

Integrating Indigenous and Scientific Knowledge Systems on Seasonal Rainfall Characteristics Prediction and Utilization

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Abstract

Kenya relies mainly on rain-fed agriculture for crop production, which has major limitations arising from seasonal variability of rainfall, onset, cessation and growing length. In this study, the growing season characteristics for Lake Victoria basin were studied with the aim of providing information for rain-fed agriculture planning. The study evaluated various criteria for determining growing season onset and cessation dates using soil water balance simulation techniques in addition to indigenous knowledge. Results indicate that frequently used traditional indicators in the region as modes of rainfall forecasting include: trees, migratory birds, winds, clouds and lightning among others. Initial evaluation of some key indicators around Eldoret area, through monitoring before onset of long rains suggest good agreement between indigenous and scientific climate knowledge and forecasting systems. Onset simulation results reveal that accumulated rainfall depth criterion of 40 mm in 4 days can be used as an operational criterion for wet sowing method. Integrating indigenous and scientific climate knowledge together with forecasting systems provides a means of aiding farmers in their decision making on when to dry sow within the established onset window. For each station in the basin probability of exceedance levels for: onset date, cessation date and growing season length were calculated. Individual station values for the entire study area were converted into surface maps using interpolation techniques to capture spatial variations for agricultural planning. Results indicate that there exists organized progression of rainfall onset within the study area with the long rains showing a southerly progression.

Key words: onset, length, season, traditional, scientific, weather forecast, Lake Victoria Basin

1. INTRODUCTION

Lake Victoria basin in western Kenya relies on rain-fed agriculture for food production. Although the region has a high agricultural potential, rainfall variability, which is being exacerbated by global climatic variability, is the greatest threat to exploiting this potential. Due to lack of access to location specific meteorological data, it is becoming increasingly difficult for farmers to match cropping patterns with important rainfall characteristics such as onset, cessation, length and amount. Indigenous knowledge based rainfall prediction techniques, which were previously used by farmers to plan rain-fed agriculture, have to a large extent, been abandoned. This paper seeks to integrate indigenous and scientific rainfall prediction techniques with a view to increasing the use of rainfall prediction in planning rain-fed

agricultural activities before the start of growing season. Maize, a staple food in the region, is used as the test crop.

This region experiences two major rainfall seasons in a year with the long rains occurring in March-May and the short rains in October-December (EAMD, 1962). Soils are often dry cultivated during the dry season and if required a cleaning cultivation is done immediately before sowing. If the soil is dry during sowing, planting is referred to as dry sowing, whereas delayed sowing until rains have sufficiently wetted the top soil, is regarded as wet sowing. In many instances farmers will be glad to sow as much as possible before the rains in order to reduce the workload once the rains have arrived. Dry sowing has high risk compared to wet sowing, but if successful, it has benefits that become increasingly obvious as the season progresses ([Kipkorir et al. 2007](#)). Some of the risks of dry sowing can be reduced by observance of onset dates of the rainy season. Whereas these dates have not been precisely determined, farmers depend greatly on their experience.

In recent years, meteorological science has made enormous progress in predicting climate. Realization that Sea Surface Temperature (SST) influence global atmospheric circulation enables scientists to formulate forecasts of seasonal rainfall for various regions. The capacity to generate and supply site-specific medium range weather forecast has been enhanced in recent times. But access by farming communities, to location specific rainfall forecast for proper decision making at farm level is very limited.

The significance of rainfall has motivated the farming communities in the tropics, to develop their own traditional methods of monitoring and predicting rainfall. These methods, which have evolved from observations and experiences over a period of time, use a set of indicators and developed reliability factors for each of them. However, the dichotomous view of indigenous knowledge and modern scientific knowledge models is seen as a cause for poor utilization of metrological data, hence the efforts to develop a continuum between these two systems. Participatory research, farmer-back-to farmer model (Amanor et al.1993) are some of the attempts towards establishing such a continuum. Subjects such as ethno-biology have tried to understand the indigenous knowledge (IK) and link it with modern science. However, the challenge is how to integrate traditional knowledge and modern sciences without substituting each other.

