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THE EFFECTS OF EAST AFRICAN LOW LEVEL JET ON FOOD SECURITY IN HORN OF AFRICA: A CASE STUDY OF COASTAL REGION OF KENYA

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ABSTRACT

Literature on rainfall variability in Eastern Africa has suggested a significant influence from local factors that control rainfall amounts and distribution in contrast to the global wind circulation systems in oceanic atmospheres. All oceans are associated with unique wind systems that reflect temperature and other physical attributes of the water masses. However, the influence of such systems on Eastern Africa has not been investigated in conjunction with unique climatic phenomena, including the June winds in the coastal region of Kenya. This study involved a review of literature and the analyses of secondary data from studies conducted in the region, including 39 years of meteorological data. The results indicated that only two months in a year, namely April and May, experience a positive net moisture regime. In all other months, predicted evaporation exceeds received precipitation. The results also suggest that the annual June winds create a cyclic depression in rainfall amounts during the long rains season, resulting in decreased soil moisture and therefore adverse effects on annual field crops. The June winds, at critical stages of maize growth, results in depressed crop yields that threaten food supply and food security. Maize yields in the region are associated over time with amounts of rain received during the long rains season. Cyclic patterns indicated that a year of higher rainfall alternates with a year of lower rainfall amounts. The study reveals that June winds causes over 95% in yield loses and suggests that the region can feed itself and export excess grains if only appropriate technologies to counter June winds effects are adopted. Since the occurrence of June winds is strongly linked to the La Niña climatic phenomenon the study suggests development of a maize yield prediction model for seasonal forecasting based on the onset of June winds during the long rains season.

Key words: June, Winds, Rainfall, Food, Africa

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INTRODUCTION

Background information

In most of the developing lowland tropics, climate appears to dominate the predictability of most agricultural enterprises [1]. Rainfall amounts and distribution are the single most important factors governing crop yields in these regions [2]. In Africa most of the food production systems are mainly rain-fed with consequent low yields.

While majority of the countries neighbouring large water bodies and proximate to the equator experience equatorial type of climate characterised by high average annual rainfall, high relative humidity, dense equatorial forests and high yields of both food and tree crops, the Eastern Africa including coastal Kenya, situated within the equatorial region (10°S-15°N) and adjacent to the warm Indian Ocean has an unexceptionally low rainfall, complicated distribution and variability [3, 4]. The high rainfall variability suggests dominance of local factors in modulating the rainfall amounts and characteristics rather than the large-scale global wind circulation system [5].

Thus although the Coastal region is endowed with enormous agricultural potential of good sandy-loam to clay loam soils, ample annual average rainfall of over 1200mm and over 3700 km^2 of arable land suitable for both food and horticultural crops, the region is highly food deficient. The region experiences chronic food shortages for most part of the year and is heavily dependent on relief food, with the bulk of the population living below the poverty line due to these physical and biophysical factors [6]. Its grain production barely meets 20% of its annual grain requirement. Indeed a single household's long rains' grain harvest lasts only 2 to 3 months at best [7, 8]. The 0.5 million metric tons (MT) annual grain yield is far below the Coastal region's production potential, estimated to be over 2.5m MT [8]. While other food deficit regions of Kenya utilise their short rains to produce maize and other cereal crops to bridge their deficit, these rains in Coastal Kenya more often cannot sustain a maize crop [9].

Given that every ocean has its own wind systems and that the wind systems are responsible for transfer of moisture and energy to cause rains, then the factors that influence wind systems in a given region equally affect the amounts of rainfall received and its distribution, and consequently crop yields [10]. Persistent at the Coast and parts of Eastern horn of Africa, unlike other regions, is the influence of high ambient temperatures and high velocity June winds [11]. Their occurrence at the critical stages of maize growth has been postulated to result in low grain yields during the long rains season. Indeed, among the major factors contributing to poor maize yields in the region, namely poor production technologies and harsh environmental conditions, high evapotranspirative demand occasioned by high ambient temperatures

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and June winds[1] occurrence have been singled out as the most important variables limiting yields of most annual crops in the region, especially cereals and maize in particular [8, 12].

