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RESEARCH ARTICLE

USING INDICES TO STUDY DROUGHT VARIABILITY IN THE LAKE VICTORIA BASIN

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ABSTRACT

This paper analyses indices of the various drought scenarios developed and tested with data available from meteorological stations around Lake Victoria in a study to determine the spatial variability of droughts in the Lake Victoria basin. Palmer's method was appropriate for describing the drought severity at the shores of the lake. The normalized difference vegetation index (NDVI) and palmer's indices were also used to compare the drought severity in the catchment. Severity maps were developed using GIS software based on both Palmer and NDVI indices, and using a soil map of the catchment, a rainfall map was also developed. These maps clearly depicted that most areas on the shores of Lake Victoria in Kenya were vulnerable to drought.

INTRODUCTION

Droughts are natural phenomena and cannot be prevented, but can be predicted by application of such important parameters as duration, severity, regional spread and their frequency to minimize their impact through management techniques. According to Shakiba *et al.*, (2010) drought varies with regard to the time of occurrence, duration, intensity and extent of the areas affected from year to year. The adverse effects of droughts on both water supply systems and environment are expected to increase in the coming years (Rossi *et al.*, 1992). Droughts are of a great concern throughout the continent of Africa because of the devastating effects they have inflicted on the economies of some of the countries. While drought may result in water shortages, diseases, and economic losses, the major impact on farmers in Kenya is decreased food production. Drought has no universally agreed upon definition (Dent *et al.*, 1987). Thomas (1965) classified drought as falling under three categories namely Meteorological, Hydrological and Agricultural droughts. Agricultural droughts have been variously defined, but are known to occur when rainfall amounts and distribution, soil water reserves and evaporation losses combine to cause crop or livestock yields to diminish markedly. The intensity of a drought can be equated to the average deficit over a whole drought period (Bonacci, 1993).

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According to Berani and Rodier (1985), drought conditions can be caused by many factors some of which are:

1. Overseeding of clouds by particulate matter from the earth's surface,
2. Increased soil heat flux due to reduced soil moisture, leading to alteration in the proportion of net radiation need as latent heat, and
3. Increased evaporation from soil surface.

Evapotranspiration (ET) is an important process of the hydrological cycle, and in the study of agricultural watersheds. The choice of method used to study ET is dependent on several factors, which include data availability, the intended use and the time required by the problem (Shih *et al.*, 1983). In the east African conditions, it has been found that Penman's method (Penman, 1949) performs better at predicting ET (Woodhead, 1968). Various indices have been proposed to analyse drought severity/intensity. The present study employed the use of Palmer method to determine the drought indices over the study area (Palmer, 1965). The PDSI has been a landmark in the development of drought indices. It enables measurement of both wetness (positive value) and dryness (negative value), based on the supply and demand concept of the water balance equation, and thus incorporates prior precipitation, moisture supply, runoff and evaporation demand at the surface level (Gutman, 1998). Kim and Valdes (2002) investigated the temporal and spatial characteristics of droughts to provide a framework structure for sustainable water resources management in a semi arid region like the study area using PDSI. The area has the potential to produce high crop yields if properly managed. This means that drought management in the area can lead to increased food security and ensure a sound economic base. Population density of 200 to 400 persons per square kilometre is found in most parts of the Lake Victoria basin, hence the need for studies on the areal extent of the drought and its severity for purposes of agricultural development. This work based on the spatial drought variation offers a fundamental knowledge necessary in planning for future prospects of water management and other related resources within Lake Victoria basin of Kenya. This information would also be vital in controlling over-cultivation, overgrazing, and deforestation, among other poor farming methods. The main objective of the study was to determine a suitable method of estimating PET in data scarce area like the Lake Victoria basin; to develop Palmer drought severity indices of the area of study; and to use indices developed above to produce a drought severity map.

Study area

The study area lies between longitudes 34°E and 35°E and latitudes 1° 30'S and 1° 20'N (fig.1). This area often experiences some of the harshest drought conditions similar to other areas in Kenya commonly referred to as arid and semi-arid lands. The climate of the area is influenced very much by the lake. According to Koppen's classification, the climate in the area is sub-humid tropical savannah (Sombroek *et al.*, 1982). The rainfall in the area is about 750mm per annum, three quarters of which is received in March to April and its distribution is highly affected by the topography.

