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Smartphone application to aid farmers on expected rainfall onset dates and associated seasonal risks of dry spells in Uasin Gishu County, Kenya

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ABSTRACT
Onset of growing season in Uasin Gishu County is estimated by farmers through observation of weather and natural migration of birds. However, rainfall characteristics have become more unpredictable, resulting in replanting due to false onset. This strains majority of farmers who are resource inadequate to meet expenses of replanting maize, the major subsistence crop in the study area. This study aimed at spatial analysis and mapping of rainfall characteristics based on historical rainfall data and gaps filled using CHIRPS sourced rainfall data to determine the relationship between the onset, cessation and length of growing season as well as occurrence of dry spells. Thereafter, dependable onset dates were derived through frequency analysis and also dry spell occurrence was done. Results were used to develop smartphone application to relay in simple and efficient manner site specific information to aid farmers in planning of farming activities, by anticipating long term risks and making appropriate adjustments to increase their farm resilience. The android smartphone application developed will help farmers in Uasin Gishu County to navigate challenges of ever changing weather patterns and lack of access to accurate weather information through relaying of timely climate and weather information. Based on study results, it is recommended that coverage of the application be extended through spatial analysis and mapping of rainfall characteristics at a regional scale.

Key words: Cessation of rainfall, Kenya, length of growing season, planning, spatial analysis

RÉSUMÉ
Le début de la saison de croissance dans le comté de Uasin Gishu est estimé par les agriculteurs grâce à l'observation du temps et à la migration naturelle des oiseaux. Cependant, les caractéristiques pluviométriques sont devenues plus imprévisibles, avec pour conséquence une nouvelle campagne de plantation à une date inappropriée. Cela concerne la majorité des agriculteurs dont les ressources sont insuffisantes pour couvrir les dépenses de semis du maïs, principale culture de subsistance dans la zone d'étude. Cette étude visait l'analyse spatiale et la cartographie des caractéristiques pluviométriques sur la base des données pluviométriques historiques et des lacunes comblées à l'aide des données pluviométriques extraites de CHIRPS afin de déterminer la relation entre le début, la cessation et la durée de la saison de croissance, ainsi que la survenue de périodes sèches. Par la suite, des dates de début fiables ont été dérivées par analyse de fréquence et un épisode de sécheresse a également été réalisé. Les résultats ont été utilisés pour développer une application pour smartphone afin de relayer de manière simple et efficace des informations spécifiques à un

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site afin d'aider les agriculteurs à planifier leurs activités agricoles, en anticipant les risques à long terme et en effectuant les ajustements nécessaires pour accroître la résilience de leurs exploitations. L'application pour smartphone Android développée aidera les agriculteurs du comté de Uasin Gishu à surmonter les défis liés aux conditions météorologiques en constante évolution et au manque d'accès à des informations météorologiques précises en relayant des informations actualisées sur le climat et la météo. Sur la base des résultats de l'étude, il est recommandé d'étendre la couverture de l'application au moyen d'une analyse spatiale et de la cartographie des caractéristiques pluviométriques à l'échelle régionale.

Mots clés: Cessation des précipitations, Kenya, durée de la saison de croissance, planification, analyse spatiale

INTRODUCTION

In Kenya, maize is the main staple food for the majority of people and is mainly produced in Uasin Gishu County, the country's grain basket, under rainfed conditions. The County experiences two rainfall seasons, i. e., the long rains and the short rains, March to September and October to December, respectively. This makes the area suitable for rainfed agricultural activities. However, the rainfall characteristics in terms of the start of the rainy season, duration and end of the season have over the years become uncertain with the recent year 2017 being among the worst; KMD, 2017.

The variability in the start of the rainy season has made land preparation and planting difficult especially for small scale farmers struggling to generate the expenses for land preparation and purchase of seed and fertilizer. Occasionally farmers have been forced to re-plough and replant resulting in their yields being affected significantly by the delayed start of the rainy season and high frequency of damaging dry spells within the growing season. Therefore, the ability to estimate effectively the right time to sow is likely to improve the chances of better yields and reduce losses as a result of crop failure.