This study was conducted to investigate the occurrence of June winds and their effects on food (maize) production and security in Coastal and Eastern regions of Kenya and by extension the Eastern Horn of Africa.

METHODOLOGY

The study area

The study centred on the lowland Coastal region of Kenya, located between 38.5ºE and 41.5º E between 0º and 5ºS and stretching from Kwale district in the south through Mombasa, Kilifi, Malindi and Lamu districts to the north, but area of influence cover the Eastern horn of Africa.

Procedure

The study involved analysis of 39 year records of rainfall data (1961-2000), wind run and review of secondary data including baseline surveys and maize yields in the region. Analysis involved deriving rainfall anomalies over the entire period and comparison of the respective means and rainfall patterns with respect to wind runs and respective maize growth stages during long rains season.

RESULTS

Monthly rainfall distribution and Potential evaporation in the region

Results in Table 1 indicate that the region experienced bimodal rainfall with at least some precipitation in most months of the year but only two months, namely April and May experience positive moisture regime for crop growth. In all other months, the potential evaporation exceeded received rainfall, implying deficit soil moisture situation for most part of the year, and reflecting a constraint in crop production in the region. The results also indicate that annual crops cultivation is possible from early April when appreciable rains have been received to offset at least 50% potential evaporation and continues up to mid July [11].

The results indicate that after peak rains in early May, the probability of a rainy day and amount of rain, suddenly dip to a low coinciding with peak June winds. A 5- day rainfall average for the month (not shown) indicates that this depression lasts 5 to 10 days with no rains.

[1] Part of the East African low level jet that manages to penetrates into mainland East Africa from the Indian ocean)

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DISCUSSION

Rainfall characteristics in the study area

Results in Table 1indicate that even though the region experienced bimodal rainfall with some precipitation in most months of the year, the short rains cannot sustain a maize crop since the potential evaporation exceeds received rainfall. This perhaps explains why little or no annual crops cultivation is done during short rains season and the land is left fallow, unconsciously replenishing soil fertility. That only two months in a year, namely April and May experience positive moisture regime for crop growth as potential evaporation exceeds received precipitation reflects a severe constraint in crop production and therefore food security in the region. This has serious implications for crop growth in that much of the received rains and therefore soil moisture evaporate long before the crop can attain maturity or produce yield. At young stages of development, maize plant tends to be tolerant to drought spells but the sensitivity to moisture stress increases with time, from floral initiation to grain filling.

The Interaction of June winds occurrence and rainfall

The effects of June winds and their mode of action are summarised elsewhere [11]. Composite Fig. 6 in [11] shows that occurrence of peak June winds occasions a decrease in rainfall probability and amounts. They cause this through subsidence by inducing cloud free conditions. Decrease in rainfall in most low-land tropics translates to a decrease or deficit in soil moisture (data not shown) and therefore impaired crop growth. A 5 day average wind run data (not shown) indicated that this depression in rainfall amounts lasted 7 to 10 days and occurred after the onset of long rains.

Indeed a look at rainfall data from other spatially distributed weather recording stations in region confirm this depression in rainfall amounts, reminiscent of the '*Ganges*' temperature depressions in India [11]. However, these depressions were also evident in months of May and July in certain years. These depressions indicate spatial and temporal variation in June wind strengths and intensity, relative to their progression through the expansive area and respective weather recording stations.

Normally, the method of imposing and the rate at which water stress develops, fast or gradual, determines plant's sensitivity, response and osmotic adjustment to prevailing water conditions [13]. More often, June winds tends to occur in the middle of long rains growing season, resulting in either splitting or shortening of the growing season.