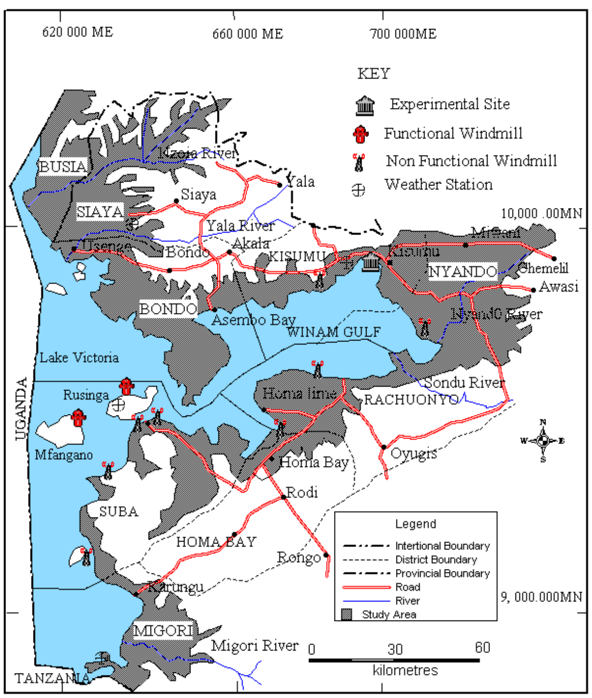

Fig. 1. Map showing the study Area

Temperatures on the eastern shores reach maximums of between 29 and 30°C (WMO, 1982). The annual humidity ranges between 61 - 89% in the morning hours and 44 – 74% in the afternoon (Agwata, 1992). According to Nyenze (1980), the areas around the lake experience actual annual evaporation (E_o) with values greater than 1000mm and monthly values range between 100 and 170mm.

The geology of the study area consists of rocks of Nyanzian age (Precambrian) and the recent deposits. The alluvial deposits and lacustrive sediments are mainly found along the shores of the Lake. Deep clay soils occur where the water movement is rather gentle, but more sandy soils are found on positions which are exposed to the wind and which have a strong water movement. The vegetation in the area of study may be described as bushed grasslands. The major land use is farming of beans, sorghum, rice, sugarcane, citrus fruits, tomatoes and cabbages, among others.

MATERIALS AND METHODS

Rainfall and temperature data, spanning twenty years, were sourced from meteorological stations near the shores of Lake Victoria, on the Kenyan side. These are Kadenge, Kisumu airport, Kibos Cotton Research Centre, Rusinga Island and Muhuru bay meteorological stations. Additionally, soil parameters were also used (field capacity, wilting point and root depth for most annual crops). These formed the primary data. Secondary data included rainfall distribution maps, soil maps and Normalized Difference Vegetation Index (NDVI) plots (obtained from Resource Surveys and Remote Sensing). Due to short breaks in data collection experienced in many of the stations used, missing data (rainfall) were estimated using methods discussed by Olwero (1998). The quality of precipitation data was tested using the double mass curve method (Shaw, 1984). Missing temperature data were estimated by averaging historical measured data. Palmer's method was employed to develop indices that classifies drought into moisture status classes ranging from extremely wet to extremely dry conditions. The droughts were specifically defined as periods in which rainfall deficits were in excess of average deficits. Potential evapotranspiration was calculated using the methods of Blaney & Criddle (1950). These methods has the advantage of requiring minimal data, as was found around the lake.

RESULTS AND DISCUSSION

Results from monthly computations of PET for the period January 1976 to December 1986 from the climatic records of Kadenge, Kisumu Airport, Rusinga Island and Muhuru Bay meteorological stations are shown in Table 2. All five methods are compared in this analysis. The correlation coefficients between the methods and Penman method are shown in Table 3. While the coefficient for Thornthwaite method is the highest; its standard error is also the highest, thus not a stable estimator with the kind of data available. The difference between the estimates from Penman and other methods and their standard deviations were calculated for areas where data was available hence comparison of the methods as shown in Table 4. The NDVI indices revealed that most parts of the shores of the Lake were moderately dry throughout the years except in 1997 and 1998 when it was green throughout the year due to El Nino rains. The drought indices reflected the severity of the droughts on a monthly basis for all the years taken for each station. The results indicated that the lake basin of Kenya and especially the area around the shores, experience drought most part of the year. According to the Palmer indices, the shores of Lake Victoria experience drought whose severity is greater than -4, which is explicitly treated as drought prone (Table 1). Through spatial analysis, the severity map was developed as shown in figure 2. The map depicts most areas on the shores of the Lake are more vulnerable to drought than highland areas in Nandi, Kakamega and Kericho counties.

