Development of Rainfall Curves for Crops Planting Dates: A Case Study of Pangani River Basin in Tanzania

Preksedis Marco NDOMBA[1]

[1] University of Dar es Salaam, Department of Water Resources Engineering, P.O. Box 35131, Dar es Salaam, Tanzania, pmndomba2002@yahoo.co.uk

Abstract
Agriculture is the backbone of Tanzanian economy. The population is sustained by crops, which are largely produced under rain-fed agriculture. The types of crops to be produced are determined by the amount of rainfall received in a given location and time. In recent years farmers in Pangani River Basin (PRB) located in the north eastern part of Tanzania have experienced variable rainfall and significant droughts. Most of the peasants are not getting enough products from their farms because of the rainfall variability, which give rise to the change of planting dates. Therefore there's need to predict the crops planting dates by developing rainfall curves. The probabilistic and statistical indices used in developing curves include probability of occurrence, percentiles, and onset and cessation of rainfall. The data used in this study was daily rainfall amount obtained from Water Resources Engineering Department of the University of Dar es Salaam (UDSM), Ministry of Water and Irrigation, Ministry of Agriculture and Food Security and Tanzania Meteorological Agency (TMA). The probability of occurrence of rainfall for each day in this study was calculated by considering the amount of rainfall which would contribute to additional soil moisture. Traditional planting dates for validation were collected through field visits and interviews. The analysis was conducted for areas around 4 representative rainfall gauging stations in PRB. The study has established the planting dates that will coincide with the onset of rainfall. Comparison between traditional planting dates and observed planting dates showed that farmers delay to plant during long rains by two to three weeks. Consequently, such practice has resulted into reduced rainy days for crops and hence affects the plant growth. The analysis further shows that farmers should plant between 10th and 17th March for area around Moshi Airport rainfall station (09337004), between 14th and 25th March for Kibosho Mission rainfall station (09337005), between 26th February and 3rdMarch for Mweka station (09337098), and between 8th and 15th March for Kilimanjaro International Airport, K.I.A, station (09337115). Also for the case of short rains the farmers seems to plant earlier than the established planting dates. As a result grains wait for a long time before getting the moisture required for them to germinate. The analysis recommends the following crops planting dates for this season: for station 09337004 from 7th – 14th November, for station 09337005 from 21st- 31th October, for station 09337098 from 20th -27th October and for the last station 09337115 from 1st – 8th November. It is recommended for further studies to consider issues such as climate change, effective rainfall and rainy days, and soil types and its properties in order to improve the results.

***Key words*: Cessation, Crops planting dates, Onset, Pangani River Basin, Rainfall curves**

1. INTRODUCTION

Agriculture in Tanzania is dominated by smallholder farmers (peasants) cultivating average farm size of between 0.9 and 3.0 hectors each. About 70 percent of Tanzania's crop area is cultivated by hand hoe, 20 percent by Ox-plough, and 10 percent by tractor. It is a rain fed agriculture. Food crop production dominates the agricultural economy, contributing about 85 percent with 5.1 million hectors cultivated annually. The major constrain facing the agriculture sector is the falling labour and land productivity due to application of poor technology, and dependence on unreliable and irregular weather conditions. Both crops and livestock are adversely affected by periodic droughts. Irrigation holds the key to stabilizing agricultural production in Tanzania to improve food security, increase farmer's productivity and incomes, and also to produce higher valued crops such as vegetables and flowers (FAO, 1998).

Maize and beans are the main staple food in PRB. Grains, especially maize, are also used as cash crops, especially during drought (Amaglo, 1997). Unlike the perennial banana, most cereals are seasonal crops. Only in limited parts of the bimodal northern Tanzania such as PRB short rains support the production of cereal crops (FAO/WFP, 1999). Paddy is mainly cultivated during the long rains. Maize is the only cereal crop grown during the short rains contributing about 70% of the overall cereal harvest. Erratic and significantly delayed short and long rains in the bimodal areas substantially affect the overall country production of cereals (Isinika et al., 2003) resulting into food shortages. This has been observed, for example, in the 1998/99 agricultural year in which erratic and significantly delayed short rains resulted in reduction of the maize planted area by 20% of the average area harvested in the 1992/93-1997/98 period, loss of seeds and necessitated replanting (FAO/WFP, 1999). Considering that maize crop is widely grown in the PRB and cultivated under rain fed condition, hence this crop was used for analysis in this study.

Perfect timing of planting dates is one of the key factors that strongly affect crop production in rainfed agriculture (Ati et al., 2002; Odekunle et al. 2005; Walter 1967; Laux, 2009). This is especially true when, as in many parts of sub-humid and semi-arid Africa, the rainy season starts with some light showers followed by dry spells, which can cause poor crop emergence or desiccate a young crop (Makarau, 1995; Laux, 2009). In the past, several theoretical methods based on the amount of infiltrated rain were developed to estimate the expected dates of planting rains and the length of the season in the region (Lineham, 1960; Donovan, 1967). With the help of a monthly (Hussein, 1987) and later, a 10-day (AGRITEX, 1989) soil water balance method, an agro-climatologically analysis of the growing season for some parts of sub-Saharan African region was performed by considering the total rainfall and crop evapotranspiration during that period. Also for other regions, several studies are available that analyze the onset, cessation, and length of the growing season (Ati et al., 2002).