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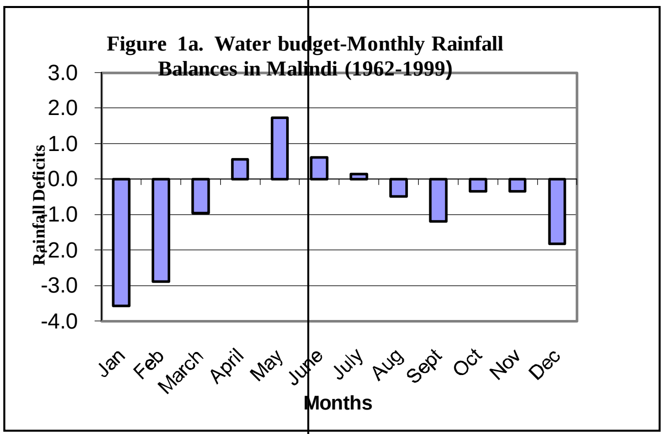
(1a)



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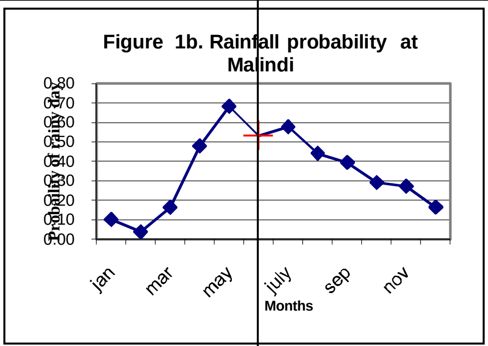

Maize developmental stages (Fig. 1c)

(1c)

	Pl		Fi		**Ta Si**		Fe/gs		**g/fil**		PM	
Month	M	A	Ma		June		July		Au			
Week			3	4	3	4	1	3	1	4	1	2

(1d)

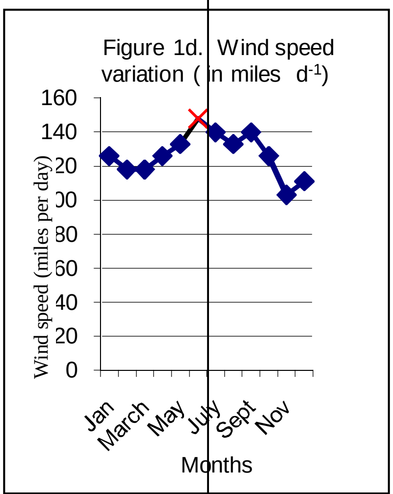

Figure 1: Coincidence of peak June wind speed, dip in rainfall probability and maize growth stages

Key: Pl=planting; Fi=Floral initiation; Ta= Tasseling; Si=Silking; Fe= Fertilisation; s/fil=Grain-set/grain filing; PM=Physiological Maturity. Underlined bold initials denote critical maize development stages sensitive to water stress. The top-bottom arrow connects timing of June winds occurrence with other variables

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Indeed rainfall data of hinterland locations indicate that rainfall amounts decrease with distance from the coast into hinterland, and that the occurrence of June winds more often signals termination of long rains and therefore end of the growing season before the crop attain physiological maturity. In Fig. 2 the triangle (marked Z) indicates the magnitude of rainfall decrease, ranging between 50 and 100mm in 1 to 2 weeks, due to June winds occurrence during La Niña years compared to El Niño years when the June's winds effects are suppressed.

Effects of high velocity June wind on crop evapo-transpiration

June wind speeds vary from 20m/s to over 50m/s, but on average are between 25 to 30 m/s. One of the effects of these strong winds is to increase the magnitude of evapo-transpiration from crops and soil surface. Wind speed affects the size of stomatal aperture openings, the amount of transpiration and also influences evaporation from the soil surface [14, 15, 16]. Strong winds increase turbulence thereby reducing the boundary layer resistance, and thus improve transport of water vapour towards the dry atmosphere [17]. However, soil evaporation forms a small component of overall seasonal water use (ET), while evaporation from crop constitutes the largest proportion [16].Crop yields increase in proportion to the amount of transpired water and the daily transpiration accumulated over a given time interval usually determines biomass production for that interval in a given climate [18, 19, 20, 21]. However, only a small proportion of the total water received in the soil is transpired by the plant and this is what is directly related to yield, the rest being lost either as evaporation from soil surface, runoff, and deep drainage. Dry matter accumulation (biomass) is parabolically related to final grain yield and as such crop growth and yields are intimately linked to plant evapo-transpiration [22]. Thus the effects of June winds on maize can be summed up as decreasing the available water for crop growth and inducing 'abrupt' soil moisture deficit, with consequent reduction in yields.