Table 1. Drought classification by Palmer's drought Index

Palmer's Index	Degree of drought
PDSI less than -4.0	Extremely dry
PDSI less than -3.0	Severely dry
PDSI less than -2.0	Moderately dry
PDSI less than -1.0	Mild dry
PDSI less than +1.0	Near normal
PDSI less than +2.0	Mildly wet
PDSI less than +3.0	Moderately wet
PDSI less than +4.0	Severely wet
PDSI greater than +4.0	Extremely wet

PDSI - Palmer drought severity Index (After Ramachandra Rao and G. Padmanabhan, 1982)

Table 2. Mean monthly PET by the five conventional methods tested

	Rusinga					Muhuru Bay				
	BC	PEN	PAN	TH	HAR	BC	PEN	PAN	TH	HAR
Jan	207.3	204.3	223.2	88.3	88	184.8	198.4	210.5	96.4	137.6
Feb	212.5	167.9	193.2	76.8	119	169.1	155.9	179.2	94.3	125.2
Mar	214	180.7	223.2	74.2	125.8	167.2	159	198.4	99.7	142.3
Apr	185.3	140.3	168.2	62.3	111.6	188.9	211.7	162	92.2	158.1
May	132.3	126.7	148.8	53.5	111	113.9	101.6	170.5	84.2	124.7
Jun	169.4	137.2	153	62.8	104.2	158.9	158.7	156	83.2	115.5
Jul	134	153.4	151.9	47.5	102.6	146	149.7	164.3	79.3	118.7
Aug	157.6	168.2	186	60.1	110.9	151.7	173.2	186	84.2	132.7
Sep	175.4	200	186	70.1	118.8	164.8	177.1	177	88.1	138.9
Oct	181.1	151.3	223.3	92.1	134.6	175.1	181.6	210.8	99.7	147.2
Nov	140.5	151.3	183	63.1	118.2	151.7	156.1	174	89.2	148.2
Dec	180.4	175.6	201.5	76.8	126.2	173.5	160.9	186	91.2	179.7
Total	2089.8	1956.9	2241.3	827.6	1370.9	1945.6	1983.9	2174.7	1081.7	1668.8

	Kadenge					Kisumu				
	BC	PEN	PAN	TH	HAR	BC	PEN	PAN	TH	HAR
Jan	191.6	163.1	179.8	71.2	167.9	199.5	183.3	210.5	79.7	127.9
Feb	175	143.6	140	65.4	149.9	193.8	155.8	166.6	71.1	134
Mar	168.8	147.4	186	67.8	157.7	191.4	164	204.6	71	141.8
Apr	133.8	95.8	126	47	128.8	160	118	147.1	54.7	120.1
May	121.5	97.8	114.7	41.4	118.7	126.9	112.3	131.8	95.1	114.9
Jun	151.6	107.7	111	50.9	131.7	144.4	122.5	132	56.6	117.9
Jul	120.9	108.4	102.3	40.4	132.7	136.4	130.9	127.1	44.9	117.6
Aug	138.6	128.1	133	48.3	143.8	148.1	148.1	144.2	54.2	127.4
Sep	155.5	123.2	144	57.3	143.6	165.4	141.9	165	64	131.2
Oct	180.6	146.8	167.4	72.7	150.4	180.8	173.4	195.3	177.4	134.7
Nov	149.5	120.6	135	57.1	134.8	145	135.9	159	60.4	126.5
Dec	167.9	124.7	167.4	65.6	145.3	174.2	150.2	184.5	71.2	135.7
Total	1855.3	1507.2	1706.6	685.1	1705.3	1965.9	1736.3	1967.7	900.3	1529.7

KEY: BC – Blaney and Criddle; PEN – Penman; PAN - Class A Pan; TH – Thornthwaite; HAR - Hargreaves

Table 3: Correlation coefficients between PET estimates by Penman and other methods

Method	Coefficient	Standard Error (SE)
BC	0.460	0.151
HAR	0.132	0.187
PAN	0.146	0.015
TH	0.653	0.204

KEY: BC – Blaney & Criddle; PEN – Penman; PAN - Class A Pan; TH – Thornthwaite; HAR - Hargreaves

Table 4. Difference of monthly PET estimates between Penman and other methods

	Kisumu Airport				Rusinga Island			
	PAN	BC	HAR	TH	PAN	BC	HAR	TH
Mean MAD (mm)	19.82	19.10	27.99	87.11	13.2	12.95	49.56	95.62
SD	11.00	12.23	14.98	33.39	9.36	8.94	23.92	14.79

	Muhuru Bay				Kadenge			
	PAN	BC	HAR	TH	PAN	BC	HAR	TH
Mean MAD (mm)	24.64	19.30	33.29	75.22	18.26	29.02	31.9	68.52
SD	19.05	14.57	31.66	24.14	12.76	10.17	53.23	11.94

MAD (Monthly Absolute Difference); SD (Standard Deviation

Spatial analysis using NDVI

Green vegetation is highly affected by climatic factors including rainfall and evapotranspiration among others and hence can be a good indication of drought severity. The NDVI is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum, and is adopted to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not.

