VERIFICATION OF MEDIUM-RANGE WEATHER FORECASTS OVER TANZANIA

BY

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ABSTRACT

There are several weather forecasting systems within and outside Tanzania issuing medium-range rainfall forecasts. However, few attempts have been made to evaluate the accuracy of these forecasts. Hence the major objective of this study was to evaluate some selected medium-range rainfall forecasts and forecasting systems issuing those forecasts. Based on the above objective, the study could firstly evaluate medium-range rainfall forecasts in selected bimodal and unimodal areas of Tanzania; secondly identify the most important verification indicators on rainfall forecast accuracy relevant to agriculture and lastly compare forecasted rainfall amounts by Accuweather with actual rainfall amounts as recorded by TMA. The datasets used include 10-day rainfall forecast generated by two forecasting systems in Africa namely; the Tanzania Meteorological Agency (TMA), the Intergovernmental Authority on Development (IGAD) Climate Prediction and Application Centre (ICPAC) formally known as Drought Monitoring Centre (DMC)-Nairobi. Others included the National Centre for environment Prediction (NCEP) in the USA, and State College Accuweather Company also in the USA, and observed 10-day accumulations of precipitation of five selected stations from TMA. The method used to investigate the overall and specific objectives included the contingency table that shows the frequency of “yes” and “no” forecasts and occurrences. In the same way, categorical statistics skill measures were computed from the elements in the contingency table to describe particular aspects of forecast performance. Results from Accuweather forecast products appeared to perform better in the short rainy season (OND) than in the long rainy season (MAM) with respect to accuracy. Similarly, the ICPAC forecasts products appeared to perform better in the OND than in MAM season. Generally on the other hand, all the three forecasting systems (NCEP, Accuweather and ICPAC) all forecasts were worse than the reference forecast based on the HSS negative skill scores obtained for all rainy seasons.

DECLARATION

I, VENERABILIS KULULETERA, do declare to the Senate of Sokoine University of Agriculture that the work presented here is my own original work, and has not been submitted for the degree award in any other university.

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The above declaration confirmed

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

Over 95% of Africa's agriculture is rain-fed. As such, rainfall will remain to be the most important factor limiting agricultural production in the arid and semi-arid regions of the tropics (Kipkorir, 2002). A significant part of the African continent is semi-arid, making agriculture a challenging undertaking. The effects of climate change will but exacerbate the situation in terms of reduction of the length of growing season as well as forcing large regions of marginal agriculture out of production (Bako *et al*., 2007). Many of the most effective measures to adapt to future climate change coincide with those that reduce vulnerability to current climate risks. This principle lies behind climate risk management, which integrates management of current climate variability and extremes with adaptation to climate change (Burton and Van Aalst, 2004; Hellmuth *et al*., 2007). This climate risk management approach offers immediate benefits to economic development in Africa, as well as longer term security in the face of changing climate.

The importance of agriculture expressed as percentage of Gross Domestic Product (GDP) and exports in most African countries, combined with farming sector's reliance on the distribution of rainfall during the rainy season make countries in the region particularly vulnerable to climate change (Siri and Santiago, 2001). The impact that climate variability has on predominantly rain-fed agrarian economies is clearly demonstrated by Tanzania and Ethiopia, where GDP closely tracks variations in rainfall. About half of Tanzania’s GDP comes from agricultural production, the majority of which is rain-fed and highly vulnerable to droughts and floods (Molly *et al*., 2007). The impacts of agricultural failure due to these extreme weather events could be better mitigated and managed with improved weather/climate prediction and enhanced rainfall monitoring capabilities (Menghestab, 2005).

Rainfall exhibits notable spatial and temporal variability (e.g. IPCC, 2007). Interannual rainfall variability is large over most of Africa and in some regions (e.g. western and southern Africa) multi decadal variability is also substantial. During recent decades, the Greater Horn of Africa (GHA) has experienced an intensifying dipole rainfall pattern on the decadal time-scale. The dipole is characterized by increasing rainfall over the northern sector (Somalia, eastern Ethiopia, and northern Kenya) and declining amounts over the southern sector (southern Kenya, northern Tanzania, Uganda, Congo tropical rainforest, and western Sudan) (Schreck and Semazzi, 2004).

