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MAKUENI DISTRICT PROFILE: RAINFALL VARIABILITY, 1950-1997

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Preface

Drylands Research Working Papers present, in preliminary form, research results of studies carried out in association with collaborating researchers and institutions.

This working paper is part of a study which aims to relate long-term environmental change, population growth and technological change, and to identify the policies and institutions which are conducive to sustainable development. The study builds upon an earlier project carried out by the Overseas Development Institute (ODI) in Machakos District, Kenya, whose preliminary results were published in a series of *ODI Working Papers* in 1990-91. This led to a book (Mary Tiffen, Michael Mortimore and Francis Gichuki, *More people, less erosion: environmental recovery in Kenya*, John Wiley, 1994), which was a synthesis and interpretation of the physical and social development path in Machakos. The book generated a set of hypotheses and policy recommendations which required testing in other African dryland environments. Using compatible methodologies, four linked studies are now being carried out in:

Kenya	Makueni District	
Senegal	Diourbel Region	
Niger	Maradi Department	*(in association with ODI)*
Nigeria	Kano Region	*(in association with ODI)*

For each of these study areas, there will be a series of working papers and a synthesis, which will be reviewed at country workshops. An overall synthesis will be discussed at an international workshop in London in 2000.

The Kenya series updates the previous study of Machakos District (which included the new Makueni District) and examines this more arid area in greater depth. The Research Leader for these studies is Michael Mortimore. The Leader of the Kenya Team is Francis Gichuki of the University of Nairobi. Michael Mortimore, Mary Tiffen or Francis Gichuki may be contacted at the following addresses.

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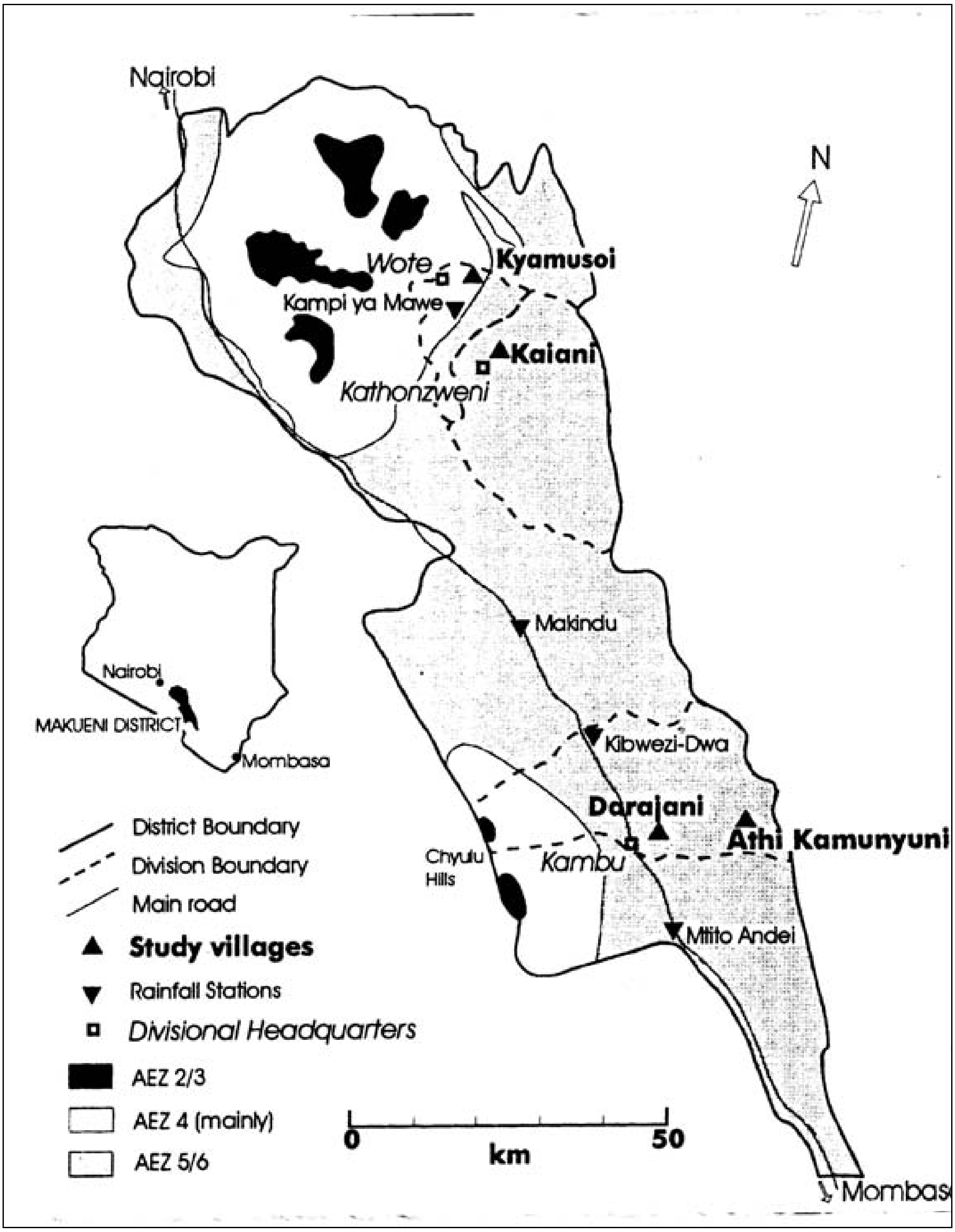
Preface map


Nairobi
N
Wote
Kyamusoi
Kampi ya Mawe
Kaiani
Kathonzweni
Makindu
Nairobi
MAKUENI DISTRICT
Mombasa
Kibwezi-Dwa
Darajani
Athi Kamunyuni
Chyulu Hills
Kambu
Mtito Andei
District Boundary
Division Boundary
Main road
Study villages
Rainfall Stations
Divisional Headquarters
AEZ 2/3
AEZ 4 (mainly)
AEZ 5/6
0
50
km
Mombas

Abstract

This paper documents annual rainfall and its cycles for Makueni District, Kenya over the past 50 years and some comparisons are made with Machakos District data. The data illustrates the unpredictability of rainfall in the study area, where the movements of the inter-tropical convergence and associated trade winds result in two distinct rainy seasons, namely the short rains (October-December) and the long rains (March-May). Data shows that the short rains normally deliver more rain, and are more reliable, than the long rains, and that droughts (years receiving less than 250 mm rainfall) in the District tend to occur in runs of two to five seasons, resulting in severe food shortages. Analysis of drought index data reveals that 43-55 percent of seasons are classified as having had light droughts or worse, whereas severe droughts occurred in 13-30 percent of seasons.

