoma region to as much as 2159 mm in Kagera region. Both altitude and latitude of the location had no relation with annual rainfall. However, water bodies like ocean and lakes greatly influenced amount of rainfall per annum. In this study, Dar es Salaam, Tanga, Mtwara, Bukoba and Mwanza received relatively higher annual rainfall than Loliondo, Morogoro and Dodoma stations mainly because the former are closer to the Indian ocean and lake Victoria respectively.

Like wise mean number of rain days varied significantly with highest (196 days) recorded at Bukoba station and least (43 days) at Dodoma station. Amount and number of rain days are highly correlated. In tropical areas where storms and hails occur, rainfall amount can not be a better indicator with regard to its suitability in crop production. On the other hand, the number of rain days per annum suggests the length of growing period for successful crop production.

Distribution of rainfall per annum particularly for the eastern zone shows two distinctive peaks. The first and smaller in December and/or January and the second and the larger, correspond with long rains, occurs in March and/or April. Two peaks are more pronounced in Morogoro and Mtwara than Dodoma and Musoma stations because the latter receive mono-modal rainfall pattern.

5.1.2 Mean annual rainfall variability

For long term planning strategies, and for the need to have clear planning decisions for crop production, annual rainfall variations play a significant role. Based on the findings, there are marked variations of rainfall for different regions between 1960 and 1997 (Table 1).

Table 1 Mean Rainfall Amount and Variability in for stations in Tanzania (1960 - 1990)

Attributes	Regions			
	Morogoro	Dodoma	Mtwara	Musoma
Location (latitude)	10^0	6°10's	11°21's	1°30's
Altitude (meters asl)	526	1120	113	1147
Mean total/annum Minimum (mm)	886	562	114	899
Maximum (mm)	1176	282	1766	507
Range (mm)	602	837	1757	1397
CV (%)	23	26	19	21

Note: Data for Morogoro were collected between 1971 and 1997.

Source: Survey results, 1997.

Highest variation (CV = 26%) was recorded in Dodoma Region followed by Morogoro (23%). Mtwara had relatively less variability (19%) over the study period. The trend of the total rainfall per annum in the study regions indicated steady amounts throughout the period. An attempt to assess change in total rainfall per annum to study climatic change was done by comparing three periods based on data collected in Morogoro District. Results indicate that in the 1970s and 1980s there was no significant difference on rainfall distribution pattern. However, in the 1990s the rainfall pattern differed slightly from the preceding years by showing characteristic tendency of both a shift of the date for rainfall onset and peak periods towards later dates for both short and long rains respectively.

5.2.1 Mean monthly total rainfall

Analysis of the result indicated significant monthly variation with two district peaks, in December for short and March/April for long rains respectively. Effective wet months are December, January, March and May. The months of June, July, and August are usually dry (Table 2). Highest (mean = 195.1 mm) rainfall occurs in April followed by March (mean = 123.5 mm). The months of August and September receive less than 10 mm of rainfall are driest.

Numbers of rain days per month are important for determining and planning crop and livestock production schedules. The number of rain days per month corresponded with the amount of rainfall. Many rain days were recorded in April (mean = 17 days) whereas September had least (mean = 2 days).

Table 2 Rainfall variables for Morogoro station 1971-1996[1]

Month	Monthly total				Rain days			
	Mean	CV (%)	Max.	Min	Mean	Min	Max.	CV (%)
January	91.6	70.5	249	11	7	1	16	56.7
February	83.7	79.9	258	1	6	0	14	64.9
March	123.5	42.0	229	64	10	2	21	4.2
April	195.1	31.9	298	87	17	12	25	17.3
May	92.8	40.4	158	13	12	5	19	37.3
June	17.0	97.7	54	0	3	0	8	83.8
July	13.3	106.0	61	0	2	0	7	90.9
August	8.0	90.0	29	0	3	0	5	112.0
September	9.5	106.3	33	0	2	0	6	100.0
October	30.8	85.7	105	0	4	0	10	71.4
November	61.7	85.0	176	1	6	0	12	65.4
December	101.7	68.4	262	1	8	0	17	54.1

Source: Calculated from SUA and DRRC, 1997.

5.3.2 Mean monthly rainfall variability

Table 2 based on data between 1971 and 1997 show monthly rainfall variability and trend with special interest in the months of November, December, January, February, March, April, and May. From the table it is apparent that monthly rainfall show considerable variations. Mean monthly total rainfall for the wet months (e.g. April) ranged between and 87 and 289 mm and from 0 to 33 mm for driest months (e.g. August and September). The corresponding coefficient of variation of mean total monthly rainfall for 26 years, are highest during dry months i.e. 97.7, 106, 90, and 106.3% respectively in June, July, August and September; than wet months, March April and December with CV recorded at 42, 31.9 and 68.4% respectively. Highest CV recorded in dry months suggest planning uncertainties especially for crops like sunflower, sorghum and cotton that require a dry spell during harvesting time for quality produce. The results are related to that of URT (1993) and Ngana (1996) based on several station in Tanzania (Table 3).