The ability to predict weather and perform seasonal forecasts has improved over the past few decades (Murphy *et al*., 2000; Colin, 2002). Short and medium-range, seasonal and long-range timescale predictions are now made routinely at a number of operational meteorological centres around the world, using comprehensive coupled models of the atmosphere, oceans, and the land surface (Kanamitsu *et al*., 2002; Coelho, 2002). The purpose of a weather forecast should be to help people make better weather-information dependent decisions. In regions that depend substantially on rain-fed farming, foreknowledge of the likely pattern of precipitation could imply substantial improvements to food security as well as profits to large-scale producers.

Weather forecasts for agriculture can be grouped into short-range forecast (up to 48 hours); medium range forecasts (3-10 days) and long range forecasts (monthly, seasonal and interannual time scales) (Ogallo *et al*., 2000). Medium range and seasonal forecasts provide a range of possible climate changes that are likely to occur in the season ahead. The principal aim of medium range and seasonal forecasting is to predict the range of values, which is most likely to occur during the coming period. Applications of medium range and seasonal predictions can therefore form the basis for sustainable development, employing scientific information to improve the current standard of life.

Research undertaken in Southern Africa has shown that seasonal/climate variability impacts on many aspects of the economy (Jury, 2002). Forecasts could aid agricultural planning by enabling decisions involving climatic risks to be better informed (Hammer, 2002). For example, forecasts could help farmers decide what type of crops to plant and when, what precautionary measures to take, whether to diversify or not, and in so doing could avoid undue risks (Sivakumar *et al*., 2002).

There are other practical examples of weather and climate information providing added value to development efforts and investments. In Zimbabwe, Pat *et al*. (2005) showed that farmers who reported changing specific decisions such as planting date or crop variety on the basis of seasonal forecasts clearly out performed farmers who did not use the forecasts, with yield gains of up to 17%.

To optimize weather information dependent decisions, verifications of these weather products has to be performed to regularly assess the accuracy and skillfulness for the user requirements, and that users have a positive perception of, and are satisfied with the products. Verification of weather forecasts has been undertaken since at least 1884 (Muller, 1944). There exists a vast array of statistics for the description of various aspects of forecast systems, such as those discussed for weather and climate by Jolliffe and Stephenson (2003); Allen *et al.* (2005); Anderson (2005); and Buizza (2005). Forecast attributes have been discussed in the context of specific types of forecasts (Toth *et al.*, 2003). Jolliffe and Stephenson (2003) for example, use classification of forecasts (i.e. deterministic, probabilistic and qualitative) on binary forecasts and continuous variable forecasts.

To assess these forecasts, two ways of scoring probabilistic forecasts are in use. One is to use some measure of the departure between forecasts and observations and the other is to do a conversion from the probabilistic form to a binary yes/no form (Zhang and Casey, 2000). Many skill-scoring schemes have also been developed and used in the verification of probabilistic forecasts in meteorology. Atger (2004) discusses examples of these approaches.

It is clear that a lot of work has been done in various countries on short and medium-range weather forecasting especially in the developed countries. However, very little has been done on the forecast verification of medium-range products in the developing countries including Tanzania. Assessment of medium-range forecasts for Tanzania constitutes the research problem of this study.

Although seasonal forecast products in different agro-climatic zones of Tanzania have been evaluated (Mwano, 2006), weekly or 10-day weather forecasts are yet to be evaluated. TMA's modeling and verification section evaluates daily weather forecasts issued by the Central Forecasting Office, but weekly/10-day weather forecasts are never evaluated.

This study is therefore expected to provide a detailed assessment of specific strengths and weaknesses of medium-range forecasts and forecasting systems issuing these forecasts. The forecasts used in this study were those generated by two forecasting systems in Africa namely; the Tanzania Meteorological Agency (TMA) and the Greater Horn of Africa (GHA) countries Drought Monitoring Centre (DMC) – Nairobi. The other two forecasting systems included the National Centre for Environment Prediction (NCEP) and State College Accuweather Company also in the USA.

1.2 OBJECTIVES

1.2.1 Overall objective

The main objective of this study was to evaluate some selected medium-range rainfall forecasts and forecasting systems issuing those forecasts.