To promote rain-fed agricultural planning, expected dates of onset of rainy period in a region would be quite vital. Previous work on rainfall onset has employed different techniques depending on the rain generating mechanisms of the region in question. Odekunle (2004) used cumulative daily rainfall data to predict onset and retreat dates in Nigeria. Nicholls (1984) used a wet season onset index in determining the existence of predictability of seasonal rainfall in Australia. Lineham (1983) used water balance method in determining onset and cessation of rainy season in Zimbabwe. FAO (1978) defined the start of the growing season as the date when the precipitation exceeds half the potential evapotranspiration. [Raes et al.\(2004\)](#) carried out an evaluation of first wet sowing dates recommended by criteria used in Zimbabwe using a soil water balance model and recommended DEPTH criterion (40 mm rainfall in 4 days), based on farmers' practices for operational use. This study analyzed onset, cessation and length of growing seasons in Lake Victoria basin, western Kenya by integrating indigenous and scientific knowledge systems with the aim of providing information to be used in advising farmers on planning for rain-fed agriculture.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in Lake Victoria Basin which lies between latitudes 1⁰ 30'N and 2⁰ 00'S and between longitudes 34⁰ 00'E and 35⁰ 45'E (Figure 1), and covers an area of about 48,000 km². The region is an area of high agricultural potential, mainly under rainfed, for both subsistence and plantation farming. There are two main rainfall seasons, the long (mid March to September) and short rains (mid October to early December) sustain rain-fed farming in the basin. These rains are usually associated with northward/southward movement of inter-tropical convergence zone (ITCZ).

(Figure 1)

Four communities, namely Nandi (Uasin Gishu and North Nandi districts), Kipsigis (Bomet and Kericho districts), Luo (Karachuonyo district), Abagusii (Kisii district) and Luhyas (Busia and Kakamega districts) were studied (Figure 1). The study covered both moderate and high rainfall areas, where rain-fed agriculture is the predominant socio-economic activity.

2.2 Data Collection

Three data types were collected for this study. First, existing indigenous knowledge on rainfall prediction and analysis, was gathered by administering a questionnaire to purposively selected sample consisting of youths, middle-aged men and women and elderly people. At least sixty respondents from each community were sampled, giving a total of 240 respondents. Additionally, in each community, at least one elder known to have rain prediction expertise was interviewed as a key informant. The questionnaire focused on identifying similarities and differences across the communities on indicators used and their interpretations.

Second, long-term climatic data from eight meteorological stations and 18 rainfall stations was analyzed. Daily rainfall records and mean daily evaporation from the 26 stations (Figure 1) were collected for an average period of 18-35 years from Kenya Meteorological Department (KMD). Mean monthly reference evapotranspiration (ET_0) was derived from class A pan measurements (E_{pan}) by using a representative pan coefficient for each of the eight meteorological stations which had evaporation data (Allen et al. 1998). Since only eight stations provided pan evaporation data, it was necessary to estimate data for the other (18) stations, based on the homogeneous zonation of the lake basin established by [Ogallo \(1989\)](#) and [Agwata \(1992\)](#). All the 26 stations were considered for onset based on wet sowing, but for dry sowing, eleven stations located around Trans Nzoia, Uasin-Gishu, Nandi and Kisumu districts were considered since dry sowing is often practiced in these areas. Finally, the study obtained indicative soil characteristics data (wilting point and field capacity) by means of pedotransfer function (Saxton et al. 1986; Saxton, 2003) by considering soil type determined from texture soil maps for the region (KSS, 1997).

Through analysis of the collected information on traditional knowledge, monitoring of key identified indicators was done for a period of four months within the long rains onset window in one area (Uasin-Gishu district) of the study area to provide information on the performance and scientific interpretations. In Kenya, scientific regional weather forecast is made available to farmers by KMD through public media. Regional KMD weather forecasts for western Kenya for the past two years were used to validate some of the identified traditional knowledge on weather and climate prediction.

2.2.1 Indigenous Climate Knowledge and Forecasting

The subject of indigenous knowledge has gained importance in recent times ([Speranza et al. 2009](#)). Indigenous knowledge (IK) is generally defined as “knowledge of a people of a particular area based on their interactions and experiences within that area, their traditions, and their incorporation of knowledge emanating from elsewhere into their production and economic systems” (Boef et al.1993). IK is a cultural tradition preserved and transmitted from generation to generation. The agro-pastoralists in Kenya use it in monitoring, mitigating and adapting to droughts ([Speranza et al.2009](#)).

Understanding the local people’s perception on climate is critical for effective communication of scientific forecasts. Since it is learned and identified by farmers within a cultural context, the knowledge base follows a specific language, belief and process, through which the local weather and climate is assessed, predicted and interpreted by locally observing local variables and experiences, based on a combination of plant, animal, meteorological and celestial bodies’ indicators, implying that indigenous knowledge on climate and weather are qualitative.