The onset criteria used in the previous studies in the region are based on a specific amount of rain that needs to be observed over an arbitrary period of several days. To avoid the occurrence of false starts, an extra qualifying criterion is generally added stating that a dry spell of so many days in a certain period, following the potential start, must not occur. Such criteria are useful for retrospective analysis but not for guiding farmers in a particular year (Ati et al., 2002). Another method employed in the tropics is that proposed by Ilesanmi (1972a,b), i.e. the cumulative percentage mean rainfall. The method of percentage cumulative mean rainfall values is used in determining the rainfall onset and cessation (retreat) dates. The method is one of the most commonly used because it is mathematically elegant, efficient, and is free of assumptions of rainfall threshold values (Olaniran, 1983; Odekunle et al. 2005; Odekunle, 2006). This method has also been argued by some researchers in favour by pointing out that it is a more rather direct approach relying on rainfall data alone rather than the mere inferential methods based on some rainfall related factors (Odekunle, 2004; Odekunle et al. 2005).

The basic procedures of the method are outlined as follows: 1) Derivation of the percentage of mean annual rainfall that occurs at each 5-day interval; 2) accumulation of the computed percentage at 5-day interval; 3) Plotting the cumulative percentage at 5-day intervals through the year; and 4) identification of the time of rainfall onset and retreat. The point of first maximum positive curvature and last maximum negative curvature on the graph of the cumulative percentage are respectively, the mean periods of rainfall onset and retreat. Alternatively, onset of the rains would be the timing of an accumulated 7 to 8 percentage of the annual rainfall, and the retreat commences after the accumulation of 90 percent of other annual rainfall (Ilesanmi, 1972a).

One of the problems with most of the approaches discussed above is that one or two large isolated showers at the beginning or end of the year may meet the specified rainfall onset/retreat criteria, thus producing unrealistic rainfall onset and retreat dates (Odekunle, 2006). The foregoing discussions suggest that there are a lot of uncertainty in predicting the onset and cessation (retreat dates of rainfall) especially for the purpose of determining crops planting dates. As a follow up to this, a number of new approaches are being proposed. One way of achieving this is through adapting some of the existing methods and complementing with new ones. Development of rainfall curves is one of the complimentary approaches suggested in this paper. These are plots of probabilistic and statistical indices of rainfall derived from a long term historical data.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

Pangani River Basin (PRB) is one of the nine basins in Tanzania. It extends from northern highlands to the north-eastern cost of the country, and lies between latitude 03° 05'00"and 06° 05' 00" South; and longitude 36° 45' 00" and 39° 36' 00" East. The PRB covers an area of 43,650 km2, out of which 3,914 km2 lies in Kenya (Figure 1). In Tanzania, the Basin is distributed amongst the Kilimanjaro, Manyara, Arusha, and Tanga administrative regions. The Kenyan portion of the basin falls almost entirely within the district of Taita-Taveta in the Coast Province. The highest rainfall, 1000-2000 mm/year occurs in the southeastern slopes of Kilimanjaro and Meru Mountains.