Interaction of June winds, rainfall and critical stages of maize development

In composite Fig. 1, when the graphs of annual water balance (Fig. 1a), rainfall probability (Fig. 1b) and monthly wind speed (Fig. 1d) and the time of occurrence of these winds were linked through an arrow (vertical line) to a chart of Pwani Hybrid (PH4) maize (*Zea mays*) growth and development stages (Fig. 1c), the June wind's effect on rainfall appeared to coincide with the critical stages of maize development.
Occurrence of water stress or soil moisture deficit during the critical stages of maize growth, namely germination, flowering, grain-set (Fig. 1c) and grain filling depresses biomass accumulation and therefore final grain yield, resulting in poor maize yields [22, 23, 24].

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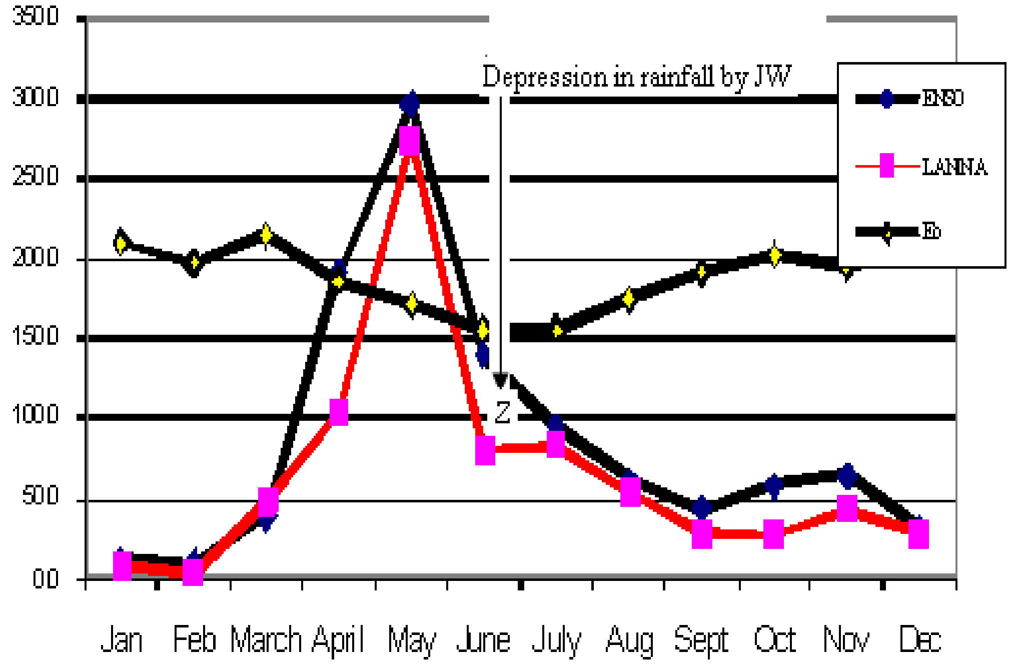

Figure 2: Depression in rainfall caused by occurrence of June winds
Note: During La Niña years, rains come late and go early in the season, while they come early and go late during El Niño years

By their high velocities coupled with high ambient temperatures, they enhance excessive evapo-transpiration, and by chasing rains away they induce drought and therefore water stress in growing field crops. Their sudden occurrence and change in velocity induces 'abrupt' soil moisture stress. Since the method of imposing and the rate at which water stress develops, fast or gradual, determines plant's sensitivity, response and osmotic adjustment to prevailing water conditions, the maize crop's sensitivity to water deficit conditions occasioned by June winds is high, and drastically curtails yield formation [13].

Effect of June winds on physiological components of maize yield

Data on dates of onset of rainfall in the region (not shown) indicates that, the timing of June winds onset and the stage of crop growth are in tandem in that, the date of onset of rains determines time of planting, and therefore stage of crop growth when June winds come. Those factors and mechanisms that occasion rainfall in the region (namely, the onset of northern summer monsoons, and therefore the south-easterlies and the ITCZ) are the same ones that trigger occurrence of June winds. The occurrence and intensities of June winds more often associate with La Niña years.