1.2.2 Specific objectives

- To evaluate medium-range rainfall forecasts in selected bimodal and unimodal areas of Tanzania.
- To identify the most important verification indicators on rainfall forecast accuracy relevant to agriculture.
- To compare forecasted rainfall amounts by various forecasting systems with actual rainfall amounts as recorded by TMA for some selected stations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Types and need for weather forecasts

Climate information and prediction products in agricultural applications can be classified into (1) Short-range weather forecasts of up to 48 hours; (2) Medium-range weather forecasts of 3-10 days; and (3) Long-range weather forecasts and climate prediction of mostly, seasonal and inter-annual time scales (Ogallo *et al*., 2000). The amount of detail contained in a weather forecast depends on the range of the forecast that is, how far into the future forecasters are attempting to gaze.

Short-range weather forecasts (SRF) cover 24 to 48 hours and are highly detailed. SRF describe the behaviour of weather variables (precipitation, air temperature, sky coverage and solar radiation, wind velocity and direction, etc.) and weather phenomena (frontal systems, anticyclones, tropical cyclones, squall lines, etc.). Out of the various factors, which control agricultural production, short-range weather forecast is one factor which man has no control and has significant potential environmental impact.

Medium-range forecasts (MRF) look at conditions from three to ten days ahead. They are more general. The forecasts look at conditions and provide a range of possible climate changes that are likely to occur in the period ahead. The starting point for medium forecasting is a good knowledge of climate, that is, the range of weather that can be expected at a particular period (Maunder, 1970). The medium range forecast products include: 1) surface pressure patterns, circulation centers and fronts; and 2) expected weather.

Long-range forecasts (LRF) extend from thirty (30) days up to two (2) years. In some countries, long-range forecasts are considered to be climate products (WMO, 2000). Long-range forecasts provide a range of possible climate changes that are likely to occur in the season ahead similar to medium-range forecasts described above.

According to Holger and Roger (2005), SRF and MRF are important for farmers in order to plan the day’s work on activities like:

- preparatory activities, such as land preparation and preparation of planting material

- planting or seeding/sowing
- crops, fruit trees and vine management; application of fertilizer, irrigation; thinning, topping, weeding; pest and disease control management of grazing systems
- harvesting, on-farm post-harvest processing and transporting of produce
- livestock production (dairy enterprises, beef systems, lamb and other livestock systems)

Furthermore, quantitative forecasts are an important source of data for simulation models that produce information useful for farmers (simulation of crop phenology, water and nutrient cycles, crop production, weed, disease and pest cycles, etc.).

In the earlier days, the most common expressed need in the use of meteorology in agriculture was simple short-range weather forecasts to plan or guide operational activities (Jagtap and Chan, 2000). Jaghtap and chan (2000) however, express that these days some agricultural agencies in Malaysia are using short and medium-range forecasts for planning daily, weekly and even monthly operational field activities. In this regard, farmers need weather forecasts to plan and organize their field activities. These ranges of forecasts create the possibility of tailoring crop management to anticipated weather conditions either to the advantage of favourable conditions or to reduce the effects of adverse conditions (Mjelde *et al.***,** 1997). Hence, advance warning of impending extreme climate events would provide important information, which could be used, for sustainable agricultural production.

Agricultural systems are notoriously responsive to climate fluctuations, creating real potential for skilful climate forecasts to improve resource management and the welfare of rural populations. Since climate shocks can have devastating effects among the rural poor, special attention is being given to understand what potential, if any, exists for using weather/climate forecasts. This can mitigate downside risk and create new opportunities for reducing poverty and vulnerability. Hence, much effort is currently being directed toward improving the skill and dissemination of climate forecasts (Hammer *et al*., 2001). Climatic variability is especially pronounced and important in the dry land regions that encompass roughly two-thirds of the African continent, an area home to roughly 50 million or so Africans, a population typically far poorer than those in higher rainfall areas (Galvin *et al.*, 2001).

Droughts and floods in the Horn of Africa that buffeted the region's, pastoralists in the past few decades have combined with recent advances in climate modelling to pique donor and government interest in weather/climate forecasting and forecast delivery channels. Considerable resources have therefore been directed toward building up climate forecasting and dissemination capacity in the region, with the Drought Monitoring Centre (DMC) in Nairobi at the hub of most of such efforts (Curry, 2001). The return on these investments depends in part on an unstated assumption that climate forecast information will prove valuable to the vulnerable populations. It is meant to help not only indirectly, as an input into early warning systems at national and regional levels, but also directly, as a basis for improving individual's choice under uncertainty. These foundational principles of information theory identify several crucial questions one needs to address to assess the value of weather/climate forecast information for any population of intended beneficiaries.