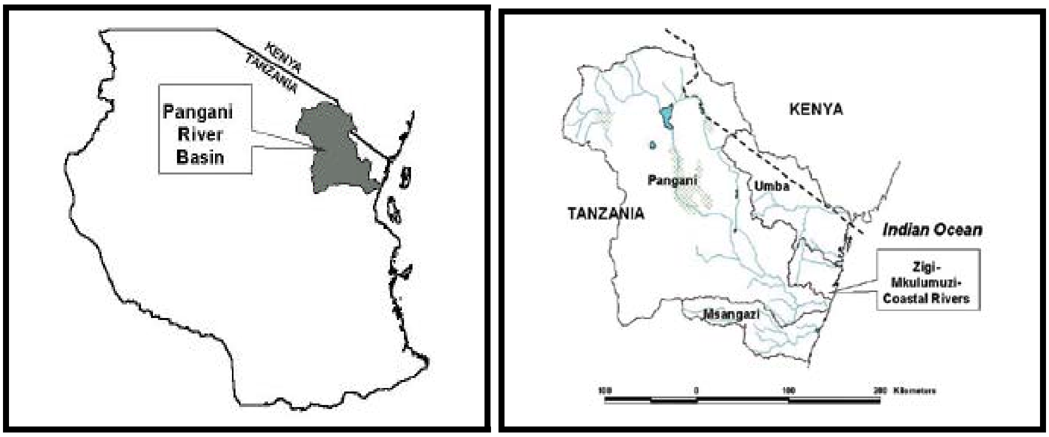

Figure 1: The Pangani River Basin spanning in Tanzania and Kenya

The mountain slopes receive average annual precipitation of more than 1000 mm. The rainfall pattern is bimodal with two distinct rainy seasons; long rains from March to June and short rains from November to December. Recent findings by RØhr and Killingtveit (2003) indicate that the maximum precipitation on the southern hillside of Mount Kilimanjaro takes place at about 2,200 m.a.s.l., which is 400-500m higher than the elevation reported in previous studies (URT, 1977). More than 50% of the basin, mainly the lowland plains are arid or semi-arid with an annual precipitation of 500-600 mm/year (URT, 1977). The seasonal variation of average temperature in the basin is minimal. It ranges from 14°C to 25°C in Kilimanjaro region, and from 17°C to 29°C in the southern of the basin. The maximum and minimum air temperatures occur in March and July, respectively. Total yield of a few large springs in the study area is estimated to be about between 15 and 20 m3/s, and these form a major part of the inflow to the NYM reservoir downstream (RØhr, 2003). For instance, Chemka springs with an almost constant flow of nearly 10 m3/s (RØhr, 2003). The upper part of PRB is characterised by relatively high potential evaporation varying from 700 mm/yr at high elevations to about 1500 mm/yr in low-lying areas. It means that for lower areas, the annual potential evaporation is higher than the annual rainfall.

The catchment comprises of complex geological formations such as North Pare Mountains, Mount Kilimanjaro, and Mount Meru. The geology of the region mainly consisted of Neogene Volcanic and pre-Cambrian metamorphic rocks, which are extensively covered by superficial Neogene deposits including calcareous tuffaceosus materials, derived from the Kilimanjaro volcanic actions (Geological Survey, 1960). The altitude in the study area ranges between 700 and 5825 m.a.s.l. The ice cap at the peak of Mount Kilimanjaro forms the highest ground in the catchment. Most of the PRB comprises of crystalline and limestone geological series, along with patches of lacustrine deposits. Areas close to Mt. Meru and Mt. Kilimanjaro are typically highly fertile alkaline volcanics (Geological Survey, 1960). The combination of soils of lacustrine and volcanic origin, as well as areas of high average annual rainfall indicate that parts of the PRB have been seen as the 'breadbasket' of Tanzania. Based on the Soil Atlas of Tanzania (Hathout, 1983), the main soil type in the upper Pangani is clay with good drainage. Actively induced vegetation, forest, bushland and thickets with some alpine desert chiefly characterize the land cover of the catchment.

Northern Tanzania is an important maize growing area that accounts for 10% of the total national production of the cereal (Nkonya et al. 1998) and it is one of the nation's maize surplus areas. The total area under maize production in the zone is about 160,700 ha, of which 70% is in the Arusha region. The major maize producing districts are Mbulu, Babati, Hanang, and Arumeru. Other maize producing districts of less importance are Moshi, and Rombo. The remaining districts (Mwanga, Same, Kiteto, Monduli, Ngorongoro, and Simanjiro) are maize deficit areas because of their unreliable rainfall. The Northern Zone has three major agro ecological zones:

(i) High Rainfall Zone: This zone receives about 1,200 - 1,500 mm of rainfall per year. Rainfall distribution is good and reliable. The zone is located on the slopes of Mt. Kilimanjaro, Meru, Hanang, Monduli, Pare, and Ngorongoro mountain ranges. It also includes Oldeani and Loolmalasinareas. Some areas located in the high plateaus fall into the high rainfall zone including Bashnet in Babati and Mama Isara area in Mbulu. Most areas in the high rainfall zone rise to an altitude of 1,500 meters above sea level (masl). Other areas are above 1,500 masl, but their rainfall is less than 1200 mm per annum .These areas are always on the leeward side of mountains, e.g. Olkokola in Arumeru. Major crops grown in this high rainfall zone are coffee in association with banana. Because these areas are densely populated, with the attendant problem of land shortage, farmers grow their maize in the drier lowland areas. The rolling topography of the zone prohibits mechanization in many areas; hence farmers prepare their fields using hand-hoes only. Livestock in the zone are either exotic or cross breeds of exotic and local dairy cows. Stall feeding is the most common feeding system in the zone (Nkonya et al.1998).

(ii) Moderate Rainfall Zone: Rainfall in this zone ranges from 800 to 1,200 mm per annum, with moderately reliable distribution and amount. Moderate rainfall areas are located between 900 and 1,500 masl. The major crops grown in this zone are banana in association with coffee and maize intercropped with beans or peas. Farmers in this zone also grow monocropped maize in the lowland plains. The livestock-keeping system in the zone is semi intensive. Land is prepared mainly with ox-ploughs and tractors. Hand-hoes are used for land preparation in areas where the terrain is steep (Nkonya et al. 1998). The mountain slopes and high plateau of Hanang, Mbulu, Babati, and some parts of Monduli fall in this zone, which is the most important area for the production of maize, beans, pigeon peas, and wheat.