Composite Fig. 1 shows that June winds tend to occur in the middle of long rains growing season and this coincides with the critical stages of maize growth. This has severe implications on maize yields. The critical maize growth stages most sensitive to water stress and therefore peak water requirement occurs at germination, flowering and grain filling [23, 24, 25]. Inadequate soil moisture at flowering results in none or poor pollination as tassels and ovules die out, and also increases asynchrony between pollen shedding and the time the stigma are receptive and thus results in limited or no fertilisation, leading to poor yields [25]. Drought reduces leaf area, leaf photosynthetic rate, delays silking and reduces grain yield components, particularly grain number. Although the rate of grain growth and actual grain filling period (AGFP) increases with increasing temperatures, this is reduced by drought conditions [26].

Occurrence of soil water deficit or termination of rains during the critical stages of maize growth and development results in low biomass accumulation and ultimately leads to low yields [22]. Besides the timing of the water deficit has more influence on crop yield than the magnitude of the deficit itself [27, 28]. Based on this principle, this would perhaps explain why occurrence of June winds in the middle of the growing season between floral initiation and grain-set ultimately results in poor maize yields in the region [13].

Modulations of June winds by ENSO

The modulation of June winds by ENSO events is outlined in [11]. Fig. 8 indicates that there are years when the rains come early and persist longer, prolonging the length of growing season with consequent increase in amounts of received rains, that is, years of '*above normal*' rains. It also shows years when rains come late and withdraw early, with lower amounts of rainfall being received and resulting in a shorter growing season, that is, years of '*below normal rains*'.

Existence of Super, major and minor El Niños (period of years with "above normal rains") in East Africa region has been reported [29]. The periods of "drier than normal years" (La Niña years) tend to occur in runs or in succession [11, 30, 31]. This has implications on the region's soil moisture regimes and therefore food productivity which tends to be highly variable. The region only gets ample food production during the El Niño related seasons, when more rains are experienced, followed by a succession or runs of droughts due to 'below normal rains' and therefore crop failures.

During these years of 'above normal rains', the June winds effects tend to be either suppressed, or come late in the growing season, after physiological maturity, in August. During years of 'below normal rains' the rains come late and withdrawal early in the season (Fig. 2), with the bulk of the season's rains being received in few days, or reduced in amount. Available data indicate that June wind occurrences and their effects tend to be more prominent during the years of 'below normal' rainfall (La Niña years).

Investigations on seasonal rainfall variability over East Africa revealed seasonal migration of the rainfall patterns associated with the seasonal migration of the Inter-tropical Convergence Zone (ITCZ), which is modulated by ENSO (El Niño/Southern oscillation) [32]. Since the East African low level jet core coincides and moves along the zone of convergence between south-easterly and north-easterly trade winds (ITCZ), then

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any shifts in the path of the ITCZ due to ENSO modulations also shifts the course of the Jet stream more inland or away from the mainland [1]. This perhaps explains the absence of the June winds and their effects in the region during El Niño years.

Magnitude of yield loses occasioned by June winds occurrence

The area under maize cultivation opened annually in coastal region is 80,000 hectares (ha) out of the 3.7 million ha of available arable land [33]. Available data show that farmers realise less than 0.4t/ha maize yields due to June winds occurrence, resulting in only 3,2000 tons (355,555 bags worth ksh. 0.53 billion) of maize grain. Thus June winds occurrence in the region occasions yield loses of over 248,000 tons (2.8 million bags) of maize worth ksh. 4.2 billion, almost equal to the national maize strategic reserves. Besides, farmers in the region use over ksh. 240 million on land preparation for maize production. Thus it can be confidently stated that the June winds have impoverished and frustrated the efforts of farmers in the region and are a major factor contributing to increased malnutrition, food insecurity and dependency on famine relief.

Since maize is the major dietary component which the Coastal community almost exclusively depend on as a source of food in their daily lives, and a major source of income to the farmers and employment in the rural areas, June winds pose a major threat to the region’s food security, and increases uncertainty in food production [12, 34].