Table 3 Coefficient of variability % (CV) for selected stations in Semi-arid Tanzania

	Months								
Station	October	November	December	January	February	March	April	May	Seasonal
Dodoma	309	186	57	60	60	57	93	192	26
Rukwa	261	132	59	54	55	55	71	104	23
Manyoni	219	130	62	50	41	64	83	87	26
Singida	267	121	61	50	50	58	96	142	30
Nzega	116	75	47	48	49	43	57	125	24
Lubanga	124	82	46	48	55	50	48	112	24
Maswa	102	78	46	55	53	47	47	83	24
Kondoa	200	93	66	60	77	61	48	99	27

Source: Ngana (1996)

5.3 Temperature variables

Table 4 indicate that highest mean maximum temperatures (above 31°C) are recorded in November, December, January and February whereas mean minimum temperatures (below 16°C) in June, July and August. Further, the results indicate that mean monthly maximum or minimum temperature variations over 26 years study period was not significant. Highest CV (4%) was recorded in the month of December. This consistency in temperature suggests that observed climate change and variability in several parts of the country is mainly attributed to rainfall variability than temperature.

Table 4 Morogoro: Summary of Mean Monthly Temperatures

Month	Maximum temperature (C°)			Minimum temperature (C°)		
	Mean	Std dev.	CV (%)	Mean	Std dev.	CV %
January	31.5	1.1	3.9	21.7	3.5	16.1
February	32.2	1.1	3.4	21.0	0.5	2.4
March	31.0	1.1	3.5	20.8	0.5	2.4
April	29.5	0.8	2.7	20.4	0.3	1.4
May	28.4	0.6	2.1	18.9	0.5	2.6
June	27.5	0.5	1.8	15.8	1.1	6.9
July	27.3	0.7	2.5	14.6	2.7	18.5
August	28.1	0.5	1.7	15.7	0.6	3.8
September	27.7	0.5	1.6	16.6	0.4	2.4
October	30.6	1.0	3.2	18.0	0.6	3.3
November	32.2	0.9	2.7	19.8	0.5	2.5
December	32.0	1.3	4.0	21.1	0.6	2.8

Source: Survey result, 1997.

5.4 Climate changes

According to Kate *et al.*, (1985) climate change occur when the difference between successive averaging periods exceeds the periodic erratic tolerance limit. These extreme erratic changes must persist for long time. The results based on data collected for 26 years indicate that there is no climatic change with regard to rainfall and temperature except for seasonal variations (Table 5). Data analysis based on three purposely identified study periods, i.e. early 1970s, 1980s and 1990 revealed no climatic change at 0.01 level of significant for both amount and number of rain days (Tables 6 & 7). These results denote that the observed cyclic climatic changes are not permanent. On the other hand, mean monthly rainfall indicate a significant change in some months.

Table 5 Morogoro: Rainfall Amount (mm) and Variability for the Three Study Periods

Period (years)	Mean Total	Mean Total rain-days	Mean Max. (mm & months)	Mean Min. (mm & month)
1971-1975	785.5	82	232.5 (April)	5.4 (August)
1981-1985	816.8	83	172.4 (April)	7.6 (Sept)
1991-1995	775.8	78	233.2 (April)	6.6 (Sept)

Source: Survey results, 1997.

Table 6 Comparison of Mean Amount of Rainfall (mm) in the 1970s and 1980s.

Variable	Years compared with	
	Early 1980s	Early 1970
Sum of difference (td)	-42.00	7.70
Mean difference (td/n)	-3.50	0.64
Sum of Sq. differences $(td-td/n)^2$	6414.44	7806.14
variance of differences (S^2)	583.14	709.64
t-calculated	-0.14	0.024
t-tabulated (at = 0.05)	1.79	1.796
t-tabulated (at = 0.01)	2.71	2.718

Source: Survey data (1997).