(iii) Low Rainfall Zone: This zone receives rainfall ranging from 500 to 800 mm per year with very erratic distribution. Low rainfall areas are always in the lowland plains below 900 masl. Studies show that drought occurs in one out of every four years. Because there is no land pressure in this zone, farmers in the high and moderate rainfall zones grow their maize and other annual crops in this area, the second most important area for maize production in northern Tanzania. The major cropping systems in the zone are monocropped maize, monocropped beans, and maize intercropped with beans. Extensive livestock-keeping prevails in the zone, making it the most important area for livestock production in northern Tanzania. Land preparation is predominantly accomplished using ox-plough and tractor (Nkonya et al. 1998). The basin is also important for hydropower generation (Figure 1). Hydropower plants operational in the basin and connected to the national grid include Nyumba Ya Mungu, NYM (8 MW), Hale (21MW), and New Pangani falls (66 MW).

2.2. Data

The data used in this study include rainfall, climatic and crop data (Tables 1 & 2). The analysis used daily rainfall amount data for the 4 selected rain gauges and representative crop (i.e. maize). The details of the rainfall stations including record length of the data are presented in Table 1.

Table 1: Details of rainfall data from representative rainfall stations.

Station Code	Name	South (deg)	East (deg)	Altitude (masl)	Start year (YYYY)	End year (YYYY)	Record Length (years)	Missing data (%)	Climatic condition
9337004	Moshi Airport	-3.35	37.33	813	1968	2005	38	1	Semi humid
9337115	K.I.A	-3.32	37.07	891	1968	2005	38	9.4	Semi-arid
9337005	Kibosho Mission	-3.25	37.32	1478	1968	2005	38	5.5	Humid
9337098	Mweka	-3.23	37.32	1463	1968	2005	38	2	Humid

The rainfall data were collected from department of Water Resources Engineering University of Dar es Salaam (UDSM), Ministry of Water and Irrigation, Ministry of Agriculture and Food Security, and Tanzania Meteorological Agency (TMA). As one may learn from the Table 1 that rainfall stations with adequate data (missing data percent less than 10%) were selected. Adequate data of rainfall is a necessity for any realistic analysis and to minimize the uncertainty in the output. Besides, reliable representative rainfall stations in the study area were selected based on the geographical proximity and climatic conditions representation. Field visit was also conducted to the study area in order to collect crops data, traditional planting dates, through interviewing the villagers or people familiar with the area (i.e. agricultural extension officers). Table 2 shows the traditional planting dates of maize crop.

Table 2: Traditional planting dates of maize crop for both long and short rains

No	Code	Name	Long rains (planting dates)	Short rains (planting dates)
1	09337004	Moshi Airport	21st March – 29th March	1st October – 7th October
2	09337005	Kibosho Miss.	25th March – 2nd April	20th Sept – 7th October
3	09337098	Mweka	25th March – 2nd April	20th Sept – 7th October
4	09337115	KIA	21st March – 29th March	1st October – 7th October

2.3. Selecting a Representative Crop

Maize is the major crop grown in Pangani River Basin and was selected for this study. Maize is grown as food crop by most farmers in the PRB. It is also a major cash crop. The crop is mostly grown in large part of the area of Babati district in Manyara region, and most parts of Arusha and Kilimanjaro regions along the slopes of Usambara Mountain ranges. Maize also grows in some of the districts of Tanga region such as Lushoto, Korogwe, and part of Handeni, Pangani, and Kilindi. Sowing maize a field is simple. The sowing depth is less critical because the seed is large compared to other cereals. The seed is therefore broadcasted and ploughed into the soil. This practice insures that the first rains are used to the best advantage. Some farmers prefer to sow in rows by dibbling the seed into the furrow behind the plough. This however facilitates weeding. If necessary, seed is planted in holes in the cultivated soil. The field is then further prepared during the first weeding. Normally maize is planted twice since the area receives bimodal rainfall. The first planting is normally done during short rains “vuli” that normally begin towards the end of September. The second planting take place during the “Masika” rains, which normally starts at the beginning of March. Northern Tanzania is an important maize growing area. It accounts for about 10% of the total national production of the cereal (Nkonya et al. 1991) and is one of the nation’s maize surplus areas. Total area under maize production in the zone is 160,700 ha, of which 70% is in the Arusha region.

2.4. Determination of Onset, Cessation and Duration of the Rainfall

The analysis of onset, cessation, and duration of rainfall involved computation of seasonal decadal rainfall values from the entire record, expressing it as a percentage of the total mean annual rainfall, and plotting the percentage cumulated seasonal decadal rainfall values against the decade numbers. The onset of the rainfall is then defined as the point of maximum positive curvature of the graph of cumulative seasonal decadal rainfall. The cessation of the rainfall is defined as the maximum negative curvature of a decadal number against percent cumulated decadal values graph for a selected rainfall station. The duration of the rainfall is determined as the period from the onset of the rainfall to the cessation of the rainfall. It is often difficult to decide on a criterion for establishing the date for the onset of the rains. This study has adapted an approach proposed by Oshodi (1971) and Ilesanmi (1972a). They empirically formulated the onset, advance, and accumulated percentage determined to establish the change points. The method involves the following key steps: i) Group 10-day rainfall values and compute the mean value for each group to obtain decadal rainfall values for each year of the record; ii) Compute seasonal decadal rainfall values; iii) Cumulate the seasonal decadal rainfall values and express as percentage of the total mean annual rainfall; and iv) Plot the percentage cumulated seasonal decadal rainfall values against the decade numbers. Besides, the result is complemented with other rainfall indices such as probability of occurrence and cumulative percentiles, known as rainfall curves in this study.