These winds are valued by the local farmers in the region as one of the most reliable early warning indicators of maize crop yields performance during the long rains season based on their time of occurrence [35]. The annual occurrence of this 1 to 2 week weather phenomena has for long impoverished and frustrated the efforts of the poor farmers in the region in that, after spending their meagre resources, either from own or borrowed credit in land preparation, planting and weeding the 80,000 hectares opened annually for cultivation, the yields are more often dismal, at less than 0.4t/ha. This is so even after using the improved seeds and fertilisers as recommended by Kenya agricultural research institute (KARI) [8, 33]. Indeed going by the low levels of technology adoption in the region, much of the modern farming technologies generated by KARI and other research organisations do not appear to achieve their intended objectives [12].

Given that recent studies point towards increasing frequencies of periods of drier than normal years and that most drought periods tend to occur in succession of 2-3 years, the frequency of abortive seasons or crop failures are likely to increase, rendering the bulk of the Coastal and Eastern African population dependent on relief food. Recent reports by the welfare monitoring survey of Kenya indicate that over 70% of coastal community live in abject poverty, part of which may be attributed to the effects of June winds [6].

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Development of maize yield prediction model

Analysis of Fertiliser Use Recommendation Project (FURP), maize trials data (1988-1992) in the region, indicates that during the years when June winds were prominent, average maize yields ranged from 0.6 to 1.2 tons per hectare (t/ha), while during El Niño years, when June winds appeared suppressed or diverted from the region, yields of 3.7 up to 4.5t/ha were realised (Table 2) [36]. District Agricultural annual reports in the region, indicated that most farmers realised less than 0.4t/ha due to June winds occurrence.

Consideration of received long rains amounts alone (not shown) revealed that the yields varied in unison with the rainfall amounts, and this appear to be modulated by the activities of the Quasi-biennial oscillations (QBO) (Fig.3). The magnitude of yield depression by the winds could be related to the sensitivity of the respective critical stages of maize growth (Fig. 1c) to 'abrupt' moisture stress conditions induced by the June winds occurrence. Thus timing of June winds occurrence at either vegetative, tasseling/silking, grain filling or at physiological maturity can be used in forecasting maize yields in the region. For instance Table 2 shows that during the years when June winds were prominent and occurred at critical stages of maize growth (marked **J**), maize yields significantly declined.

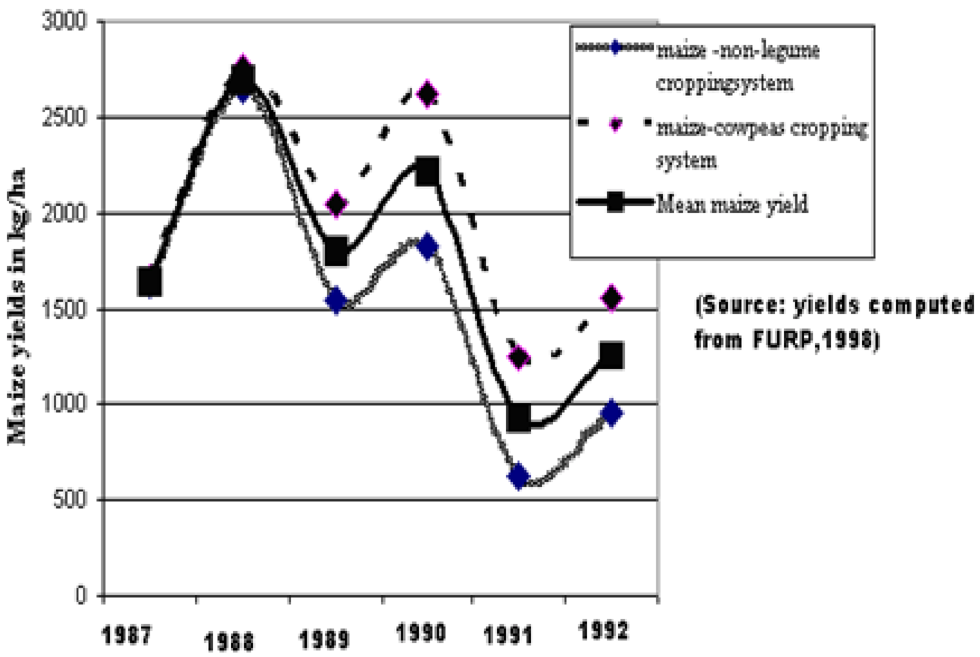

Figure 3: Maize yields trend in Coastal region of Kenya

Note: The maize yields vary in unison with changes in long rains amounts due to Quasi biennial oscillations

Given the recent advances in weather forecasting techniques and prediction of ENSO activities, development of a maize yield prediction model for the region is feasible [5].