Weather predictions are used by farmers to make critical short-term decisions and adaptive measures on rain-fed farming. However, seasonal climate predictions are mostly used by farmers to prepare themselves for anomalies. Different predictors (environmental, biological and traditional belief) are common among farmers to take critical farm decisions and adaptive measures. This knowledge evolves from locally defined conditions or needs and incorporate personal perspectives that evolve from slightly modifying the knowledge to meet current needs and situations. In general, elder persons are more knowledgeable and are able to give more indicators with their reliability ratings. The variations in indigenous knowledge in a community are based on age, gender, kinship affiliation, ideology and literacy. Knowledge is passed through older generations through causal conversations, mostly during practice in the field. The enhanced variability in climate reduces farmer’s confidence of the predictors thus increasing the need for scientific forecasts ([Speranza et al. 2009](#); [UNEP, 2008](#)). The challenge, therefore, is to provide reliable forecast through appropriate methods that should be largely accessible to and based on the needs of farmers.

2.2.2 Scientific Climate Forecasting

In Kenya, KMD develops seasonal forecasts based on specific regional predictors using numerical statistical tools. The seasonal forecast for March-April-May long rains considered in

this study is mainly based on prevailing and expected SST anomalies over the Indian, Atlantic and Pacific oceans as well as other factors that affect the country's climate. The methods used include statistical models, dynamical models and expert interpretation (KMD, 2009). For the long rains, forecast is normally released during the second week of March by KMD and communicated to the public through daily newspapers, radios and TV.

2.2.3 Bridging the Knowledge Systems

The scientific forecast deviates from traditional farmer's prediction in scale and to some extent on predictors. Farmers have been using a combination of various biological, meteorological and celestial bodies as indicators to predict rainfall. While scientific forecast are developed using meteorological indicators predictors such as wind, SST and pressure patterns among others. The traditional forecast is highly location specific, mostly at village level within a radius of 1-2 km² derived from an intimate interaction with micro-environment observed over a period of time. However, scientific forecasts are generated at much larger geographic scale (60 - 300 km²) and depend on the dynamics of global metrological parameters. Though the reliability of traditional indicators is not definite, it helps farmer to prepare for timing and distribution, while scientific forecast helps them to prepare for the expected amount. In this way it is possible to establish a continuum between scientific and traditional forecasts, which combines the scale and time of onset of rainfall.

2.3 Data Analysis

The questionnaire data were extracted and tabulated to show similarities and differences in use of different techniques for rainfall prediction. The study looked for similarities and differences in prediction across space, as well as their relative reliabilities as reported by respondents with a view of identifying the most widely applicable and reliable indicators. Specifically, the study sought to determine the frequency and reported reliability of different indicators among the studied communities. The study also sought to interpret the scientific bases of each indicator so as to establish any linkages between the indigenous and scientific approaches. Finally an attempt to validate some of the indigenous knowledge was done by monitoring predictors and comparing observations to scientific and real onset dates in a site in Uasin Gishu district.

2.4 Simulation of Onset, Cessation and Length of Growing Season

Soil water balance simulation technique was used to determine onset, cessation and length of growing season based on historic climatic data.

2.4.1 Onset Criteria

Onset is quantified by DEPTH method described by [Raes et al.\(2004\)](#), which considers a cumulative rainfall depth that will bring the top 0.25 m of soil profile to field capacity during a maximum of 4 days. The corresponding threshold rainfall quantifies the field inspection method by farmers to determine whether conditions are favourable for wet sowing. This is achieved by digging a test hole, usually a day after a rain event. Evaluation of the onset criteria revealed that a threshold value of 40 mm rainfall during a maximum of 4 days is appropriate for the study area ([Mugalavai et al. 2008](#) and [Kipkorir et al. 2007](#)). For each of the 26 stations, and for each of 18-35 years of the period that daily rainfall data was available, RAIN software Kipkorir (2008) was used to determine the actual onset dates for each year. On the other hand, germination for dry sowing is quantified by considering a cumulative rainfall depth that will bring the top 0.10 m (seeding depth) of the soil profile to field capacity within two days ([Kipkorir et al. 2007](#)).