Strategies used by farmers to manage rainfall constraints include: the use of drought-escaping crop varieties, and experimentation with breeding drought tolerant maize; the use of long season, deeply rooting pigeon peas which can survive the dry season between short and long rains; the mixing of drought-escaping and drought-tolerant varieties of maize with Katumani composites, and; the establishment of perennial grasses and trees in order to increase water use efficiency by utilising rainfall outside the cropping season. The rainfall constraints faced by households in Makueni District have led to a number of impacts on investment, including: delays (five to six years) in reaping profits from investments in soil conservation and amelioration, and increased risks to these investments generally; difficulties in installing conservation measures during the dry season because of soil hardness; low priority given to investments in soil fertility improvement due to the perceived high risk of crop failure, the high cost of fertiliser, and the high labour requirement of low cost soil fertility enhancement practices; leakages of water from conservation structures during dry seasons, leading to reduced effectiveness, and; increased stress to livestock during dry seasons due to the scarcity of fodder and watering points.

Résumé

Ce rapport examine la pluviosité annuelle et ses différents cycles dans le district de Makueni au Kenya, au cours des 50 dernières années, et la compare avec celle du district de Machakos. Les caractéristiques pluviométriques des régions étudiées sont résumées dans la figure 1. Ces données illustrent le caractère imprévisible de la pluviosité dans cette zone.

Les déplacements de la zone de convergence intertropicale et des alizés qui lui sont associés créent dans les régions étudiées deux saisons des pluies distincts, baptisées «petite» (de Octobre à Décembre) et «grande» (de Mars à Mai). La répartition des précipitations annuelles entre ces deux saisons est indiquée dans le tableau 3. Ces relevés montrent que pendant la petite saison les précipitations sont plus abondantes et plus régulières que pendant la grande saison. Les données concernant la pluviosité moyenne saisonnière (tableau 4) montrent qu'aucune évolution à long terme ne semble apparaître dans ce domaine. La figure 4 indique que les phases de sécheresse (les années où les pluies annuelles sont inférieures à 250 mm) semblent se produire sur des périodes de 2 à 5 saisons consécutives, ce qui provoque des disettes. La figure 6 montre que,

depuis 40 ans, les grandes saisons des pluies ont été plus irrégulières que les petites, particulièrement pendant la période 1977-97, et que ces irrégularités concernent la date où les pluies commencent (figure7). La plupart du temps, pendant la saison des pluies, les précipitations mensuelles et saisonnières sont inférieures à l'évapotranspiration potentielle (figure 8).

Toutes les périodes de sécheresse depuis 1920 ayant provoqué des disettes, des déficits en fourrage, une destruction du cheptel, et des interventions externes ou locales sont récapitulées dans le tableau 6. Un indice de sécheresse pour chaque saison des pluies, grande ou petite, de 1950 à 1997, a été calculé ainsi que la probabilité de sécheresses légères, modérées ou fortes pendant ces périodes (tableau 7). D'après ces données on voit qu'il y a eu des sécheresses légères ou modérées pendant 43-55 pour cent des saisons et de fortes sécheresses pendant 13-30 pour cent des saisons.

Les stratégies employées par les agriculteurs pour s'adapter au régime pluviométrique et à ses contraintes sont, entre autre, les suivantes :

- utilisation de variétés de plante échappant à la sécheresse, avec essais portant sur la culture d'une variété de maïs qui résiste à la sécheresse;
- utilisation des pois cajans, lesquels ont un long cycle cultural et des racines profondes, ce qui leur permet de survivre pendant la saison sèche, entre la petite et la grande saison des pluies, qui est une période où la pluviosité est inférieure à 70 mm et où les précipitations sont très irrégulières;
- la culture mélangée de variétés de maïs résistantes à la sécheresse et de variétés y échappant, avec la variété composite Katumani;
- L'établissement de bandes de graminées pérennes et d'arbres, lesquels favorisent l'infiltration de l'eau de pluie en dehors du cycle cultural, ce qui permet donc une meilleure exploitation de cette ressource.

Le régime pluviométrique a imposé aux familles du district de Makueni des contraintes qui ont eu un certain impact sur leurs investissements, avec notamment :

- des retards (de 5 à 6 ans) avant de pouvoir bénéficier des profits réalisés grâce à leurs investissements dans l'amélioration et la conservation des sols, et en général le risque que ces investissements soient affectés;
- des difficultés pour établir des structures permettant la conservation pendant la saison sèche en raison de la dureté des sols;
- le peu d'intérêt présenté par le fait d'investir pour améliorer la fertilité des sols pour certains agriculteurs qui considèrent qu'il y a un grand risque d'échec au niveau des cultures, que les engrais sont trop chers et que les pratiques culturales permettant l'amélioration de la fertilité des sols et qui ne demandent pas beaucoup d'argent exigent une force de travail considérable.
- Des pertes d'eau au niveau des structures permettant sa conservation pendant la saison sèche, et donc réduisant leur efficacité;
- Une pression accrue sur le cheptel pendant la saison sèche en raison du manque de fourrage et de points d'eau.

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List of acronyms and abbreviations

AEZ:	Agro-ecological zone
DI:	Drought index
NGO:	Non-governmental organisation
MIDP:	Machakos Integrated Development Programme
PET:	Potential evapotranspiration

1 INTRODUCTION

1.1 Background

Past rainfall studies on the semi-arid areas of Makueni District have highlighted its inter-annual and intra-seasonal variability and reported ways to cope with it (Dowker, 1971: Braun, 1977; Jaetzold and Schmidt, 1982; Stewart and Faught, 1984; Downing *et al.*, 1988; Potter, 1988; Mutiso, 1991).

1.2 Objectives

This profile, therefore, aims to analyse current data to distinguish the effects of rainfall variation from those other factors influencing farmers' investments. This is to be achieved by documenting:

1. Annual and seasonal rainfall variability;
2. Rainwater deficit/surplus;
3. Drought trends;
4. Implications of rainfall variability and water scarcity.

Table 1: Characteristics of study sites

AEZ*	Kyamusoi LM 4	Kaiani LM 5	Darajani LM 5	Athi IL 6
Time of settlement	*1950s*	*1960s*	*1960s*	*1970s*
Mode of settlement	Government supported settlement	Spontaneous settlement	Spontaneous settlement under govt guidance	Spontaneous settlement
Predominant land use	Cultivation cattle	Cultivation cattle	Cultivation beef cattle	Cultivation goats
Access to market	Good	Good	Good	Poor
Administrative division	Wote	Kathonzweni	Kibwezi	Kibwezi

*Lower midland (LM) zones extend over an elevation of 800 to 1300 m in Eastern Kenya and have an annual mean temperature of 21-24^{o}C, with a minimum temperature greater than 14^{o}C. LM4 is a marginal cotton zone with an annual average rainfall 40-50 percent of potential evaporation. The climatic conditions are fair to poor for cotton and maize, fair for pigeon peas and good for sisal. LM5 is a lower midland livestock-millet zone with an annual average rainfall 25-40 percent of potential evaporation. The climatic conditions are fair to poor for millet, cowpeas and sisal. The natural pasture can support low density grazing. IL6 is an inner lowland ranching zone, not suitable for rainfed crops and with natural pasture that can support low to very low grazing density (Jaetzold and Schmidt, 1982).

1.3 Methodology

The study was carried out in the semi-arid areas of Makueni District. The study focused on four study villages, namely: Kyamusoi in the marginal cotton zone (LM4); Kaiani and Darajani in the sorghum/millet/livestock zone (LM5) and Athi Kamunyuni in the livestock zone (IL 6) (see Figure 1). The characteristics of these study areas are summarised in Table 1.