The accuracy of forecasts depends on effective measurement of known predictors, model quality and local interpretation. In 1997-8, indicators showed that an El Niño was in progress, and would cause drought in NE Brazil, southern Africa and Melanesia (ODI, 1999). Preparations were made throughout southern Africa, causing considerable scepticism when the expected drought failed to materialize. Similarly, predictions for January to March 1999, adjusted by the SARCOF meeting in December 1998, predicted above average rainfall in southern Africa, whereas observed rainfall was in fact lower than average. These technical failures have had the effect of enforcing more humility on climatologists and called into question the utility of widespread dissemination of forecast material.

Growing understanding of ocean-atmosphere interactions and advances in modelling the global climate systems now provide a usable degree of predictability several months in advance for many parts of the world (Goddard *et al*., 2001). Integrating weather/climate forecasting with agricultural system analysis can increase its effectiveness (Hammer *et al.*, 2002; Meinke *et al*., 2004).

Unganai *et al*. (2004) quantified the economic benefits of applying weather forecasts for smallholder farm management in Zimbabwe. Controlled on farm experiments and a household economic model were used for the investigation. They found that, farmers who use weather information to decide on time of planting and nitrogen fertilizer application stand to benefit economically.

2.2 Performance measures of weather forecasts

Jolliffe and Stephenson (2003) optimized classification of forecasts on binary forecasts, categorical forecasts, continuous variable forecasts and probability forecasts to assess the performance measures of weather forecasts. With a binary forecast of an event, a contingency table is usually constructed to count the correct predictions of observed events (hits), their non-prediction (misses), the prediction of non-observed event (false alarms) and the correct prediction of non-observed events (correct negatives) (Mason, 2003).

There are many different skill scores that attempt to assess the above forecast performance measures, i.e. how much better the forecasts are than those which could be generated by climatology, persistence or chance. A few of these scores and parameters are discussed below.

Accuracy is the number of correct forecasts for events and non-events divided by the total number of forecasts. Accuracy measures how well the forecasts correspond with the observations on average and is given as:

$$Accuracy = \frac{hits + correct\ negatives}{total} \quad \text{……………………………….. (1)}$$

Where hits is the number of correct predicted events and correct negatives is the event forecast not to occur, and did not occur. The range of values for accuracy goes from 0 to 1. The later value being desirable (Murphy, 1993). An accuracy of 1 means that all occurrences of the event were correctly forecasted. The accuracy is greatly influenced by the most common category. For example, in a contingency table for rain the 'no' events may greatly out number the 'rain' events. The accuracy may therefore give misleading information about the skill of the forecast, particularly in dry regions (Mills *et al.*, 1997).

Bias is a measure of the correspondence between the mean forecast and mean observation and is given as:

$$Bias = \frac{hits + false\ alarms}{hits + misses} \quad \text{………………………………………….. (2)}$$

Where hits is the number of correct predicted events, false alarms is the event to occur, but did not occur and misses is the event forecast not to occur, but did occur. It Indicates whether the forecast system has a tendency to underforecast (bias<1) meaning that the event was forecasted less than it was observed or overforecast (bias>1) meaning that the event was forecasted more than it was observed (Fraedrich and Leslie, 1988). Bias =1 (unbiased) means that the event was forecasted the same number of times that was observed. Bias in general does not measure how well the forecast corresponds to the observations, only measures relative frequencies. Bias ranges from 0 to infinity. Perfect score being 1.

Probability of detection (POD) which is referred to in the older literature as prefigurance, is another possible score to calculate. The POD is simply the fraction of those occurrences when the forecast event occurred on which it was also forecasted (Wilks, 1995). The values range from 0 to 1 and a perfect model would score 1.

False alarm ratio (FAR) answers the question: what fraction of the predicted “yes” events actually did not occur (i.e., were false alarms) (Murphy, 1993). FAR is sensitive only to false predictions, and not to missed events. This score can always be decreased by under forecasting the number of severe events, but only at the cost of more missed events. The range of FAR values for any forecast model is from 0 to 1. A perfect system will score a value of 0 while a value of 1 would indicate the forecasting system to have a predicting skill equivalent to random chance. Also a system that is forecasting constantly the same values will also score 1.

Probability of false detection (POFD), answers the question: What fraction of the observed “no” events were incorrectly forecasted as “yes” (Murphy, 1993). The values range from 0 to 1 and a perfect model would score 0.