Previous work on estimating the probable start of the planting season has employed different techniques depending on the rain generating mechanism of the region in question. Some of these methods are based on accumulated depth of rain and the soil water balance approaches (de Arruda and Pinto, 1980; Sivakumar, 1992; Sharma, 1996; Adiku *et al.,* 1997; Barron *et al.*, 2003; Mebrhatu *et al.,* 2004; Raes *et al.,* 2004). In this approach, a day is considered an appropriate planting date after a specific amount of rain falling over a day or several days has been received. Oshodi (1971) using the simple pentad method arrived at isochrones for the start and end of rainy seasons in Nigeria. Nicholls (1984) used a wet season index in determining the existence of the seasonal rainfall in Australia. Calooy (1981) used auto regression models in predicting the seasonal rainfall in Bangladesh. Stewart and Hash (1982) evaluated the suitability of a given crop for a semi-arid location in Kenya using a water balance approach. Individual seasons were categorized according to date of rainfall starting and its adequacy for maize. For bimodal rainfall regions of Kenya, it was shown (Stewart, 1985), that if the start of rains is early, maize could be grown, but in the case of delayed start, which occurs in about half the number of years, sorghum and millet should be favored over maize.

The presence of a relationship between the start, length and duration of the planting season is vital towards the planning of agricultural activities for a farmer. A study by Oladipo and Kyari (1993) indicated the length of the growing season is more sensitive to the start of the rains than the end and therefore reliable prediction of rainfall characteristics especially the start of the season is necessary for a more productive farming. Hence, the analysis of rainfall characteristics for agricultural purposes necessitates the inclusion of trends in rainfall, the start and length of growing season, distribution and variability of rainfall within the seasons. For planning of rainfed agriculture, dependable probability levels of the start, duration and end of the rainy seasons is paramount. This probability of occurrence should then be accessed by the farmers in the right time through the most convenient channel to enable farmers realize the potential benefits associated with utilization of such information. This paper highlights the development of a smartphone based system for aiding farmers in their decision making which was developed and tested using Uasin Gishu County as a case study.

MATERIALS AND METHODS

Study Area. Uasin Gishu County lies between the coordinates 0.51430 N- 0.63330 N and 35.02070E- 35.26970 E. The county shares common borders with Trans Nzoia County to the North, Elgeyo Marakwet County to the East, Baringo County to the South East, Kericho County to the South, Nandi County to the South West and Kakamega County to the North West. It covers a total area of 3,345.2 sq. km. It is a highland plateau with altitudes falling gently from 2,700 metres above sea level to about 1,500 metres above sea level. The topography is higher to the east and declines gently towards the western border.

The rainfall in the study area is influenced by various factors with the main ones being, topography, and wind patterns. There are two main rainfall season in the study area, the 'long rains' occurring from March to September and the 'short rains' which occur from October to December. Daily rainfall and temperature data records from two meteorological stations (Eldoret and Eldoret International Airport meteorological stations) and four weather stations (Moiben, Turbo, Moi and Timboroa weather stations) distributed in Uasin Gishu County were obtained. The data were used to calibrate CHIRPS data which is a spatial rainfall data using the double mass curve approach. The data were then used to determine the onset, cessation, length of growing season and the associated dry spell risks.

Growing season rainfall characteristics. Onset was quantified by the depth method as described by Reas *et al.* (2004). It considers a cumulative rainfall depth that will bring the top 0.25 m of the soil profile to field capacity during a maximum of 4 days. AquaCrop model (Raes *et al.*, 2004) was used to identify suitable planting dates. According to Huggins *et al.* (1981) the start of planting season can also be described as when precipitation exceeds 0.5 reference evapotranspiration (ET_0). In this study, rainfall was generally expected between March to September and October to December. Based on these two seasons planting strategies have been defined by the first definition. The ETo for each station was determined using ETo calculator from the FAO website (Allen *et al.,* 1998). Crop factors were then used to approximate crop evapotranspiration for no water stress conditions (Allen *et al.,* 1998).

The end of the planting season (cessation) has been quantified as the date on which the water stress in the root zone of the maize crop exceeds the threshold value. According to Huggins et al. (1981) the end of planting season can also be described as when the utilization of the assumed quantum of stored soil moisture (100 mm) after precipitation falls below ET_0.

The length of the planting season has been determined by finding the difference between the ending and the starting date. However, it should be noted that the start, length and end of the season are not fixed but is a range of values with associated probabilities. These probabilities have been obtained from statistical analysis using Rainbow software (Raes *et al.,* 2004).

A 'dry spell' is a period where the weather has been dry, for an abnormally long time, shorter than and not as severe as a drought (Muthugama *et al.,* 2011). For this research, a dry weather is defined to be when rainfall is less than 1mm. According to Reddy method (1983), dry spell can be described as when the simple ratio of weekly precipitation (P) over Reference Evapotranspiration (ET_0) is less than 0.5. (i.e. P/ ET_0 0.5 translates to a dry spell.) Based on the same method, crop failure has been anticipated to be when the growing period is less than five weeks in one year.