Four rainfall stations (see Table 2) were selected on the basis of data availability and proximity to the study villages. These rainfall data were analysed and used to describe rainfall variability and trends, water availability and drought trends.

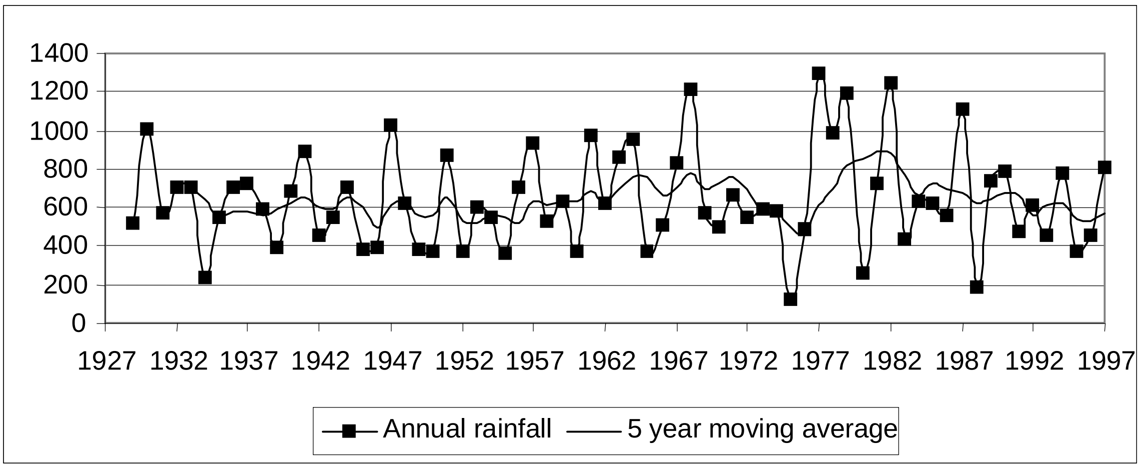
Rainfall is the most important source of water in semi-arid lands located a long distance from perennial rivers. Semi-arid areas experience unpredictable and unreliable rainfall, creating conditions that oscillate from humid to arid at a high and unpredictable frequency, making efficient and productive utilisation of the scarce rain water resources challenging, particularly for resource poor farmers.

Table 2: Characteristics of selected rainfall stations

Name	Longitude/ Latitude	Station Number	Elevation (m asl*)	Start
Kampi Ya Mawe	1° 51' S 37° 40' E	9137075	1230	1957
Dwa Plantation Ltd, Kibwezi	2° 24' S 37° 59' E	9237002	984	1926
Mtito Andei (Tsavo Park)	2° 45' S 38° 08' E	9238009	984	1957
Makindu	2° 17' S 37° 50' E	9237000	1076	1926

* m asl = metres above sea level

Figure 1: Annual rainfall at Dwa plantation, Kibwezi, 1927-97 (mm)



2 RAINFALL TRENDS AND VARIABILITY

2.1 Annual rainfall

Annual rainfall analysis of four stations (Table 2) in the semi-arid areas was undertaken to assess long-term trends and changes in rainfall characteristics. Dwa Plantation Rainfall station, near Kibwezi town, has the longest data and was used to assess variability over seven decades. Figure 1 shows annual rainfall variability at Dwa Plantation. The rainfall varied around a mean of 644 mm between 1928 and 1997. There is a high variability from year to year with a range of 117 and 1298 and a standard deviation of 249mm. The longest low rainfall period was observed between 1969 and 1976. A similar cluster of low rainfall years was reported between 1931-35. The low rainfall of the 1930s led to widespread environmental degradation, particularly in the sub-humid Akamba Reserve, leading to the realisation of the need for more land to relieve the population pressure (Tiffen *et al.*, 1994). A higher variability of annual rainfall is observed for the period 1977-98 than the period 1947-68.[1] The 5-year running mean was increasing for the period 1947-68 and decreasing for the period 1977-98. The farmers who settled the area in the 1950s have observed this trend, and the increased variability.

Annual rainfall at the four stations for the period 1950-97 is presented as 5-year means in Figure 2. There is no evidence of significant trends in annual rainfall over the period, but it ranged between 200 and 1400 mm. Consecutive low rainfall years are observed in 1969-76 and 1991-5. Annual rainfall oscillates between a high and a low value every 2-3 years, and consecutive years of low annual rainfall occur every 9-11 years. The high temporal variability and lack of a clearly defined rainfall cycle illustrate the unpredictability of the rainfall. The area therefore oscillates from semi-humid to arid conditions. The farmers are, however, unable to take advantage of the wetter conditions owing to their unpredictability. Resource-poor farmers have no choice but to invest in low input production systems to minimise their losses in bad years. Hence low and erratic rainfall is one of the main factors influencing the type and amount of farmers' investments in these semi-arid conditions.

Table 3 presents the mean, median, standard deviation and probability values. The mean annual rainfall ranges from 598 to 669 mm. The standard deviation of annual rainfall ranges from 221 to 287 mm. For the four stations annual rainfall greater than 937 mm is received in only 10 percent of the years. The 90 percent probability values indicate the lower limit of rainfall expected in nine out of ten years, thereby defining extreme drought as rainfall below these values.

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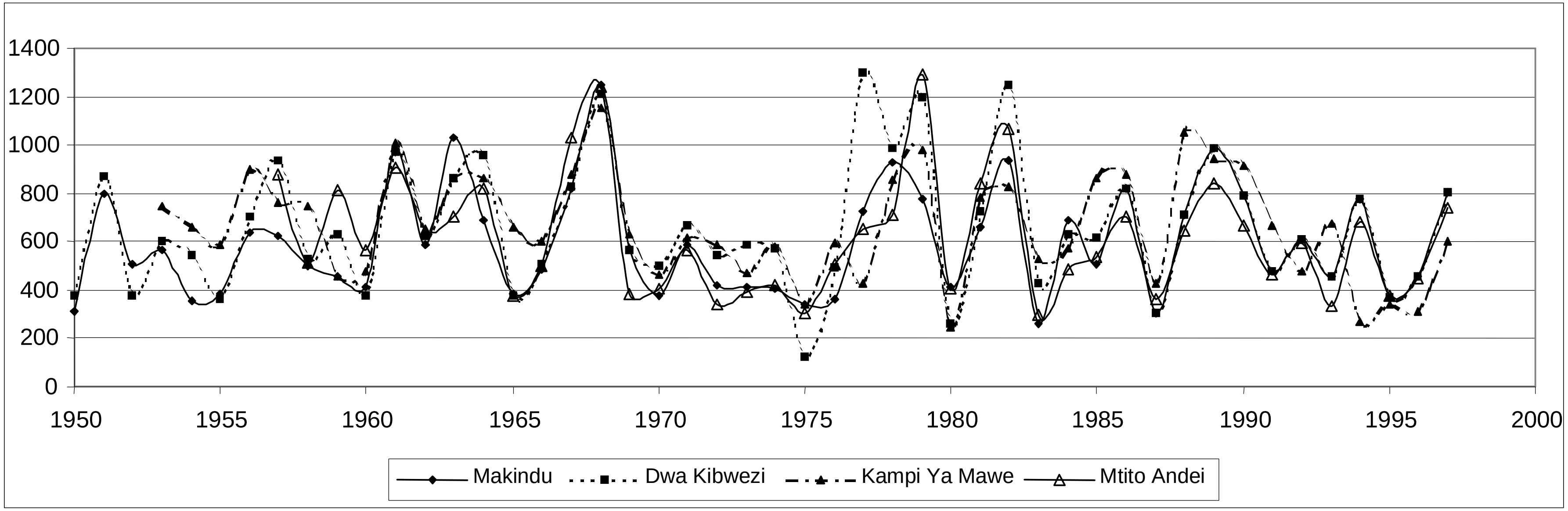
[1] The standard deviation, kurtosis and skewness are 294, -0.38 and 0.53 respectively for the period 1977-98, and 255, -0.83 and 0.45 for 1947-68.