Critical success index (CSI) measures the fraction of observed and forecasted events that were correctly predicted. A perfect model would score 1 and 0 indicates no skill (Murphy, 1993). Doswell *et al.* (1990) noted that the CSI takes no account of correct forecasts on non-events in potentially hazardous weather situations, allowing this score to be optimized by over-forecasting.

Another measure, among the many variables, should be mentioned. The Equitable threat score (ETS) measures the fraction of observed and forecasted events that were correctly predicted, adjusted for hits associated with random chance (Murphy, 1993). ETS is a modification to the CSI that takes into account the number of correct forecasts of events (hits) that would be expected purely due to chance. ETS ranges from 0 to 1, with 0 indicating no skill. ETS seems to be one of the most popular, but suffers from the disadvantage shared by several other measures, namely a strong dependence on the number of correct forecasts of events that would be expected purely due to chance (Stephenson, 2000).

A Heidke Skill Score (HSS) is another measure of forecast score. In a tercile forecast system, a large number of random forecasts will have an expected hit rate of 33.3%. The hit rate can be adjusted to a score that has a chance value of 0 (Heidke, 1926). HSS ranges from minus infinity to 1, 0 indicates no skill. Perfect score being 1. A score of +1will indicate a set of perfect hits and a score of -1 a set with no hits. The HSS is the percentage of correct forecasts obtained after subtracting the number of forecasts that would have been correct by chance and is given as:

$$\text{HSS} = \frac{(\text{hits} + \text{correct negative}) - (\text{expected correct})_{\text{random}}}{\text{N} - (\text{expected correct})_{\text{random}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where

$$(\text{expected correct})_{\text{random}} = \frac{\left[\begin{array}{l}(\text{hits+misses})(\text{hits+false alarms}) + \\ (\text{correct negatives+misses})(\text{correct negatives+false alarms})\end{array}\right]}{\text{N}}$$

N is the total number of observed and forecast occurrences and non-occurrences.

A skill score measures the relative quality of a forecasting system compared to another reference forecasting system. Climatology (long-term average) is commonly used as a reference for medium range or long-range forecasts, whereas persistence may be used in the case of short-term forecasts. However, a reference forecast that is clearly unskillful, using no knowledge at all about climate or weather (e.g. some sort of a random forecast) is required to obtain an absolute measure of forecast skill.

Many skill scores used to evaluate weather forecast are inequitable, in the sense that constant forecasts of some events lead to better scores than random forecasts (Grandin and Murphy, 1992). Inequitable skill scores may encourage forecasters to favour some events at the expense of other events, thereby producing forecasts that exhibit systematic biases or other undesirable characteristics.

Most of the common scores have been criticized on various grounds. All have a dependence on decision threshold which can render comparisons meaningless (Mason, 1989). Many also depend on a sample climate, so that comparisons of forecasting systems in different climates may be invalid.

Stephenson (2004) described the behaviour of several commonly used scores as the climatologicalcal probability of the events tends to trivial limits of 0 (= no skill) or 1 making them unsuitable to measure forecast ability. This behaviour makes it difficult to get good assessment of forecast accuracy. He recommended that the accuracy, bias and HSS be used instead for verifying the forecasts.

2.3 Forecast verification concepts

Forecast verification is the process of determining the quality of forecasts through the assessment of the degree of similarity between forecasts and observed conditions (Murphy and Winkler, 1987; Murphy, 1993). Forecast verification techniques allow comparison of the relative merits of competing forecasters or forecasting systems. Much work has been done in the area of investigating forecast value and forecast verification, most notably in the works of Murphy (1991). The forecast is compared, or verified, against a corresponding observation of what actually occurred, or some good estimate of the true outcome. The verification can be qualitative or quantitative. In either case, it should give information about the nature of the forecast errors.

The initial step of creating a matched set of forecasts and observations can be one of the most difficult aspects of forecast verification. In order for verification results to be valid and meaningful, it is critical that the forecast and observed events are matched as closely as possible, in terms of domain, spatial representativeness, and so on (Brown, 2001). Various techniques are usually employed to assist in bringing about this close match between observations and forecasts. These appropriate techniques depend on the definition of the forecast event. In particular, forecast attributes are defined differently depending on whether the forecasts are continuous, categorical, or probabilistic. Contingency tables are used in many different types of forecasts.