Data analysis. The probability of the occurrence of rainfall was estimated using Rainbow software. In the probabilistic analysis of onset and cessation, the data were fitted into a log normal distribution, which had the best fit. The onset and cessation were then divided into four significant levels based on the probability of non- exceedance. Very Early 90%, Early 80%, Normal 50%, late 20%, Very late 10%.

Upon the establishment of the probabilities of onset, cessation, length of growing season and associated risks, spatial mapping was done using Kriging method in Arc GIS for all the parameters as it provides an optimal solution for griding(Johnson, 2009). Kriging generally involves quantifying the spatial structure of the data, i.e., fitting a spatial dependence model to the data, and making prediction for an unknown value of a specific location. Predictions of unknown values are achieved by using the fitted model from the spatial data configuration and the values of the measured sample points around the prediction location.

Smartphone application. A smartpone application was developed for android operating system. This is because the existing smartphones operating systems android, iOS, Windows 10 Mobile Black Berry 10, Tizen, Sailfish OS and Ubuntu touch have their own advantages and disadvantages. However, on comparison android has comparative advantage upon the rest with a leading world market share of about 86.1% followed by iOS of 13.7% according to Khalid *et al.* (2017). Android is therefore increasingly becoming popular among the smartphone users because of various reasons; it is an open source Operating System which developers find it easy to configure their newly developed applications to android, thus attracting the developers coming up with new technologies. Cost effective marking is enjoyed by android operating system due to the support from Google play making marketing of developed android applications much easier. Android Operating System facilitates an integration of the various mobile applications being offered by android. This offers flexibility to developers of applications. The success rate, reduced cost of developing smartphone applications, large market base being enjoyed by android and the availability of android based smartphones at low cost amongst other mentioned factors led to the decision of developing an android application to aid farmers establish dependable onset days in Uasin Gishu County. However, for the farmers aged above 60 years, using the application has become challenging and a simpler version to convey the same in a text is being developed.

RESULTS AND DISCUSSION

Studies have indicated the existence of three rainfall peaks within the western Kenya region that forms part of Uasin Gishu. This led to the categorization of seasons as: March- May, June – September and October –December (Beltrando -1990). However, in this study only two seasons have been considered, March- September for long rains and October to December for short rains.

It was observed that there was a strong correlation between spatial and point rainfall data. This formed a good basis for calibration of the spatial data before being used for the analysis of onset, cessation and the associated risk levels. Figure 1 shows a regression plot of satellite and point rainfall data for Eldoret meteorological station with a strong coefficient of determination of 99.77%.

From the results of onset it was established that there was a trend on the progression of onset days within Uasin Gishu County. It starts from early March to end of April. The areas far North, South and North-western part have their onset earliest, then it slowly progresses to the central part of the region. Some areas are considered homogenous zones having the same physiographic features. For some areas, e.g. Eldoret International Airport, they have localized climate due to the activities of the airport and the effects from the neighboring Nandi County which is cool and wet. Figure 2 (a) illustrates the distribution of very late onset for Uasin Gishu County.

Cessation results also showed a general progression starting from the furthest point in the North and South and ending at the central part of the region as shown on Figure 2 (b). Cessation and onset results are linked by the length of the growing season. And depending on the strategy utilized, either very early, early, normal, late or very late, the length of the season will vary and hence the cessation date. Generally, it was observed that the central part of the region that experiences late onset and cessation despite the strategy used have the longest growing season length while the extreme north and south having their onsets and cessation early having the shortest season length (Figure 3(a)).