Figure 2: Annual rainfall trends (5 year running averages, mm)



Source: Field survey, November, 1999.

Table 3: Annual and seasonal rainfall probabilities (mm)

Period of analysis	Statistical parameter	Makindu[1]	Dwa Kibwezi[2]	Kampi Ya Mawe[3]	Mtito Andei[4]
Calendar year Jan-Dec	Mean	598.2	669.4	666.2	621.3
	Median	566.1	613.1	647.6	568.8
	SD*	226.1	269.0	220.8	248.8
	10% probability	937.5	1193.8	943.4	1064.3
	20% probability	798.5	955.7	874.1	875.2
	90% probability	352.2	373.9	339.6	337.4
Agricultural Year Oct-Sep	Mean	595.2	655.7	665.6	625.5
	Median	558.5	608.0	667.9	607.1
	SD	209.7	238.4	244.0	201.6
	10% probability	904.0	1097.9	974.0	1038.4
	20% probability	758.0	862.8	873.7	812.7
	90% probability	332.8	313.1	323.2	242.4
Long rains Mar-May	Mean	196.1	241.7	267.0	235.5
	Median	178.1	243.9	240.1	216.4
	SD	103.7	127.6	135.4	136.0
	10% probability	366.8	416.0	452.8	494.6
	20% probability	279.6	328.4	355.2	376.3
	90% probability	92.9	52.4	118.6	66.6
Short rains Oct-Dec	Mean	327.7	352.9	302.2	325.2
	Median	279.1	319.4	289.2	292.1
	SD	178.4	176.6	161.4	154.3
	10% probability	595.2	581.2	493.6	564.3
	20% probability	464.7	543.7	447.4	440.3
	90% probability	155.1	175.8	120.5	140.8

Source: 1. Based on 1950-97 data (Makindu); 2. 1928-197 data (Dwa); 3. 1953-97 data (Kampi Ya Mawe); and 4. 1957-85 data (Mtito Andei).
*Standard deviation

Table 4: Long and short rains and dry season rainfall (percent of annual rainfall)

	Makindu	Dwa Kibwezi	Kampi Ya Mawe	Mtito Andei
March-May rains	33	37	45	40
October-December rains	55	60	51	53
Dry season rains	12	3	4	7
Total	100	100	100	100

2.2 Seasonal rainfall

The movements of the inter-tropical convergence and associated trade winds result in two distinct wet seasons, namely the short rains (October-December) and the long rains (March-May). The distribution of the annual rainfall into the rainy periods is shown in Table 4. March-May, October-December and dry season rainfall (June-September and

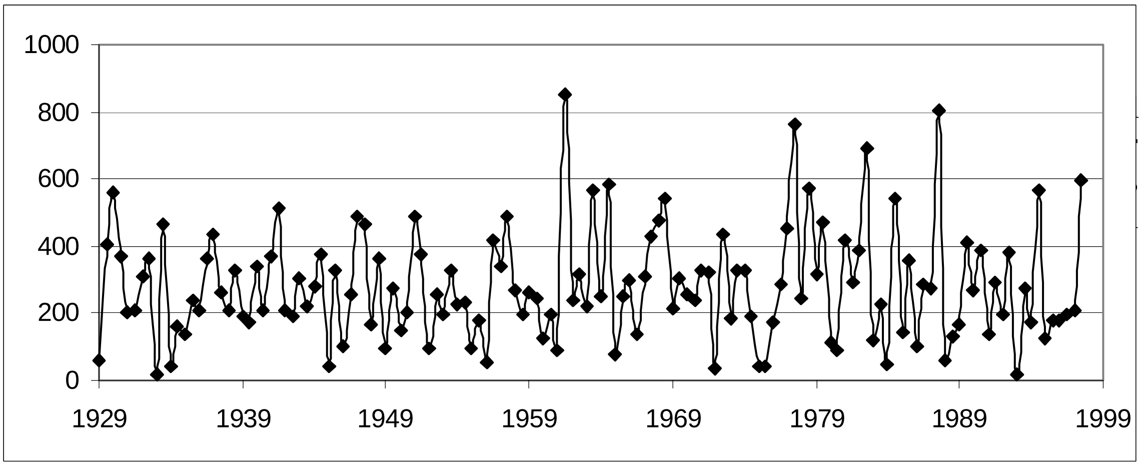
January-February) account for 33-45, 51-60 and 3-12 percent of the annual rainfall respectively.

Seasonal rainfall analysis was used to highlight the variability of rainfall within the year. Mean seasonal rainfall for the four stations was computed for different periods to assess whether there are significant changes over time. Table 5 shows that there is no evidence of a long term trend in seasonal rainfall[2], though differences in mean seasonal rainfall values are attributed to random variability. Interstation variability is insignificant, with the exception of Kampi Ya Mawe, the northernmost station, which received more rainfall in the long rains and less rainfall in the short rains than the other stations during the last 25 years. The short rains seasons have more rainfall and are more reliable than the long rains.

Table 5: Average rainfall by 30 year periods at four stations (mm)