6 Implications of climate change and variability for sustainable agriculture and economic development

6.1 Implications on agricultural production

Productivity of rain-fed agriculture practised in Tanzania varies with rainfall amount and distribution. In years when rainfall is not favourable in terms of amount and distribution problems of decreased production total crop failure have been reported (Majira, May 1997; Kasasse, 1992 and Mascarenhas, 1968). Since agriculture contribute more than 50% of the GNP and 75% of the export earnings see Kashuliza and Ngailo 1993) unfavourable rainfall pattern greatly affect agriculture production hence the economy of the country. The record drought of 1973 is still considered as one of the main reason for poor economic performance in the late 1970s and early 1980s (URT, 1993)

Table 7 Comparison of Mean Annual Number of Rain Days (mm) in the 1970s and 1990s.

Variable	Early 1980s (1985)	Early 1970 (1971-75)
Sum of difference (td)	5.20	1.35
Mean difference (td/n)	0.43	32.61
Sum difference square $(td-td/n)^2$	20.46	32.61
Variance of difference ($S^{2)}$	1.86	2.96
t calculated	0.31	0.78
t tabulated (at [= 0.05)	1.79	1.79
t-tabulated (at [= 0.01)	2.71	2.71

Source: Survey Data (1997)

6.2 Dwindling balance of payment

Following unfavourable climate, use of small foreign currency reserve for importing food becomes a necessary condition. Problem of limited balance of payment for most developing sub-Saharan Africa countries is well understood. When food importation becomes necessary, other development plans are greatly affected, thus causing further impoverishment of the population.

6.3 Lack of food to feed the population

Lack of food result in malnourished population that cannot contribute to the economic development of the country. Another problem, which is now becoming a national problem, is that of environmental refugees. Every year hundreds of refugees (mostly livestock keepers) avoids miseries caused by extreme climate variability dominant in one area and move to areas with friendly climate. The effects of such movements environmentally, socially and economically, though not well established, in most cases are too severe to revoke.

7 Some environmental mitigations supplementing rainfall with irrigation

Tanzania has got more water bodies than any other country in the Sub-Saharan Africa so is a water shade (catchment area) for the four main African rivers; the Zambezi, Rufiji, Congo and Nile (Hella, 1997). With this advantage irrigation remains the most potential solution with regard to episodes caused by rainfall variability. The transition to irrigation at various magnitudes should be given priority.

7.1 Selecting most stable cropping systems

It is acknowledged that some crops have high ability to tolerate drought than others (Aucland, 1971). Crops like maize, rice and beans are susceptible to adverse weather conditions while sorghum and pearl millet have considerable ability to withstand drought. With this respect, selection of crops with the ability to withstand variability caused by adverse climate should be a policy if sustainable production and insurance on household food security is to be reached.

Some cultural practices conserve loss of moisture from the soil through evapo-transpiration. In areas where rainfall uncertainty and variability is high, the objective should be to maintain soil moisture. Thus unexpected drought can cause little damage to crop growth and yield. Some of the documented cultural practices include; ridging, mulching, terracing, contour farming, cover cropping, etc. Evidences show that most of these practices are not adopted by small scale farmers due to labour constraints and conflicting interests in case multiple practices are to be adopted. Effort should be done to ensure that farmer adopt these practices.

8 Conclusion and recommendation

Climate change is a risk management issue but unlike, flood and earthquakes, for which records dates back hundreds of years, there is no historical experience to guide the assessor on climate change. Although no permanent changes in climatic attributes have been recorded, the country is ill prepared for the recurrent cyclic variations. From the foregoing conclusions the following recommendations are made:

There is a need to improve climate based data collection and analysis and selection systems in the country. Reliable assessment of environmental episode greatly depends on the records of the past events.

There should be a close collaboration between Meteorological Department, Agricultural Research Stations and Planning Commission. There is a need to conduct further research on climate characteristics across specific geographical matrices to assess rainfall patterns with respect to these geographical coordinates. The analysis of the vulnerability to climate of the current and proposed patterns of land use and development need to be done. These will assist to assess the capacity of both the biosphere and society to adopt to climate change.

References

Ashimogo, G.C. (1995); Analysis of Different Maize Storage Systems in Tanzania: A Case Study of Maize in Sumbawanga District, Tanzania. Verlag Koester - Berlin.

Aucland, J. (1971); *East African Crops* Oxford University Press, UK

Christianson, E., I. S. Kikula, W. Ostberg, (1991); Man-land Interrelationships Environmentally Sustainable Intensive Livestock Systems in Semi-arid Central Tanzania. pp. 128-131.

Christianson, C., I.S. Kikula (1996); Changing Environments: Research on Man-Land Interrelations in Semi-arid Tanzania. SIDA's Regional Conservation Unit, Report No. 13.

Hare, R. W.; J. H. Ausubel, M. Berberian (1985)/; (Eds) Climate Impact Assessment: Study of the ilteraction of Climate and Society. SCOPE/ICSU; John Wiley & Sons LTD. Toronto.