2.4.2 Cessation Criteria

Cessation is quantified by considering the date when water stress, assessed by means of water stress coefficient K_s (Allen et al.1998) in the root zone of a maize crop exceeds a threshold value of 0.4. For each of 26 stations and for each of the 18-35 years that daily rainfall data was available, soil water content in the root zone was simulated using RAIN software. When water stress occurs, K_s decreases linearly from one with soil water content to zero at wilting point. Cessation of rainy season is assumed when K_s drops below 0.40 within cessation window.

2.4.3 Length of Growing Season

The length of growing season (days) for a particular year is taken as the difference between the Julian day numbers of determined cessation date and determined onset date for that year.

2.5 Statistical Analysis

Probabilities of exceedance of onset and cessation dates and of length of growing season were calculated using frequency analysis in RAIN software. Although RAIN uses normal probability distribution function, data can be transformed using log, square or square root functions. After selecting the type of distribution with the best fit 80, 50 and 20% probabilities of exceedance were determined and used as indicators of early, normal and late onset and

cessation dates respectively. For the length of growing season 80, 50 and 20% probabilities of exceedance were determined and used as indicators of short, normal and long season.

3. RESULTS AND DISCUSSIONS

3.1 IK Weather Indicators

From analysis of questionnaires administered in eight areas of the study area (Kisumu, Busia, Kakamega, Trans Nzoia/Uasin Gishu, North Nandi, Kisii, Buret/Kericho/Sotik and Bomet/Transmara), results indicate that the key weather indicators used to predict occurrence of rainfall by various communities in the region can be categorized into five broad groups (Kipkorir et al. 2009): (i) plant indicators (trees); (ii) meteorological indicators (temperature and wind); (iii) animal indicators (insects, birds, frogs and livestock excitement); (iv) celestial bodies (sun, moon, stars) and (v) hydrological indicators (lake and streams). The key indicators were considered as those with a rank score of at most four percent per category.

From the results (Kipkorir et al. 2009) it is established that there is similarity of key indicators per category among the various communities in the region. Plant indicators mainly indicate the rains are about to start, thereby giving farmers an opportunity to plan their farm activities, especially farm preparations and sowing. Formation and movement of clouds are significant in monitoring and predicting rainfall occurrence and performance. There are specific locations, which if frequented by clouds and lightning would signal a good rainfall season. On the other hand animal indicators seem to apply when the rainfall season is in progress. The noise they make and livestock excitement level tell farmers about the nature of rains already in progress.

3.2 Monitoring of Indicators

To provide information on the performance and scientific interpretations of identified traditional knowledge indicators gathered as predictors, monitoring of migratory birds and four tree types identified as key predictors was done for the region around Eldoret from early January, 2009 to mid April, 2009. The migratory birds called *Magungu* in Luo and *Kaptalaminik* in Nandi formed one single major animal indicator monitored. They mark the closeness to rainfall onset and signal the speeding up of land preparations. These birds pass from south to north during the period February/March and might be associated with the movement of the ITCZ. During the monitoring period the birds were spotted on the 12th and 13th March 2009 around Eldoret area with the bird's general direction of movement from south towards the north. This was followed by a slight amount of rainfall of 1.9 mm on 14th March

2009 and the onset of the rainfall season on 2nd April 2009 based on the wet sowing. This represents a normal onset for the region (Table 1) and about 20 days lead forecast based on the migratory birds as prediction indicator with medium to high reliability (Kipkorir et al. 2009). This compares well with the results for five out of the eight areas that indicate that onset is expected two to three weeks after spotting the migratory birds.

For the weather parameters of traditional indicators of rainfall, results (Kipkorir et al. 2009) indicate that thick and dark clouds forming at horizon and wing veers or breaks to east indicates onset is near. However the thicker and darker the clouds indicate expected heavy rainfall. When wind blows eastwards it indicates near rainfall and when it blows westwards the rainfall is far or the cessation of the rain season is starting. When lightening strikes in near horizontal position, no rainfall is expected soon, however when it strikes in near vertical position the onset is near. During the end of the last week of March 2009 (just before onset of rains on 2nd April 2009), within the monitoring period, these wind and clouds characteristics were observed suggesting that they are good short term indicators of rainfall onset.