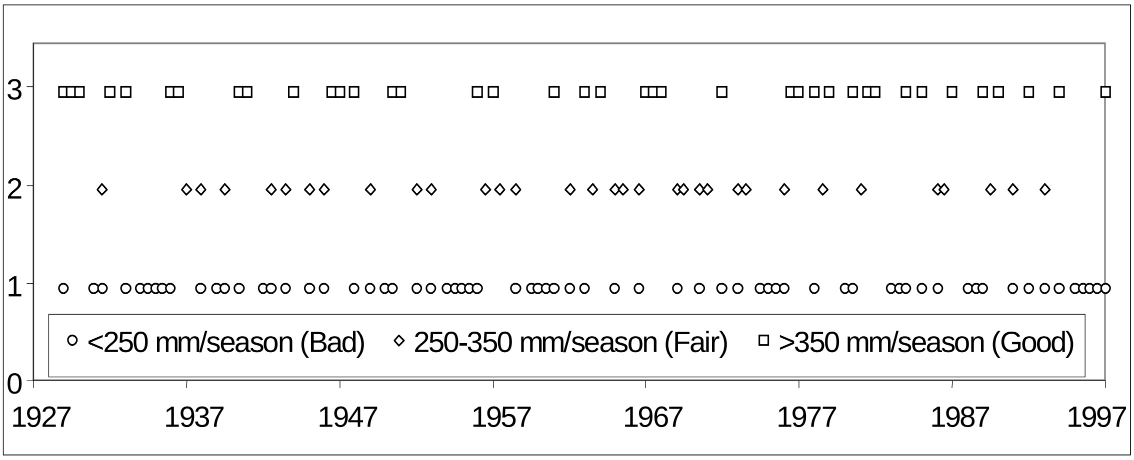
Station	Makindu		Dwa Kibwezi		Kampi Ya Mawe		Mtito Andei	
	Mar-May	Oct-Dec	Mar-May	Oct-Dec	Mar-May	Oct-Dec	Mar-May	Oct-Dec
1931-60			215	295				
1941-70			226	343				
1951-80	200	310	226	354	258	306		
1961-90	212	349	219	395	284	324	237	328
1951-71	212	325	233	354				
1953-71	199	326	228	358	281	340		
1957-71	219	342	250	378	300	317	271	336
1972-90	200	329	200	384	276	306	226	312
1972-97	186	336	189	376	257	274	215	319
Range	186-219	310-349	189-250	295-395	257-300	274-324	215-271	312-336

Figure 3: Seasonal rainfall variability at Dwa, Kibwezi (mm)



[2] October-December rainfall at Dwa Kibwezi shows an increase from 295 for the 1931-60 period, to 395 for 1961-90. This increase is partly compensated for by the changes in March-May rainfall.

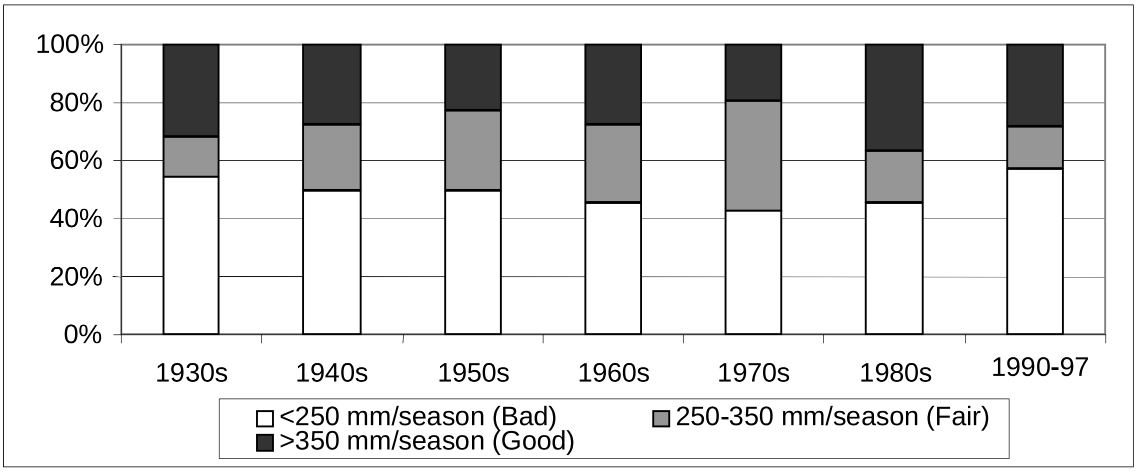
Figure 4: Chronology of bad, fair and good rainfall seasons (Dwa Kibwezi)



Makueni Composite maize requires a seasonal rainfall of at least 250 mm (Mortimore and Wellard, 1991). This was therefore used as a threshold value for defining a bad rainfall season.

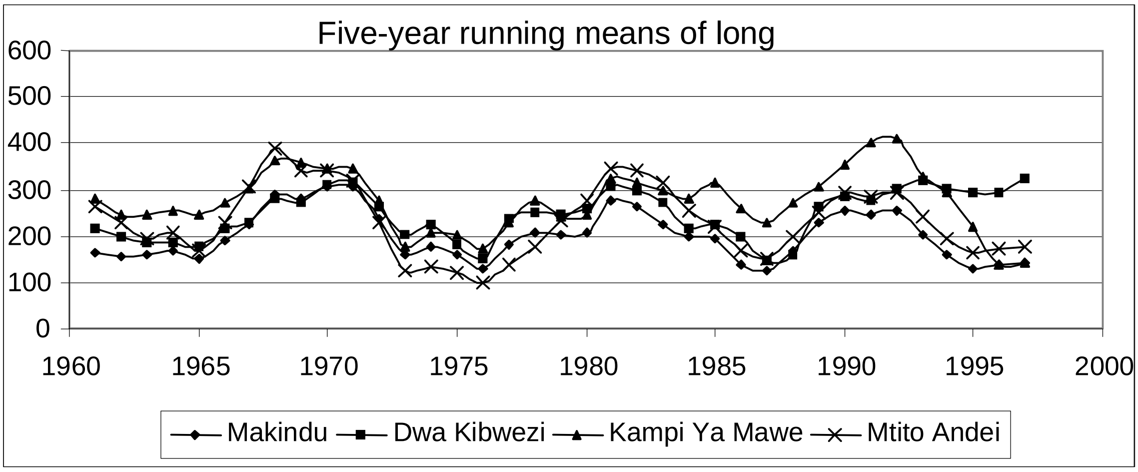
Seasonal rainfall was divided into three classes, namely: (1) bad seasons with rainfall less than 250 mm; (2) fair seasons with a range of 250-350 mm; and (3) good seasons with rainfall greater than 350 mm. Figure 4 presents the chronology of bad, fair and good rainfall seasons. Bad seasons occur characteristically in runs of 2-5 seasons rather than singly. This results in severe food shortages. Analysis of the frequency of bad, fair and good seasons for each decade shows that the 1980s had the highest percentage of good seasons, while the 1990s had the highest percentage of bad seasons (Figure 5). The results are compatible with those of Jaetzold and Schmidt (1982), and Downing *et al.* (1988).