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CONCLUSION

The main effects of June winds can be categorised based on their specific effects on: - (i) plants and yield; (ii) Soil moisture; (iii) prevailing weather (rain and ambient temperatures). They '*chase away*' rains by creating cloud free conditions adversely affecting the amount of rains received, soil moisture for crop growth, and also enhance excessive evapo-transpiration thereby aggravating soil water deficit. These effects can be summarized as follows: -

1) The weather during June winds 1-2 weeks occurrence during the long rains growing season tends to be excessively windy, moderately hot and dry;
2) Rainfall probability decreases and the growing season shortens or is split midway;
3) Plants tend to be stressed, weakened and highly susceptible to pests and disease attacks, especially stalk borer and maize streak due to excessive evapo-transpiration; the soils also dry faster causing imbalance in water uptake, and immobilisation of macro and in particular micronutrients, making them unavailable to the plant, further stressing the complex chemistry of the plants leading to low yields.

The fact that June winds occurrence is strongly linked to La Niña events and therefore ENSO activities present a good opportunity for predicting their time of onset during crop growth and gauging their severity on expected crop yields. This offers possibility of developing a maize yield prediction model for the region as part of an early warning system. The frequency and characteristics of these droughts years can be fairly predicted with some certainty. Relevant trainings need be conducted to increase awareness and improve in decision making. Equally, since crops yields in Coastal and Eastern Kenya have been observed to vary in unison with received long rains amounts, whose pattern is modulated by Quasi-biennial oscillation and that dry years occur in runs and into a trough, this important knowledge can be used in rationalizing input use, resource allocation and marketing in agriculture.

RECOMMENDATIONS

Farmers in the region need be sensitized about the behavior of the rainfall and wind patterns on how they affect their final harvest and therefore their livelihoods to enable them make informed decisions in allocation of their limited resources. Technologies that ameliorate the effects of high temperature and high wind velocities on crop growth and yield need be developed to stabilize crop yields in the region.

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Table 1: Mean monthly rainfall and potential evapo-transpiration (Eo) for Malindi

			Long rains season							Short rains season			
Months	Jan	Feb	**Mar**	**Apr**	**May**	**June**	**July**	Aug	Sept	**Oct**	**Nov**	**Dec**	Total
Mean monthly rainfall in mm	11.4	9.4	**39.9**	**194.8**	**305**	**143.2**	**97.7**	63.0	44.9	**65.2**	**70.5**	**33.7**	1078.7
Eo in mm	210	197	**215**	**186**	**171**	**156**	**156**	175	191	**202**	**195**	**205**	2259
Net moisture regime	-198.6	-187.6	**-175**	**8.8**	**134**	**-12.8**	**-58.3**	-112	-146.1	**-136.8**	**-124.5**	**-171.3**	-1180.2

Note: Only April and May experience positive moisture regime, in all other months potential evaporation exceeds received precipitation

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Table 2: Maize yields in Coastal Kenya (1987-1992), as affected by June winds occurrence

	Years of trials and maize yields in kg/ha						
Site	1987 **J**	1988 **M**	1989 **N**	1990N	1991 **J**	1992**J**	Mean
Mtondia	2108	3105	1512	2814	1062	-	2111
Mtwapa	1183	1501	1008	1353	428	-	1094
Lutsangani	-	2475	2459	3033	1174	1021	2553
Lamu	-	3722	2228	1691	1057	1492	2348
Mean	1645.5	2700.7	1801.6	2222.5	930	1256.2	1917

(Source: FURP, (1998).

N.B: The years marked **J=** June winds (JW) came in month of June, show lower yields; **M**= JW in May, coinciding with vegetative stages of maize growth, show no significant decline in yields; **N=**absence of June winds or they came late in the growing season

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