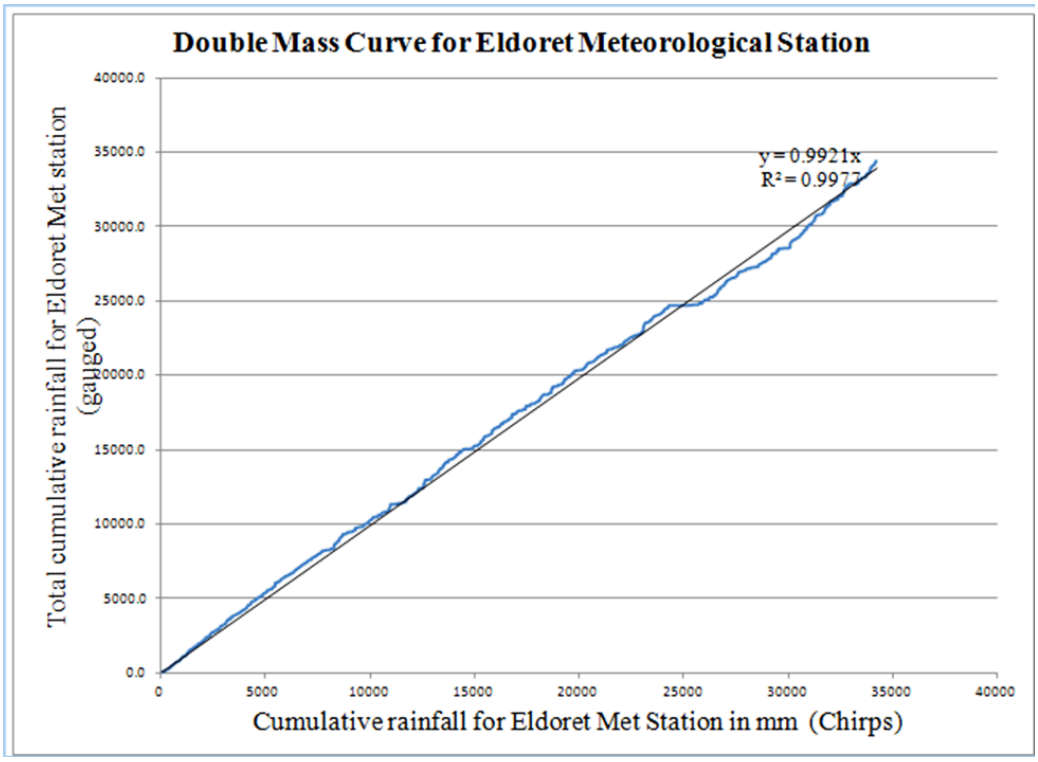
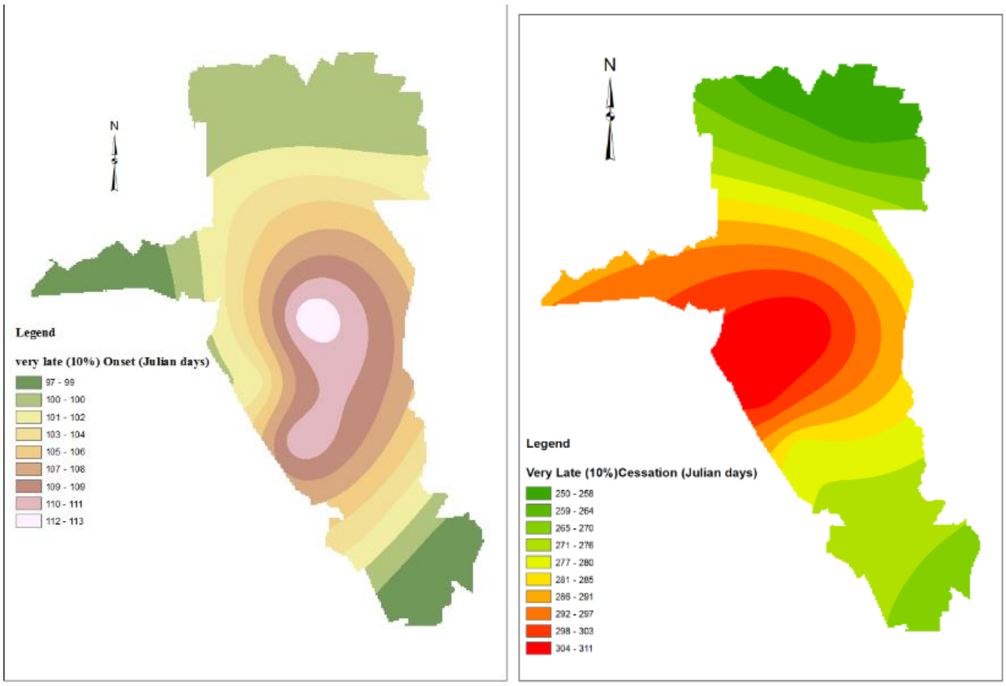
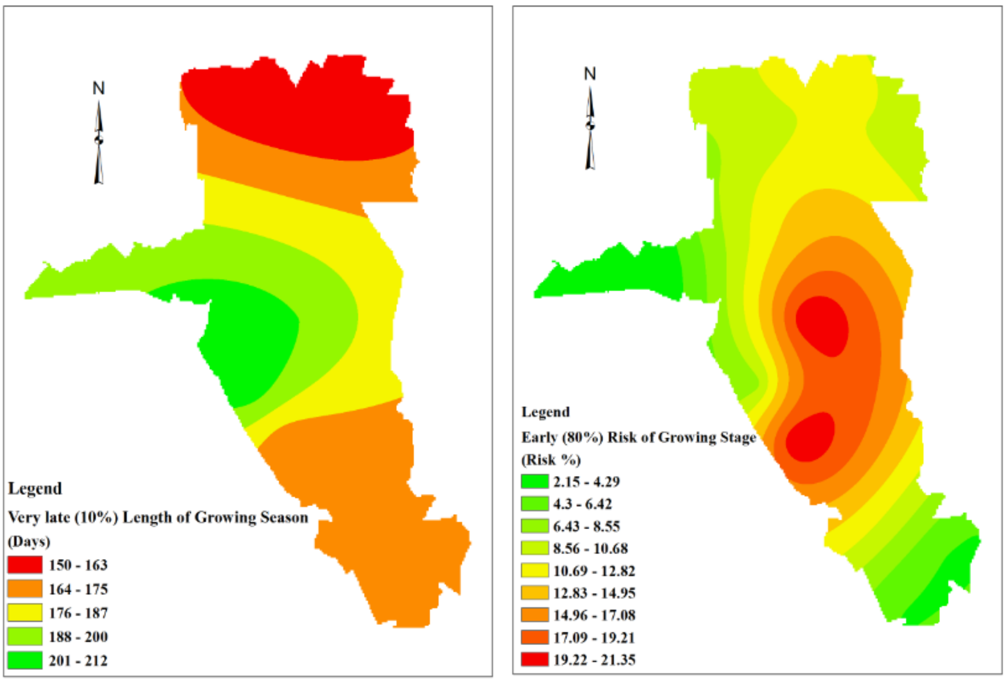