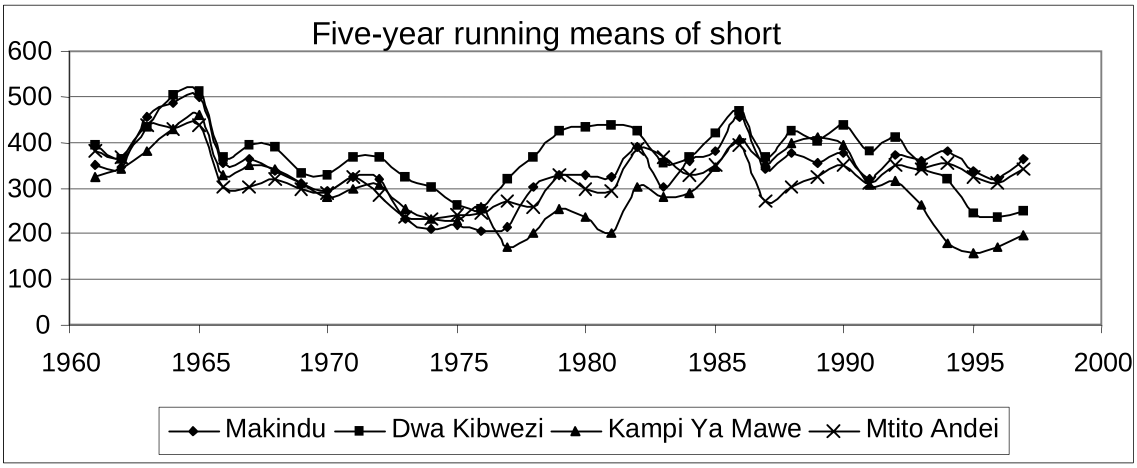
Figure 5: Decadal distribution of bad, fair and good rainfall seasons (Kibwezi)



Seasonal rainfall trends were assessed in terms of 5-year running means (Figure 6). There is evidence of cycles, consistent with findings by Mutiso *et al.* of cycles of 9-11 years in the long rains and of 16-22 years in the short. The variability of the long rains is higher than that of the short rains, particularly in the period 1977-97.

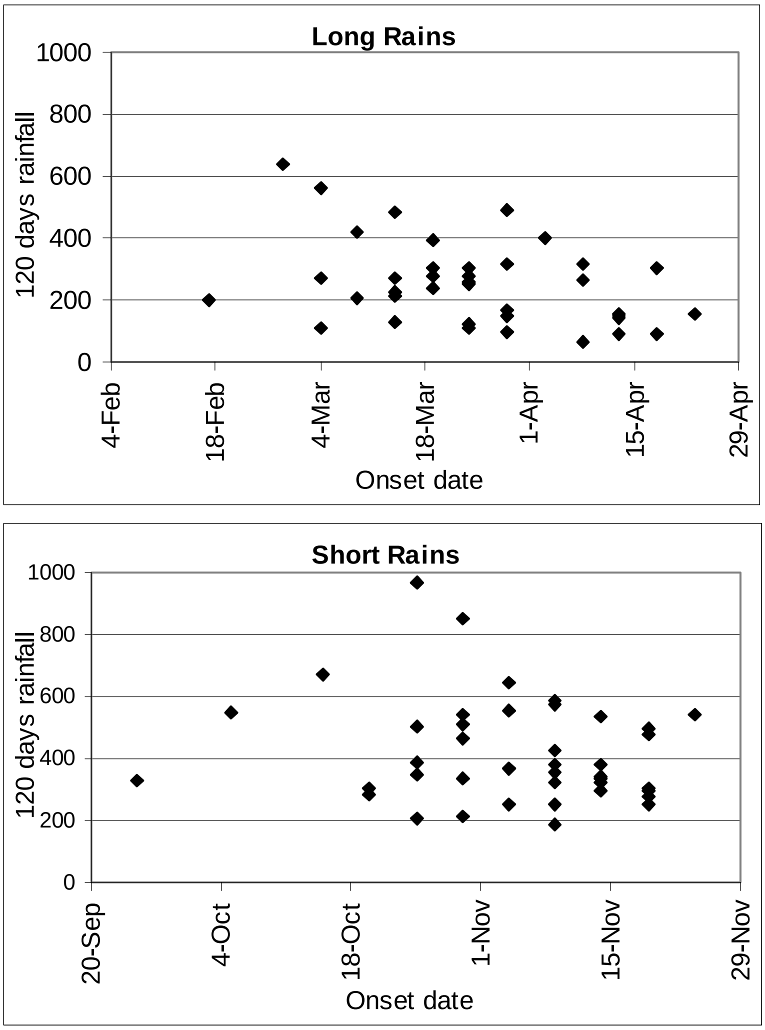
Figure 6: Seasonal rainfall variability (5-year running means: mm)





The data show that seasons with an earlier onset are more likely to have higher rainfall. Onset is defined as the first pentade in each period (15 February-28 May; 15 September-24 November) receiving = > 30mm. Stewart (1991) made a similar observation for Katumani rainfall data. He reported that different seasonal rainfall parameters pose different risks, each calling for a different type of response. He proposed the use of 'response farming', a method of identifying and quantifying probable seasonal rainfall and using this information to guide management responses (plant population and fertiliser input).

Figure 7: Relationship between onset of the rains and rainfall in 120 days following