Meteorologists have been concerned with the practice of forecast verification for many years. For example, Rainman a computer package for worldwide mapping of seasonal rainfall information at district and regional scales has been in use for quite some time (Clewett *et al.*, 1999). Further, Rainman has also been used by a broad section of community including producers, agribusiness, schools and universities. Primary producers have been using climate risk information from the Rainman for effective property management planning, tactical decisions making and financial business management (Owens *et al.*, 1996). Rainman analyses follow accepted scientific conventions by applying several statistical tests to seasonal forecasts (Clewett, 2002). The analysis of data via statistical methods can be accomplished by a variety of tools, and a key point is to decide on what tools to use. Goddard *et al.* (2003) used Ranked Probability Skill Score (RPSS) to assess the International

Research Institute of Climate Prediction (IRI) seasonal forecasts. The assessment was performed for the entire globe.

Forecast verification encompasses many different methodologies to define the quality of the forecast, using either a deterministic or a probabilistic approach (Cherubin *et al*., 2001). Cherubini *et al*. (2002) verified precipitation forecasts against either a set of standard low resolution gauge observations from the Global Telecommunication System (GTS) or against a set of upscaled high-resolution observations from the Mesoscale Alpine Program (MAP). In support of Earth System Research Laboratory (ESRL) verification efforts, a Real-Time Verification System (RTVS) is being developed as a tool for assessing the quality of weather forecasts (ESRL, 2004). RTVS is designed to provide a statistical baseline for weather forecasts and model-based guidance products, support real-time forecast operations, model-based algorithm development, and case study assessments. To this end, RTVS was designed to ingest weather forecasts and observations in near real time and store the relevant information in a relational database management system (RDBMS).

Ebert (2002) verified ensemble forecasts for a 28-month period over Australia using poor man's ensemble. Poor man's ensemble is a set of independent numerical weather prediction (NWP) model forecasts from several operational centres. The poor man's ensemble consisted of 24-h and 48-h daily quantitative precipitation forecasts (QPF) from seven operational NWP models. Results indicated that forecasts of the probability of precipitation (POP) were skillful for rain rates up to 50mm day^{-1} for the first 24-h period, exceeding the skill of the European Centre for Medium-range Weather Forecasts (ECMWF). The skill and accuracy of the ensemble mean QPF far exceeded that of the individual models for both forecast periods when standard measures such as the root-mean square error and equitable threat score were used. The model hit rate for rain events were 0.59 - 0.68 for the first 24-h period and somewhat smaller, 0.53 - 0.62 for the second day.

A survey of methods currently in use or in development has been performed, focusing on the verification of weather elements (Bougeault, 2003). The following is a summary of main verifications of weather elements currently performed at operational centres: (1) Australia: The rainfall forecast is verified against an analysis of 24-hour rain gauge data over continental Australia. (2) United States: Global (medium range, 15 days) and regional (short-range, 48 h) ensemble forecasts generated operationally at National Centre for Environmental Prediction-Washington (NCEP) are currently evaluated against gridded Numerical Weather Prediction (NWP) analysis fields.

Marx *et al*. (2003) in South Africa investigated the accuracy of the predicted rainfall for the summer months (October – March) of 1994 to 1998 for Vaal Dam Catchment using the South Africa Weather Service (SAWS) hit score method.

Results indicated that the verified 24h rainfall forecasts were generally less accurate.

Luciana and Maria (2006) evaluated weather forecasts for values of maximum and minimum temperatures in Rio de Janeiro city for 24, 48, 72, and 96 hours in the period from May to September 2004 and July to September 2005 using the categorical comparison (hits or misses) between forecast and observations. Results showed that temperature forecasts, both maximum and minimum, over estimated the values of the observed temperatures.

Ken (2007) matched short term warnings (tornadoes, severe thunderstorms, flash floods, and spatial marine warnings) issued by the NOAA/National Weather Service (NWS) against actual weather events that have occurred. He designed quantitative, or verification measures with which to gauge the quality of source. Two primary measures namely; Probability of detection (POD) and false alarm (FAR) were calculated. Results showed that POD was lower than the associated country-based legacy value. Similarly, results indicated little change in FAR from country-based verification numbers.

Banitz (2001) evaluated short-term rainfall in South Africa, including maximum and minimum temperature forecasts from 1702 stations across the country divided into 19 geographical regions valid up to 48 hours ahead. The period evaluated was from January 1998 to February 2001. Rainfall evaluated was by means of a yes/no contingency table. Results showed that temperature forecasts generally tended to be accurate to within a limit of 2.3°C. Tendencies of rainfall forecasts showed that rainfall was forecast more often than it occurs.