2.5. Development of Rainfall Curves

The rainfall curves were developed for different seasons of rainfall i.e. long rains and short rains in all selected rain gauge stations. In this analysis the distribution of amount of rainfall was developed by using statistical and probabilistic parameters: percentiles of 25, 50 and 75 and probability of occurrence of rainfall of each day in each month of both seasons of growing. The percentiles were calculated from daily rainfall amount data as arranged in Table 3. In general, a percentile greater than 75 is considered above normal a percentile between 25 and 75 is considered normal, and a percentile less than 25 is considered below normal.

Table 3: Arrangement of amount of rainfall on each day in mm unit for the month of November for the period 1968- 2005 for Moshi airport station (09337004)

	Days in the Month of November																													
Year	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***	***16***	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***	***28***	***29***	***30***
1968								5	2			5			1				3	16	22	6	19	1		4	14	5		
1969													21		30		1		5			4		3				1		5
1970				2																		4								
1971																				11								1	1	2
1972			3		6	36		3	3			20	5	2	12		2	43	6			3							1	
1973														23						1	14	1				4			1	
1974			1	6		1	25				5	3																		
1975																	5												1	
1976						3																3	10							
1977						7		34								2				1					6				1	
1978							38							3	1			1	9	6			22	10		20	29		1	6
1979								2																						40
1980					2		3	3	4	1					32		23	1				1	2	1		9				
1981								2			3						6							5	1				16	
1982										1	14		2	13	5	30							34		9	18	43	2	10	84
1983																				4					31	1				
1984	4	2	9	2			1				13	31	13				2				1		3	4	6		4			
1985						2	18				62	2						1								5	26	1		

Year	***Days in the Month of November***																													
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***	***16***	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***	***28***	***29***	***30***
1986																				4	6	4	19	10		10			3	1
1987							1											13												
1988			3		2	9	4	7				1									2									
1989								1						1		2												2		
1990							10	8				7	19	17					53	52	9									
1991								1		14									1				7	15		1				
1992			1	2						2		3						73									11			
1993						1		1															9		30	5				
1994	1	13											4	3			6											2		
1995																										1	8		1	
1996																			1	1		1						6	2	
1997	3		10	12	6										2	7		2	1		34		3	24						2
1998							2										2	5							8	2	1			
1999										1	14			2	12		1			2		2	5		11	5				14
2000														2			2				2	1	5			4		1		1
2001		4	48	2										2	2										3					
2002						1								2					1								1	22		
2003																								1				5		
2004					16	6	3																		3					
2005				1		2				2											2	5	12	1						

Note 1: Numbers in *italic* are days in the month of November.

2: Blank entries are for zero rainfall values (i.e. No rain days)

The statistical parameters, i.e. percentiles as well as the probability of occurrence of rainfall were computed for each column of Table 3. The percentile rank was calculated using Equation 1.

$$R = \frac{P}{100} x(N+1) \qquad [1]$$

where R is the percentile rank, P is the desired percentile, and N is the size of the record. The probability of occurrence of rainfall was calculated by using Equation 2

$$P(E) = \frac{n(E)}{n(S)} \qquad [2]$$

where P(E) is the probability of occurrence of an event; n(E) is the number events; and n(S) is the size of sample space.

In this analysis the probability of occurrences of a rainfall of each date was obtained by counting the number of days with recorded rainfall amount greater or equal to 5 mm (i.e. rainfall event). Then it was divided by the size of the sample space which is the total number of years from 1968 to 2005. After obtaining all the parameters required i.e., the probability of occurrence of rainfall and percentiles, cumulative percentiles and probability of occurrence against time (dates), curves were plotted in one graph; two sets each for long and short rains and for all stations.

2.6. Determination of Crop Water Requirement

The probability of occurrence of rainfall and percentile are not the only criteria for establishment of planting dates. The amount of water required for a particular crop should also be considered. The crop water requirement for the maize was determined so as to understand whether there was a shortage of water or not for the growth of selected crop at a particular established planting date.

The calculation procedures for crop water requirement and crop evapotranspiration, ETc, consists of: i) Identifying the crop growth stages, determining their lengths, and selecting the corresponding Kc coefficients; ii) Adjusting the selected Kc coefficients for frequency of wetting or climatic conditions during the stage; and iii) Calculating ETc as the product of ETo and Kc. The basic formula used to calculate maize crop water requirement is as in Equation 3 below.

ETc = Kc.ETo [3]

where ETc is water requirement of maize (in mm/day); Kc is the crop factor (or coefficient), and ETo is reference crop evapotranspiration (in mm/season) (Allen et al., 1998).