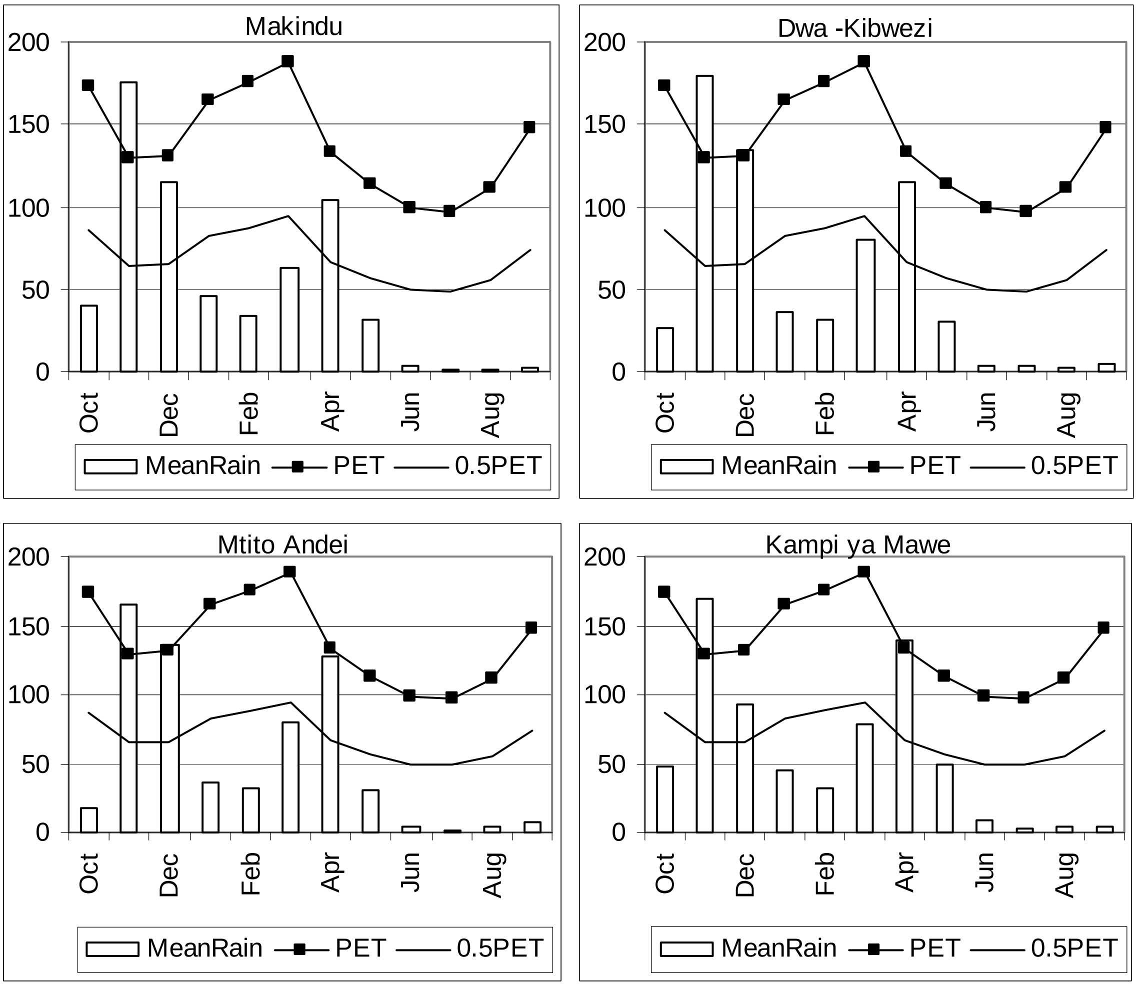


3 WATER DEFICIT OR SURPLUS PERIODS

Seasonal and monthly rainfall and potential evapotranspiration (PET) were used to assess periods of water deficit or surplus. Analysis of rainfall at Kampi Ya Mawe for the period 1980-90 (22 rainfall seasons) shows that only nine seasons received rainfall higher than PET. Six received rainfall less than half of PET (Figure 8).

June, July, August and September are the months with the highest water deficits. During the wet years, PET is exceeded for 3-5 months, with at least one dry month between them. In some years rainfall comes unexpected during June-September, as in Mtito Andei in 1968. During dry years, water deficits occur for at least 10 months, most months receiving less than 50 mm.

Figure 8: Monthly Rainfall and PET



4 DROUGHT TRENDS

Droughts of different intensities have been reported since 1895 (Mutiso *et al.*, 1991). A full chronology of droughts between 1895 and 1987 is presented in Tiffen *et al.* (1994). Table 6 presents drought years that resulted in food and fodder shortages, livestock deaths, and external or local interventions that had an impact on the inhabitants of semi-arid Makueni District. Drought responses depend on the nature and extent of the drought, and vary from short to long-term coping strategies undertaken by the household, community and/or Government.

Drought indices (DI) for the four stations were computed using the following equation:

$$DI = \frac{P-X}{S}$$

where P = seasonal rainfall, X = the long-term average for the season, and S = the standard deviation of the seasonal rainfall (Downing *et al.*, 1988).

Table 6: Droughts, external and local interventions

Decade	Drought years	External interventions	Akamba response
1920s	1928/29	Appeal for famine relief dismissed by the governor. Incentives for destocking intensified.	Intensified petitioning for Government to expand the Akamba Reserve.
1930s	1933/34 and 1939	Maize and pigeon peas distributed and cattle tax suspended. Maize imported and crop export banned. Compulsory destocking.	Continued demand for expansion of the Akamba reserve.
1940s	1943/44/45/46 and 1949	Maize imports, famine relief, intensified soil conservation. Government promotes resettlement.	Settlement in Makueni.
1950s	1950 and 1954/55	Famine relief, soil conservation, resettlement, dam construction.	Migration and settlement
1960s	1960/61/65/69	£1m spent on food aid in 1960/61 drought. Large food imports.	Cattle movements. Spontaneous resettlement.
1970s	1972/73/74	Food aid, promotion of drought resistant crops, stock improvement programmes.	
1980s	1980/81 and 1983/84	Previous bumper crop exported NGOs food for work programmes. MIDP project assistance.	
1990s	1994-95	Famine relief, food-for-work.	Sold cattle.

Adapted from Tiffen *et al.*, 1994: 40-41.

The drought index was computed for each long and short rainy season (1950-1997) and the drought classified as light, moderate or severe. Seasonal indices for Dwa Kibwezi and Kampi Ya Mawe are presented in Figure 9. A long series of drought results in severe hardships, loss of planting material, loss of animals, and a high dependency on external assistance (famine relief or remittance from relatives). Using a DI of -0.8 as the definition of a severe drought, the graph shows that in the six years 1991-96, Kampi Ya Mawe had six seasonal ‘severe droughts’. However a sharp upward trend was apparent in 1997, as shown in Figure 2, and was continued by high rainfall in 1998 (El niño).

The seasonal drought index probabilities were computed for three classes. Table 7 shows that 43-55 percent of the seasons are classified as having had light droughts or worse, whereas severe droughts occurred in 13-30 percent of seasons.

Figure 9: Drought indices for Dwa Kibwezi (1957) and Kampi Ya Mawe (1953-97)

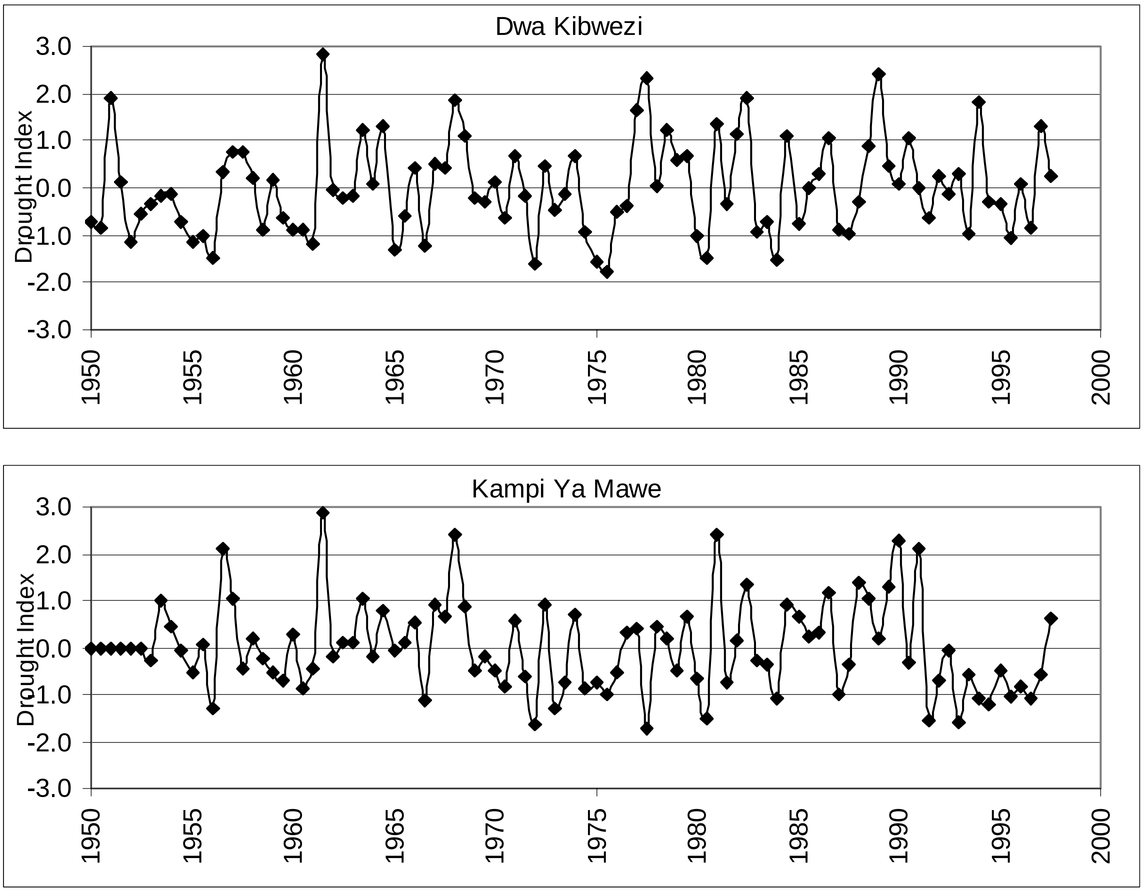


Table 7: Seasonal drought probabilities (percent of years)