Regarding the plant indicators, three tree species namely *Schrebera alata* (Kakarwet), *Bothriocline fusca* (Tepengwet) and *Flacourtia Indica* (Tungururwet) in Nandi (names in brackets) were considered. These are the plant indicators that had high rank scores (Kipkorir et al., 2009). The trees monitored were identified around Lemook village, 15 km south of Eldoret town. The monitoring exercise was done at intervals of seven days, from 25th January 2009, using photography (Kipkorir et al., 2009). Results indicate that for monitored *Schrebera alata* tree by 15th February 2009 it had full flowers and new emerged leaves, however full leaves were attained after 4 weeks. For *Flacourtia Indica* tree, it developed new leaves and flowered on the second week of February, then developed mature leaves after two weeks. Lastly for *Bothriocline fusca* (Tepengwet) attained full flowering by mid of February and flowers dried by the end of the third week of March. These results suggest a reasonable agreement with the observed normal onset in the beginning of April for the 2009 season.

There are two factors that undermine the sustainability of traditional forecasts based on animal and plant indicators. The first is that the environment in western Kenya region is in a state of perpetual transformation. There is widespread degradation of ecosystems which leads to loss of animal sanctuaries, including their flora and fauna they subsist and nest on. This is particularly as a result of rapid population increase, high demand for agricultural land and the prevailing

change in climate. With the current population increase and climate change trends, it is predicted that some parts within western Kenya are likely to undergo biodiversity transformation that leads to loss of some plant and animal species, as more land is brought under agricultural production. Secondly, demographic dynamism due to modern socio-economic trends will strongly affect transferability of indigenous knowledge. The youth are increasingly spending very little time with their rural families, as they pursue education and employment opportunities away from their communities. This limits the process of inter and intra-generational transfer of indigenous climate forecasting knowledge.

3.3 Integrating Scientific and Indigenous Weather Knowledge

During the 2009 long rains season, weather was predicted by KMD and communicated to the public through daily newspapers on 13th March 2009. For the western Kenya region, the forecast indicated that the region could receive increased likelihood of slightly enhanced rainfall (normal rainfall tending to above normal) and the rainfall onset was expected to be between the second and third week of March 2009 in the western part and then progress eastward within the season (KMD, 2009). In the forecast, onset was expected during the second week of March for Western and Nyanza provinces while onset was expected during the third to the fourth week of March (normal onset)(Table 1) in the northern part of Rift Valley province. Using both sowing criteria during the monitoring period, onset was determined as 2nd April for wet sowing and germination date of 2nd April for dry sowing which compares well with the KMD forecast for 2009 long rains. The above results suggest that by integrating scientific and indigenous knowledge in weather forecasting, indigenous knowledge helps the farmer to prepare for timing and distribution, while a scientific forecast helps them to prepare for the amount.

(Table 1)

3.4 Simulated Onset, Cessation and Length of Growing Season

Many studies have indicated the existence of three rainfall peaks within western Kenya. In this study only one season used for crop production under rainfed system was considered and therefore, for stations that showed three peaks, the first two peaks (March-September) were considered as the long rains. The calculated early, normal and late onset and cessation dates and the calculated short, normal and long length of growing season for the long rainy season are given in Kipkorir et al. 2009. For some selected probability levels the onset and length of growing season are plotted as surface maps in Figure 2 and Figure 3 respectively. Whereas a

long growing period may be an indication of higher seasonal rainfall, within season dry spells may occur and depress crop yields.

(Figure 2)

(Figure 3)

4. CONCLUSION AND RECOMMENDATION

Indigenous knowledge for determining rainfall onset among the various communities in Lake Victoria region was collected and analyzed. Results indicate that, the frequently used traditional indicators as modes of rainfall forecasting and planning of rainfed agriculture, include plants (trees), migratory birds, insects (butterfly, red ants, termites), stars, moon, winds (direction, strength and timing), clouds (position and movement), lightning (location and patterns) among others. The indicators used are mostly local and are well understood in the communities; however the specific indicators slightly vary from community to community. Initial validation of some key indicators through monitoring before onset of the rains resulted in some agreement between the indigenous and scientific climate knowledge and forecasting systems. Results obtained in this study suggest that by integrating scientific and indigenous knowledge in weather forecasting, indigenous knowledge helps the farmer to prepare for timing and distribution, while a scientific forecast helps them to prepare for the amount. The evaluation of the onset criteria using soil water balance techniques indicated that use of the accumulation of 40 mm of rainfall in 4 days from new rains is suitable for determining rainfall onset in the region and can be used as an operational criterion by transforming it into a wetting front criterion. The farmer will therefore be expected to observe the wetting front, which should approximate to the initial rooting depth for the crop in question. When these conditions are achieved, wet sowing can be done. The identified onset and cessation dates and the corresponding lengths of the growing season can be presented in form of dependable probability of exceedance levels, which are quite valuable for planning. Based on the encouraging results of this study, it is recommended that the identified IK indicators should be further monitored for a period of at least three years to provide more information on the performance and scientific interpretations. Also greater emphasis should be placed on enhancing environmental conservation and management to reverse the negative biodiversity transformation that leads to loss of key plant and animal species used as indicators for predicting occurrence of rainfall by various communities. Based on the study findings the following guidelines are recommended for use by farmers, with the help of extension staff, in their decision making on the appropriate sowing periods within Lake Victoria basin.