The ETo was estimated from pan evaporation data. Four growth stages with different crop coefficient, Kc, and different lengths of time period, are as given by Allen et al. (1998) and were adopted (Table 4)

Table 4: Crop factors and period for maize crop growth stages.

	Initial stage	Crop development stage	Mid-season stage	Late season stage
Crop factor, Kc	0.40	0.80	1.15	0.70
Period(days)	20	35	40	30

After getting the value of Kc, crop evapotransipiration ETc was obtained by using crop coefficient approach. The crop evapotranspiration, ETc, is calculated by multiplying the reference crop evapotranspiration(ETo), by a crop coefficient(Kc), ETC = KC ETO as in equation 3. The value of crop water requirement ETc guided the analysis of predicting the planting dates.

2.7. Determination of Planting Dates

The planting dates for crop especially maize in the four selected stations in the basin were obtained by using the onset of the rain dates, rainfall curves and information on crop water requirements. Onset which corresponds to the planting dates could be located depending on the length of growing period as follows:

For the long rains which are normally 4 months growing, the planting date is located where 12 days after planting the accumulated water in the soil should be 15 mm and for the short rains which are normally 3 months, growing the planting dates is located where 9 days since planting the accumulated water use should be 10 mm. The planting dates were established for both seasons i.e. long and short season.

3. RESULTS AND DISCUSSIONS

3.1. Predicted Onset, Cessation and Duration of the Rainfalls

The work was undertaken in order to provide an essential guide to the farming community as when, on the average, the rains are likely to starts and end in their respective areas. A representative Onset and cessation result for Mweka gauging station is presented in Figure 2. The results of onset, cessation, and duration of rainfall and mean annual rainfall for each selected station are presented in the Table. For the long rains season, the minimum rainfall duration observed is 7 decades which is 70 days for all the stations considered, this occurs in station 0933115 as shown in Table 5. The maximum rainfall duration noted is 11 decades (110 days). On average the onset of the rainfall for all the selected station is between March 11-March 20 and the cessation is between May and July.

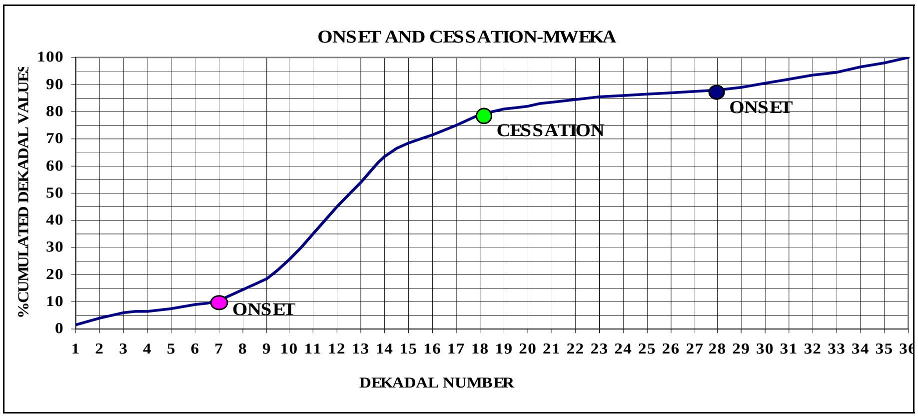

Figure 2: Plot of the cumulated seasonal Rainfall for Mweka station 09337098.

The variation of the onset, cessation and duration of rainfall within the basin is logical because the stations used were selected to represent various climatic conditions of the basin.

For the short rains season, onset is in 28th decade, i.e. between 27th September – 6th October, and retreat (cessation) of the rainfall occurs in 36th decadal, i.e. from 21st December to 31st December. Here the duration of rainfall is 80 days (Figure 2).

Table 5: Summary of onset, cessation and duration in decades (10days) for both seasons

10DAY STRUCTURE DURATION IN DECADES (10DAYS) LONG RAINS				
No.	Station	Onset	Cessation	Duration
1A	09337004	March 11 – 20	May 30 – June 1	8
2A	09337005	March 21 – 30	June 19 - June 28	9
3A	09337098	March 1 – 10	June 29 – July 8	11
4A	09337115	March 11 – 20	May 20 - May 29	7

10DAY STRUCTURE DURATION IN DECADES (10DAYS) SHORT RAINS				
1B	09337004	October 7 – 16	December 21 – 31	7
2B	09337005	Sept 27 – October 6	December 21 – 31	8
3B	09337098	Sept 27 – October 6	December 21 – 31	8
4B	09337115	October 7 – 16	December 21 – 31	7

3.2. Developed Rainfall Curves

Results obtained from curves for representative stations, i.e. Mweka (09337098), and Kibosho Mission (09337005) for long rains seasons are presented in Figure 3 and Table 6. In March the probability of occurrence of rainfall for most of the days was less than 0.6; the highest probability of occurrence for this month is 0.53 which appears in 25th March. The values of 25th percentile for this month are poor because all the dates show that the percent of the rainfall distribution which is 25% or below is zero. For the 50th percentile the highest value is 1mm which appears in 25th day, for the other remaining days the distribution of the rainfall is zero and for the 75th percentile the highest value is 6.5 mm which appears in different dates within March.