Hatibu, N, T .E. Simalenga, (Eds.); (1993) Research Program in Soil-Water Management in Semi-arid areas of Tanzania. In: Proceedings of the Research Planning Workshop, 13-15 January, 1993, Dodoma Tanzania.

Hella, J. P. (1997). Wetland Areas of Tanzania: Current and Future Strategies for Sustainable Utilization. A Paper to be Presented at the RIO+5 Workshop. Rio de Janeiro, Brazil 9-13th March, 1997

Hulme, M. (1994); Century Scale Time Series of Regional Rainfall Anomalies in Africa. *In* Boden, T. A.; D. P. Kaiser; R. J. Sepanski; and F. W. Stoss (Eds.) Trends 93: A compendium of data on global change. Oxford NY.

Jackson , (1972); The spatial correlation of fluctuation in Rainfall Over Tanzania. A Preliminary Analysis. Arch. Met. Group. Un-biok Ser B 20 167-78

Kashuliza, A. K, N.L. Ngailo, (1993); Operational and Financial Performance of Farmers Cooperatives in Tanzania: Some Lessons for Policy Reforms. Hull paper in Developing countries, Humberside England

Kasasse, C. I. (1992); Determination of the Effective Length of Growing Season in Tanzania. Unpublished M.Sc. Thesis, Sokoine University of Agriculture, Morogoro Tanzania.

Land Resource Development (LDC) (1987); *Tanzania: A Profile of Agricultural Potential* . ODA UK , 26 pp

Liwenga E. T.(1995) The Impact of Land Conservation. Measures on Household Good Security in Kondoa Eroded Area -Tanzania. MSc. Thesis, Agricultural University of Norway, Noragric. Norway.

Mahita, M. S (1984); The Use of Water Balance Models in Optimization of Cereal Yields in Semi-arid Tropical Region. A PhD. Thesis University of Reading, UK.

Majira Newspaper (May 1997); Watu wafa kwa njaa Lindi . Majira news paper, Business printers Dar es Salaam Tanzania.

Mascarenhas, A,C. (1968); Aspects of Food Shortages in Tanganyika (1925 - 1945). Journal of Agricultural Association of Tanzania. pp 37 - 59.

Mashinga, T .N. (1996); Adoption of modified Pandey Bioeconomic Model for Evaluation of Economic Feasibility of Rainwater Harvesting (RWH) for Supplementary Irrigation in Semi-arid areas of Tanzania. Unpublished MSc. Thesis, Sokoine University of Agriculture, Morogoro Tanzania.

Msambichaka, L. A.;B. Ndulu; H.K.R. Amani (1983); *Agricultural Development in Tanzania: In Policy Evolution, Performance and Evaluation; The First two Decades of Independence*. Friedrick Elbert Sifting. FRG.

Mzengeza, T. R. (1994); Determination of Onset, end Duration and Variability of Rainfall in rice Growing Seasons in Malawi. Unpublished MSc. Thesis, Sokoine University of Agriculture, Morogoro Tanzania.

Ngalesoni, G. S. (1996); Relating Erosivity factor to Soil loss: A Case Study of Hombolo and Morogoro sites. Unpublished MSc. Thesis, Sokoine University of Agriculture, Morogoro Tanzania.

Ngana, J. O. (1990); Modeling of Periodic Features in Seasonal Rainfall and its Implications to Water Resources and Agricultural Planning. IRA. Research report No. 79 UDSM.

Ngana J.O (1991); Selection of Probability Distribution for Estimating Reliably Seasonal Rainfall in Semi-arid Central Tanzania. IRA paper No. 79. UDSM.

Ngana, J.O (1993); Rainfall, Agriculture and Famine in Dodoma District BRALUP Research Report No 6. UDSM. Pp 4-18.

Perry, L T., R. W. Kates (1972); Natural Hazards and Human Adjustment to Agricultural Drought in Tanzania: A pilot Investigation.. BRALUP Research paper No. 13 UDSM Tanzania.

Simwanza, I. H. (1996); Evaluation of Rainfall Interception Models in a Rain Fields in Zambia. Unpublished MSc. Thesis, Sokoine University of Agriculture, Morogoro Tanzania.

UNCED (1992); *Our Common Future*. Oxford University Press, New York. USA.

United Republic of Tanzania (URT) (1988); *Population Census 1988: A preliminary report*, Bureau of Statistics Dar es Salaam

United Republic of Tanzania (URT) (1993); Basic Data in Agricultural and Livestock Sector. Statistics unit, Planning and Marketing division. Dar es Salaam Tanzania.