Guidelines for sowing

The recommended sowing guidelines are presented in six steps as follows :

1. The user defines the onset window for his area – (earliest possible onset date for example: 11th March in North Rift region based on long term experience and rainfall data analysis).
2. The user should ensure that farm inputs: seeds and fertilizer have been purchased; and 1st ploughing done, before the earliest possible onset date defined in step 1.
3. From Table 1 or maps (Figures 2 and 3), the user should find the dependable levels (dates) of onset: early, normal or late.
4. The user observes the indigenous knowledge predictors found in his area (animals, plants, weather among others).
5. The user should then check the KMD press release on seasonal forecast:
 - (i) the week that onset is expected in his region
 - (ii) the expected amount of rainfall during the forecast period
6. Within the onset window and guided by KMD forecasts (step 5) and Indigenous knowledge observation (step 4), the user should plan for agricultural operations timing:
 - (i) Field preparations-second ploughing, field cleaning among others
 - (ii) Decide on the crop type or crop variety to be sowed based on the expected onset date and amount (step 5); if the onset is late there might be need to sow early maturing crop or variety
 - (ii) Decide on sowing dates using:
 - dry sowing (more risk)-early sowing or
 - wet sowing (less risk)-delayed sowing
7. Wet sowing is preferred for a growing season that record normal or late onset.
8. Dry sowing is preferred for a growing season that record early or normal onset.

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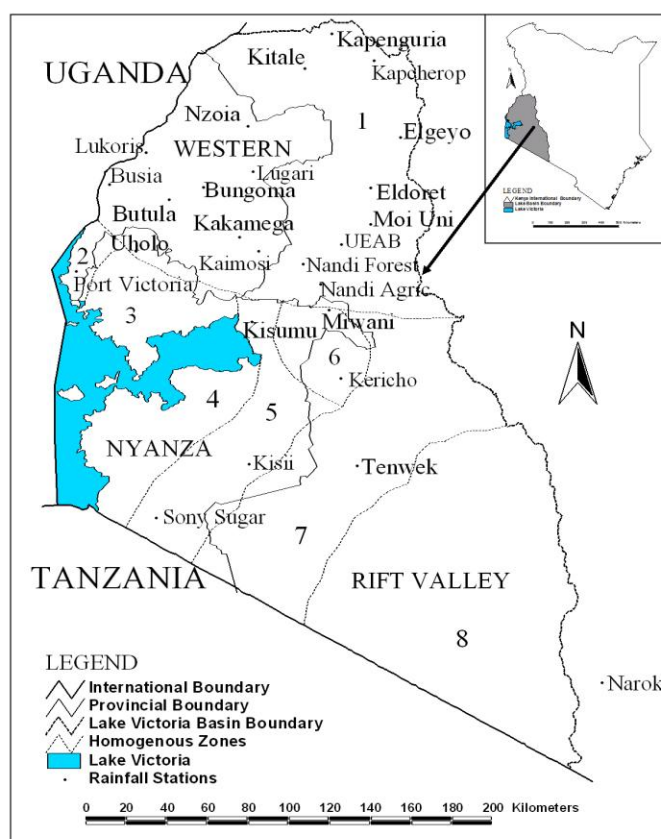


Figure 1: Location of study area with indication of eight homogenous zones for Kenyans Lake Basin superimposed with twenty six rainfall stations (Modified from Ogallo, 1980)