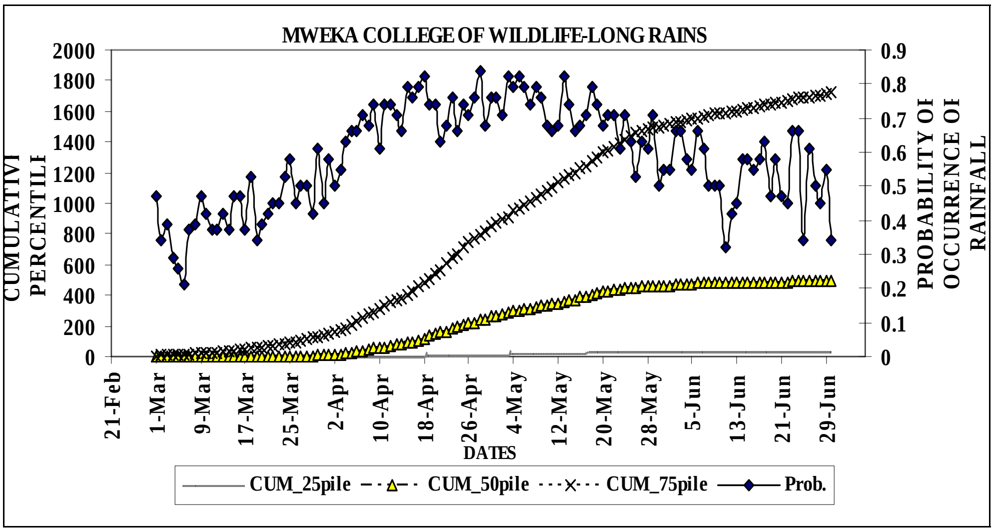

Figure 3: Probability of occurrence of rainfall and cumulative percentiles against time (dates) for long rains for Mweka station (09337098)

In April the probability of occurrence of rainfall starts to increase and becomes very high for some of the days in April. For instance 20th day of April the probability of occurrence was 0.89 and the other remaining days the probability of occurrence was about 0.42. For the case of percentile (distribution of rainfall) the values start to increase slightly compare to March. In April the largest value of 25th percentile was 7 mm which appear on 20th of April and for 50th percentile the largest value was 14.5 mm which appears on 20th of April and for 75th percentile the values increases rapidly and show that the distribution of rainfall which is equal or below the 75 percent is very high in April compared to March, the highest value was about 40.0 mm and the minimum value was 5.5 mm. For the 25percentile the value does not increase for the first fifteen days of April, the values were zero for those days, but later on the value starts to increase slowly for some days.

For the month of May the probability of occurrence of rainfall becomes high throughout the month with lowest and highest values, 0.5 and 0.87, respectively. So this month has higher probability of getting rainfall for almost all days. Incase of distribution of rainfall which was calculated in terms of percentiles, the 25th percentile values for this month were not so good because most of the values were zero's and the highest value was 1.25 mm which is very small values compare to the amount of the rainfall required by maize. For 50th percentile which is the same as median, the values are still fairly low with highest value of 13.5 mm. For 75th percentile which is the same as the third quartile, the values increase steadily and become so large compared to the other previous percentiles, the lowest value in this case is 5 mm and the highest value is 37 mm.

In June the probability of occurrence of rainfall starts to decrease although in some days does not change. Most of the values in this month range from 0.34-0.63 but most of the values concentrate in 0.50. For 25th percentile the result looks similar to the one in March where there's no any distribution of rainfall, all the values were zero while when the percentile was 50 the values does not change significantly but they increase slightly from zero to highest value of 3.0 mm. For 75th percentile the values in this case is higher compared to the previous percentiles 25 and 50. It demonstrates that the distribution of rainfall is at least greater than that of 25 and 50 percentiles. Although the values have increased a bit, it still indicates that the long rains end in June. The probability of occurrence of rainfall falls sharply in this month.

Table 6: Summary of the rainfall distribution for long rains in station (09337005)

Month	Maximum values observed from different percentile			Range of Probability of occurrence
	25	50	75	
March	0	1	7	0.11 – 0.53
April	7	15	40	0.42 – 0.89
May	2	14	37	0.50 – 0.87
June	0	3	10	0.34 – 0.63