Table 5. Mean monthly NDVI for the five meteorological stations studied

Month	Kisumu airport	Kibos	Rusinga island	Kadenge	Muhuru bay
January	0.494	0.549	0.504	0.594	0.560
February	0515	0.525	0.490	0.530	0.534
March	0.543	0.560	0.502	0.571	.0573
April	0.496	0.552	0.533	0.584	0.556
May	0.533	0.650	0.603	0.658	0.637
June	0.464	0.578	0.558	0.628	0.573
July	0.363	0.535	0.580	0.535	0.639
August	0.265	0.337	0.331	0.178	0.412
September	0.273	0.460	0.476	0.504	0.486
October	0.398	0.533	0.566	0.555	0.504
November	0.419	0.505	0.463	0.618	0.543
December	0.504	0.559	0.453	0.629	0.579

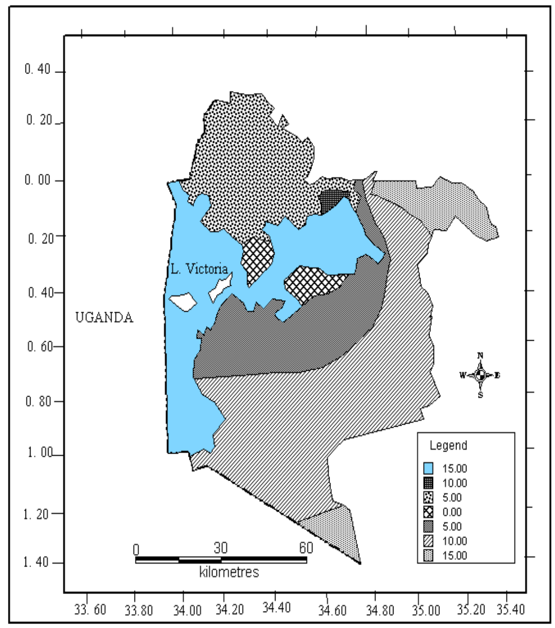

Fig. 2. Drought severity map of study area based on Palmer's Indices

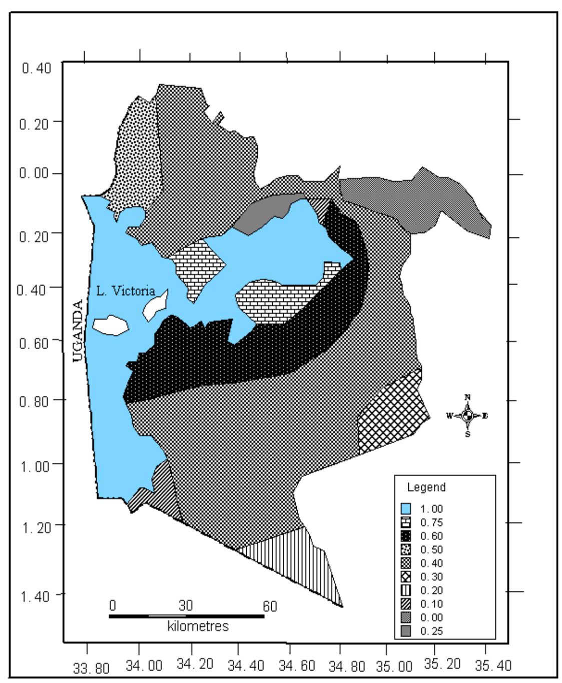

Fig. 3. The Drought severity map developed from NDVI

According to Holme *et al.* (1987), health vegetation will absorb most of the visible light that falls on it, and reflects a large portion of the near infra-red light. Unhealthy or sparse vegetation reflects more visible light and less near infra-red. Bare soils on the other hand reflect moderately in both the red and infra-red portion of the electromagnetic spectrum. NDVI values are represented as a ratio ranging in value from -1 to 1 but in practice extreme negative values represent water, values around zero represent bare soil and values over 6 represent dense green vegetation. The data was derived from satellite images (resolution of 1.1km) Table 5. Based on the NDVI indices derived, severity map was developed as shown in Figure 3. The results of the NDVI did indicate that most parts of the shores of Lake Victoria experience drought throughout the year. This was in agreement with the spatial representation using palmer indices. There are three distinct seasons in a year in the area studied, described by the rainfall patterns. These are: the dry season (January to March), long rains season (April to September) and the short rains season (October to December). PET values calculated corroborate this, showing January to March having the highest PET values and least in the long rains season.