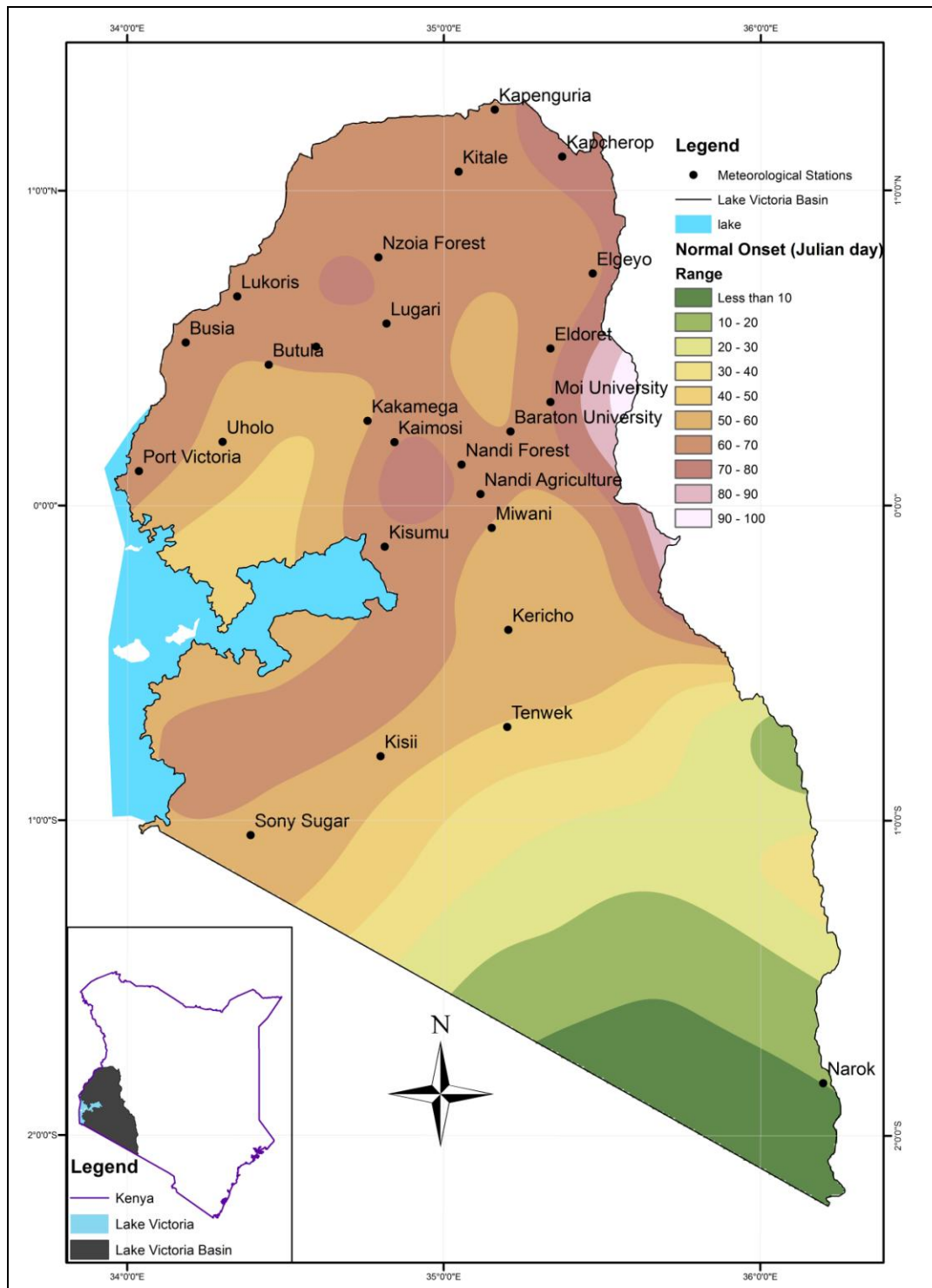


Figure 2- Normal (50% probability of exceedance) onset day (Julian day) for long rains.