Figure 1. Double mass curve for Eldoret Meteorological Station



(a) (b)

Figure 2. Spatial distribution of very late onset (a) and cessation (b)



(a) (b)

Figure 3. Spatial distribution of length of the growing season (a) and risk of dry spell during the initial stage at 80% significant level (b)

The results of dry spell analysis showed that there is a high chance of a very early onset being a dry day. The risk of having a dry spell during a very early onset is high ranging between 0.1 and 0.3. Also, a very early onset has the least probability of experiencing dry spell during the development and the mid- stage for all the stations. These two stages are critical to the maize plant as it is when flowering and seed development takes place. Hence, the strategy of planting at the very early onset is of advantage to the farmer. When utilizing this strategy, the farmer is likely to do dry sowing and the amount of moisture in the soil will be least compared to the other strategies of early, normal, late and very late sowing. This will protect the seed from spoiling by presence of moisture that is not sufficient to support germination. It is then expected that with time the seed will germinate and there will be sufficient moisture in the soil from the expected rainfall for the entire season.
It is important to note that when the different strategies for sowing are used, there are different expected levels of dry spells within the development stages of the maize crop. The general trend is that the probability of a dry spell within any of the four development stages, (initial, development, mid and late stages) decreases starting with the least when utilizing the very early onset strategy to the very late strategy. Therefore, despite the advantage of having more than sufficient rainfall when utilizing the very late onset strategy and having low probability of failed germination, it is important for the farmer to evaluate the possible risks of dry spell within the growing season that will have a significant impact on the yield. It is therefore advisable to utilize the early or very early onset that have the lowest risk of experiencing dry spells during the growing season. Figure 3 (b) shows the spatial distribution of dry spell risk during the initial stage.

The android application "Farm app" developed in this study can be downloaded from play store using the link: https://play.google.com/store/apps/details?id=com.collengine.sulu.myweatherapp

CONCLUSION

The onset and cessation dates were identified from spatial rainfall data for the entire of Uasin Gishu County. The identified onset and cessation dates and lengths of the growing season are presented in the form of dependable probability of exceedance levels, which are quite valuable for planning of rainfed agriculture. Analysis of onset results indicates there is an organized progression of rainfall onset within the county. Cessation also has trend that is closely related to the onset but to some extent is influenced by localized effects.

The use of spatial data to fill the missing point data to determine onset and cessation dates has proved to be successful from the strong correlation between the point rainfall data and spatial rainfall data. Hence, the development of android application from spatial rainfall data can enable farmers from all over Uasin Gishu County to be able to access climatic information affecting their agricultural practice at their farm levels. Therefore, the success of implementation of this android application for Uasin Gishu County should enable expansion of coverage to a regional scale and for a wider variety of crops.

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STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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