Conclusions

From the studies, it was clearly demonstrated that the Blaneyanley & Criddle method of PET was superior to the others in the light of the available data. In areas where both meteorological and hydrological data are readily available, Palmer drought index and NDVI methods could be used for drought analysis in Kenya. In view of spatial extent of the drought studied in this catchment (Fig. 1), it was pertinent that proper planning of the basin is necessary. With the understanding of the spatial extent of drought in a region, the government can take action towards mitigating general impacts of the disaster. Early action will enable people to protect livelihoods, with attention to productive assets, address health issues of vulnerable groups, support education and help to mitigate conflicts. Subsistence production may be improved through soil conservation, irrigation, cropping in diverse areas and agro ecological zones, and the planting of drought resistant crops like cassava, sorghum, cotton and finger millet. Considering the right place for the right crop in the catchment may be an alternative way of handling the drought disaster in such catchments, known to be of high potential as far as agriculture is concerned. One limitation of the study was the use of the generalized crop factor k, which exaggerated the results. Lack of continuous meteorological data was another hindrance to the use of more robust models.

REFERENCES

Agwata, J.F.M. 1992. The response of L. Victoria levels to regional and global climate changes. M. Phil Thesis, Moi University, Kenya.

Berani, W. and Rodier, H. 1985. Hydrological drought. WMO reports ,Vol, 39.

Bonacci, O. 1993. Hydrological identification of drought. Hydrological Processes. 7:249-262.

Chumo, J.K. 2011. Spatial variability of droughts in the lake Victoria basin of Kenya.

Dent, M.C., Schulze, R.E., Wills, H.M. and Lynch, S.D. 1987. Spatial and temporal analysis of the recent drought in the summer rainfall region of southern Africa. *Water SA* 13:37-42.

Guttman, N.B. 1998. Comparing the Palmer drought index and the standardized precipitation index (SPI). Journal of the American Water Resources Association, 34, 113-121.

Holme, A., Burnside, D.G and Mitchell, A.A. 1987. The development of a system for monitoring trend in range condition in the arid shrub land of western Australia. Australian Rangeland journal 9; 14-20.

Nyenze, M. 1980. The distribution of actual evaporation – evapotranspiration over east Africa. Kenya Meteorological Department Research Report No. 7, Nairobi, Kenya

Olwero, J.G.N. 1998. Some aspects of drought in the Lake Victoria basin Kenya. M. Phil Thesis, Moi University, Kenya.

Palmer, W.C. 1965. Hydrological identification of drought. Hydrological Bureau, Washington D.C., USA.

Penman, H.L. 1949. The dependence of transpiration on weather and soil conditions. *J. Soil. Sci*. 1:74.

Rossi, G., Benedini, M., Tsakiris, G. and Giakoumakis, J. (1992). *On regional Drought Estimation and Analysi*s; water resources management, 6:249-277, Kluwer academic publishers, Netherlands.

Shakiba, A., Mirbagheri, B. and Kheiri, A. 2010. Drought Analysis using SPI and its effects on groundwater resources in East of Kermanshah, Iran. EMS Annual meeting abstracts vol. 7, EMS 2010-335, Tehran, Iran.

Shih, S.F., Allan, L.H, Hammond, L.C., Jones, J.N.; Rogers, J.S. and Smajstrla, A.G. 1983. Basin wide water requirement estimation in southern Florida. Trans. *ASAE* 26(3):

Sombroek, W.G., Baun, H.M. and van der Pouw, B.J.A. 1982. Exploratory soil map and agro climatic zone map of Kenya.

Thomas, H.E. 1965. Reality of drought is always with us. Natural History, 74:50-62.

Woodhead, T. 1968. Studies of potential evapotranspiration in Kenya. EAAFRO, Nairobi

WMO 1982. Hydro-meteorological survey of the catchments of lakes Victoria, Kioga and Albert. Vol. IV Project findings and recommendations. WMO, Geneva.

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