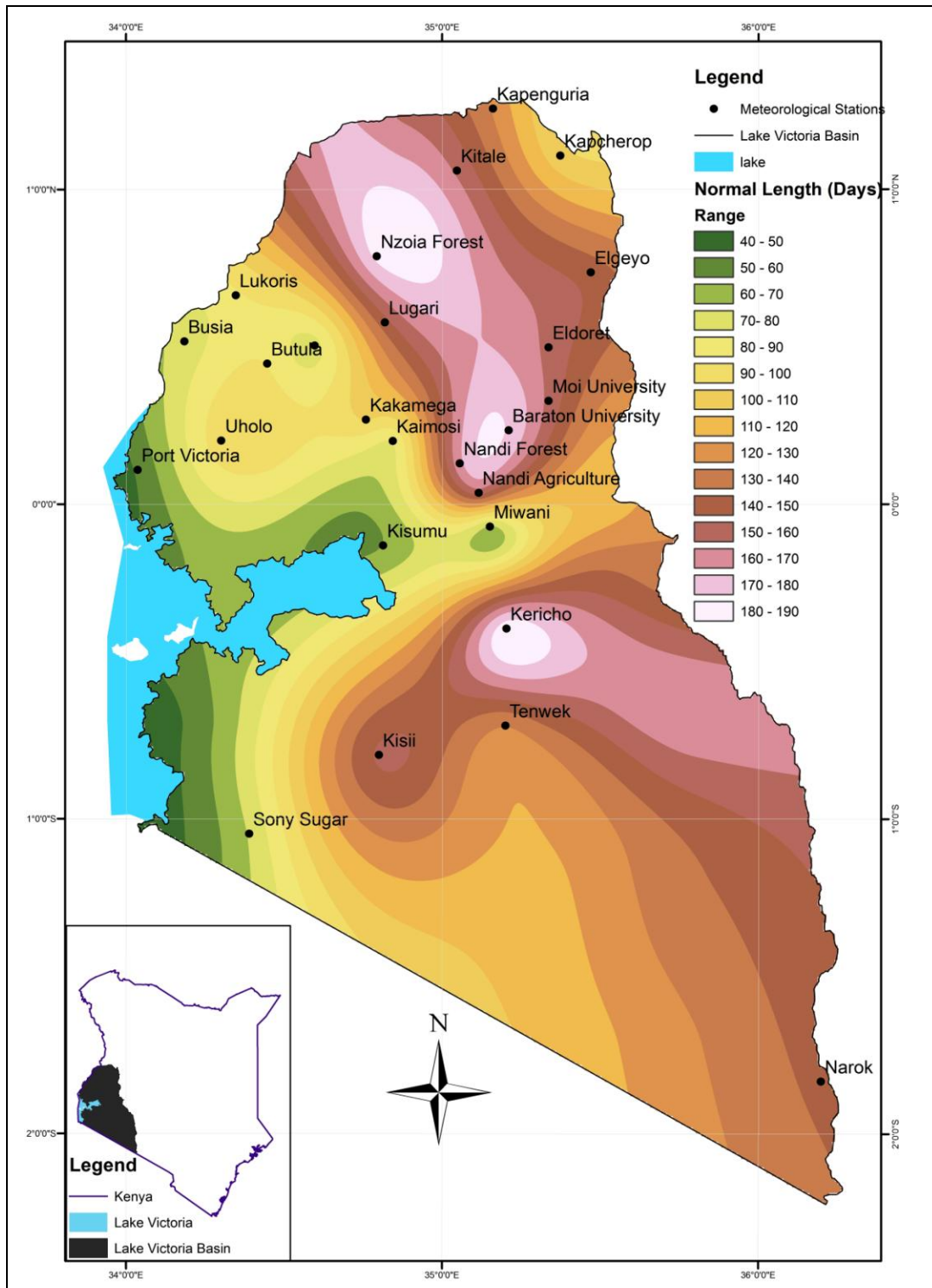


Figure 3- Normal (50% probability of exceedance) length of growing season (days) for long rains.

Table 1: Simulated onset dates (date/month) for wet and dry sowing methods for selected stations

Station	Dry sowing			Wet sowing		
	Early	Normal	Late	Early	Normal	Late
Kitale	15/3	2/4	13/4	20/3	5/4	24/4
Kapcherop	16/3	28/3	11/4	27/3	13/4	30/4
Elgeyo Forest	16/3	27/3	7/4	18/3	3/4	22/4
Eldoret	16/3	1/4	19/4	28/3	13/4	30/4
Moi University	16/3	28/3	11/4	17/3	1/4	20/4
Baraton	12/3	21/3	31/3	15/3	28/3	13/4
Lugari Forest	16/3	24/3	2/4	19/3	3/4	22/4
Kaimosi	14/3	24/3	4/4	19/3	1/4	16/4
Nandi Agriculture	14/3	27/3	12/4	15/3	30/3	18/4
Ahero	5/3	12/3	20/3	16/3	26/3	5/4
Miwani	28/2	12/3	27/3	9/3	22/3	5/4