Drought	Index range	Makindu	Dwa Kibwezi	Kampi Ya Mawe	Mtito Andei
		Short rains (October-December)			
Light drought or worse	(DI<=-0.2)	55	51	48	53
Moderate drought or worse	(DI<=-0.5)	43	40	36	35
Severe drought	(DI<=-0.8)	30	26	25	20
		Long rains (March-May)			
Light drought or worse	(DI<=-0.2)	47	43	50	50
Moderate drought or worse	(DI<=-0.5)	36	32	36	35
Severe drought	(DI<=-0.8)	13	26	18	23

DI <= -0.2 – light drought; DI <= -0.5 – moderate drought and DI <= -0.8 severe drought (Downing *et al.*, 1988)

5 IMPLICATIONS OF VARIABILITY AND WATER SCARCITY

Rainfall variability has resulted in floods, and hydrological and agricultural droughts and periods of bumper harvests and crop failures, all of which have influenced the land users' perception of the environment and levels of investment undertaken.

5.1 Primary production

Under rainfed farming, rainfall is the only source of water and therefore a crucial resource in the production of crops, grasses and trees. In the study area, rainfall amount, distribution patterns and intensity vary tremendously, creating a risky primary production environment. The inhabitants of these areas have no alternative but to seek strategies to cope with the frequent water scarcity and crop failures.

Short growing seasons

The crop-growing seasons (when rainfall amount exceeds half of potential evapotranspiration) are short and hence the farmers have to grow drought-escaping crops. The fact that some seasons support maize production has encouraged farmers to continue growing the crop, experimenting in breeding drought escaping varieties. Their efforts are supported and complemented by the Kenya Agricultural Research Institute, which has released Makueni composite, a variety well suited to these harsh climatic conditions.

Mortimore and Wellard (1991) reported that the shortness of the growing season and the frequency of drought were the main agro-climatic challenges in crop production. They found that the average length of growing season in AEZ 5&6 was about 50 days, for both long and short rainy seasons. In response to the droughts a crop breeding programme at Katumani Research Station allocated priority to drought-escaping and drought-resistant genotypes. A drought escaping mechanism requires rapid crop development to maturity, whereas a drought resistance mechanism requires some quiescence during dry spells, after which they can resume growth without permanent injury. Maize varieties developed at Katumani were aimed at taking advantage of drought-escaping mechanisms. The success of the maize breeding programme is evidenced by the release of Makueni composite maize for the areas with less than 250 mm of seasonal rainfall. Makueni composite requires 55 days to reach 50 percent silking, compared to the local Machakos white variety that takes between 76 and 79 days, with yield ranges of 2.5 to 3.5 and 1.8 to 4.0 tons/ha respectively. The success of this breeding programme is credited with permitting population growth in AEZ 4 and inducing accelerated migration into AEZ 5 (Lynam, 1978, cited by Mortimore and Wellard, 1991).

Dry seasons

The short and long rainy seasons are separated by a short dry season (January-February), which receives on average of 70 mm of rainfall. The consequence is a longer growing season that can support pigeon peas and other perennial crops, grasses and trees. The deep-rooted characteristic of pigeon pea enables the crop to utilise soil water that is stored below the depth reached by shallow-rooted crops.

Farmers' responses

Farmers adapted the Katumani maize varieties by extensive on-farm selection and crossing, so that they could use seeds from their own harvests and improve yields. Mohammed *et al.* (1985, quoted by Mortimore and Wellard, 1991) noted that this low investment, low risk strategy was suitable for composite varieties such Katumani B because the frequent crop failures would lead to regular fresh seed input. Farmers plant Katumani varieties in some fields and local varieties in others to capitalise on rainfall uncertainty. Mortimore and Wellard (1991) reported that in Ngwata, Katumani composite B was grown along with a local variety (Kinyanyana) and Kitale 512. Katumani varieties give higher yields when rainfall is poor, but local varieties outyield Katumani varieties when seasonal rainfall exceeds 3000 mm (de Wilde *et al.*, 1967, quoted by Mortimore and Wellard, 1991). Another argument advanced for mixed strategies of combining improved local varieties, and using drought-tolerant rather than drought-escaping varieties, is the labour constraint which normally ensures that only a small percentage of the maize crop area can be planted early.

Influence on natural vegetation

Perennial grasses and mature trees can increase water use efficiency by utilising the rainfall outside the cropping season. Tree and perennial grass establishment is, however, constrained by the moisture deficit at the end of the rainy season. Farmers of Athi Kamunyuni reported that the heavy rains experienced in 1997/1998 resulted in bush encroachment, as grasses were smothered by non-palatable forbs.

5.2 Secondary production

The production of cattle, sheep and goats is dependent on the availability of grazing resources, whose dynamics are directly influenced by rainfall regimes. Rainfall data show that in most areas there is a four month dry period (June-September). Availability of grazing resources is further constrained by the natural decomposition of dry vegetation and termite feeding.

Secondary production during the dry season is further constrained by livestock water scarcity. This forces some farmers to trek long distances to fetch water for livestock, or to take the livestock to watering points. A lack of communal grazing land, family or hired labour to herd animals, and the poor quality of pasture constrain livestock production further. During severe drought periods, many livestock die due to inadequate feeding and watering, and livestock diseases (Fall, 2000).

5.3 Links between rainfall and investments in soil and water conservation

Investment in soils and water conservation, like other investments, are proportional to the perceived returns on the investment. High rainfall variability (unreliability) therefore influences investments in soils and water conservation, as noted in the following observations.

1. Benefits of investment are not realised within a reasonably short time period. A cost-benefit analysis showed that it takes 5-6 years to start reaping the benefits of soil conservation under semi-arid condition (Thomas, 1997).

2. The opportunity cost of rural labour is relatively low during the dry season. This is sometimes considered to be the ideal time to invest in soil and water conservation activities. Unfortunately, due to low rainfall, the soil can be too hard and the animals too weak to provide the much needed power. Thus, not much conservation work can be achieved during this time.
3. Investments in soil improvement do not get the priority they deserve, due to the perceived high risk of crop failure, the high cost of fertiliser, and the high labour requirements of low cost soils fertility enhancement practices. Mortimore and Wellard (1991) reported that when rainfall is unreliable, inorganic fertilisers are not only a risky investment, bur may increase water stress in a dry season, thereby damaging rather than assisting the crop.
4. High seepage and evaporation losses from dams, and long dry spells, reduce the effectiveness of dams and their adoption by farmers.

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