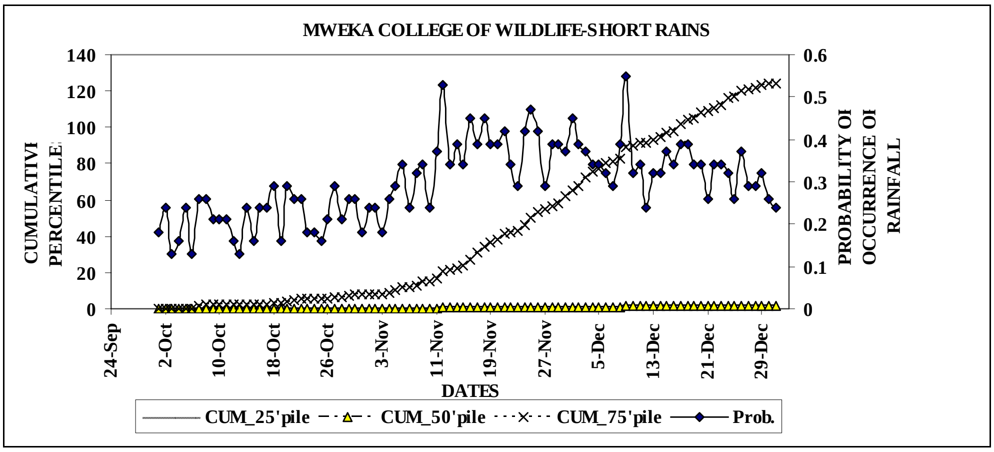

Figure 4: Probability of occurrence of rainfall and cumulative percentiles against time (dates) for short rains of station (09337098)

For the short rains the amount of rainfall is very small compared to that of long rains as it has been shown in Figure 4 above .The 25th percentile values are all nearly zeros indicating that the amount of rainfall at this percentile is below normal. Also the 50th percentile plot depicts the same pattern. For 75th percentile the values are a bit higher compared to the latter percentiles. The highest value from this percentile is 8.75 mm. This is a very low distribution of rainfall compared to that of long rains. The highest probability of occurrence of rainfall in this season is 0.47 which appears at 45 and 63 days of a season. The 75th percentile cumulative value is 119.5mm for the all days of the season. This is estimated as about 8.32% of that of long rains. Also Figure 4 shows that the onset of the rain for the short rains season starts at 34thday of the season which is at the beginning of November. This delay is likely to shorten the length of the growing season, which in turn will cause a drop in the total production from the short rains season "vuli" harvest, which contributes 15 percent of the total national crop harvest.

3.3. Estimated Crops Planting Dates

Although in this study the percentiles computed were 25 percentile, 50 percentile and 75 percentile, the percentile used for establishment of crops planting dates was 75 percentile, which is the third quartile. This is because the distribution of the rainfall represents above normal condition. Planting dates for the all selected stations are shown in the Tables 7 & 8.

Table 7: Estimated planting dates for the long rains season.

No.	Station name and code	Planting dates
1	Moshi Airport (09337004)	10th March - 17th March
2	Kibosho Mission(09337005)	14th March - 25th March
3	Mweka Col. of Wildlife (09337098)	26th February - 3rd March
4	Kilimanjaro International Airport(09337115)	8th March - 15th March

Table 8: Estimated planting dates for the short rains season.

No.	**Station name and code**	**Planting dates**
1	Moshi Airport (09337004)	7th November - 14th November
2	Kibosho Mission(09337005)	24th October - 31st October
3	Mweka Col. of Wildlife (09337098)	20th October – 27th October
4	Kilimanjaro International Airport(09337115)	1st November – 8th November

The established planting dates as shown in the Tables 7 & 8 were associated with their probability of occurrence of rainfall. Also in this study traditional planting dates were used in validation purpose of the method.

3.4. Comparison Between Estimated and Traditional Planting Dates

Reference is made to Tables 2, 7& 8, the planting dates established from this analysis and those which were obtained from the field are different. For the long rains for all stations the analysis shows that the farmers delay to plant their crops by almost two to three weeks. The delay results into farmers failing to coincide the planting dates with the onset of rainfall. Besides, the number of days for the crop growth gets reduced. For the case of short rains the farmers do planting earlier than estimated planting dates by again two to three weeks. This may result into the distortion of grain which was already in the soil for long time before attaining the required soil moisture. Field observation indicates that most of the people around Kibosho Mission (09337005) and Mweka (09337098) do not sow their seeds during the long rains season. They always depend on the short rains because their areas are characterized by hills and their farms are located on the water clogging areas. So if this happens they would automatically loss their crops.

4. CONCLUSIONS AND RECOMMENDATIONS

A study was performed to establish planting dates that coincides with the onset of rainfall. It is found that the decrease in crop production has been contributed by farmers not observing the appropriate planting dates as determined by this study. Comparison between traditional planting dates and the observed planting dates shows that farmers delay to plant during the long rains by two to three weeks. Consequently, such practice has resulted into reduced rainy days for crops and hence affecting plant growths. The analysis further recommends that during the "masika" season farmers should plant crops between 10th and 17th March for area around rainfall station 09337004, between 14th and 25th March for station 09337005, between 26th February and 3rd March for station 09337098, and between 8th and 15th March for station 09337115. Also for the case of short rains farmers seems to plant earlier than the established planting dates. As a result grains wait for a long time before getting the moisture required for them to germinate. The analysis recommends the following crops planting dates for this season: for station 09337004 from 7th – 14th November, for station 09337005 from 21st - 31th October, for station 09337098 from 20th -27th October, and for the last station 09337115 from 1st – 8th November. It is recommended for further studies to consider issues such as climate change, effective rainfall, soil types and its properties in order to improve the results.

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