The Tanzania Meteorological Agency (TMA) evaluated daily rainfall forecasts covering most of the country (TMA, 2006). Daily rain forecasts were compared with actual observations to measure their accuracy. The period evaluated was from November to December 2005. Out of all 8 zones, which were used to categorize weather forecast, the POD for November 2005 was found to be 74.5% and the mean probability of detection for the month of December 2005 was 70.4%.

Mark *et al*. (2001) evaluated medium-range forecast (3 to 5 days) for the period 1 November 1999 through 31 October 2000, a one-year period at Nashville, Tennessee. Three traditional verification statistics were used to analyze the accuracy of precipitation forecasts: the false alarm ratio (FAR), probability of detection (POD), and critical success index (CSI). Results from the year-long extended forecast showed that POD's were fairly high for the first 3 days, ranging between 68% and 84%, with FAR's just above 50% indicating that roughly three quarters of the observed rain events were correctly predicted.

Someshwar (2002) ran a high-resolution meso-scale model (MM5) at the National Centre for Medium Range Weather Forecasts (NCMRWF) on real time basis. The medium-range weather forecast from MM5 was compared with those obtained from the observations and T80 operational global model. Results indicated that the MM5 model was able to make fairly good forecasts of rainfall associated with the systems over the Indian region. The predicted rainfall was much larger than the observations due to western disturbances, which produce severe weather over the Indian region during the winter season.

Mwano (2006) evaluated GHACOF and SARCOF seasonal forecast products in different agro-climatic zones of Tanzania. The period evaluated was from 1998 to 2003. The rainy seasons analyzed were September-December (SOND) and March-May (MAM) for GHACOF and October-December (OND) and January-March (JFM) for SARCOF. The SARCOF forecast products appeared to perform better in the OND season than in the JFM season while GHACOF forecast products appeared to perform better in the SOND than in MAM season.

Banitz (2001) evaluated long-range rainfall forecasts of South Africa for 19 districts covering most of the country and found their forecasts to be reliable. The period evaluated was from January 1998 to March 2001. The Hit Rate (HR) ranged from 100% at the beginning of the evaluation to 50% when torrential rains occurred in the country.

There has been on the other hand, a growing appreciation for the need for probabilistic rather than deterministic forecasts especially for longer-time forecasts (e.g. medium-range and seasonal). There are fundamental issues on the interpretation of probability in such systems (Wilks, 2000; de Elia and Lapraise, 2005). The prequential interpretation of probability has recently been illustrated in an assessment of financial forecasts (Bessler and Ruffley, 2004). Later studies have examined in more detail some of the undesirable properties of well-known probability such as the Brier Score and have proposed variant approaches (Mason, 2004); Muller *et al.*, 2005; Gneiting *et al.*, 2005).

The use of theoretical information measures such as entropy has been proposed to assess resolution of probabilistic forecasts (Roulston and Smith 2002) and such approaches also appear to be promising for the verification of forecasts of point process events such as earthquakes (Daley and Vere-Jones, 2004; Harte and Vere-Jones, 2005). Such approaches are also potentially useful for the point process events that occur in meteorology such as individual weather systems, extreme rainfall events, etc. (Stephenson and Doblas-Reys, 2000).

Another possible approach for generating probability forecasts is to produce an ensemble of forecasts. Ensemble forecasting is now a major activity at many forecasting centres around the world.

Probabilistic forecasts with ensemble prediction systems (EPSs) have found a wide range of applications in weather and climate risk management, and their importance grows continuously. For example, the ECMWF applies a 51 member system for seasonal climate forecasts (Anderson, 2005). The rationale behind the ensemble method used is to approximate the expected Probability Density Function (PDF) of a quality by finite set of forecast realizations.

Seasonal forecasts of climate variables such as rainfall and temperature are often presented as a probability of occurring within a certain category such as above or below average (two categories) or above, near, and below average (three categories or tercile forecast) (Figure 1). The probability of occurrence in each forecast category is usually expressed as a percentage probability figure with the total probability in all categories adding to 100%. The main reason for providing a probability value is because probabilistic forecasts have the advantage that they can convey the uncertainty associated with the forecasts in a quantitative way (Murphy, 1977). The users, on the other hand, would simply prefer the Yes/No answers on whether it would be wet or dry.

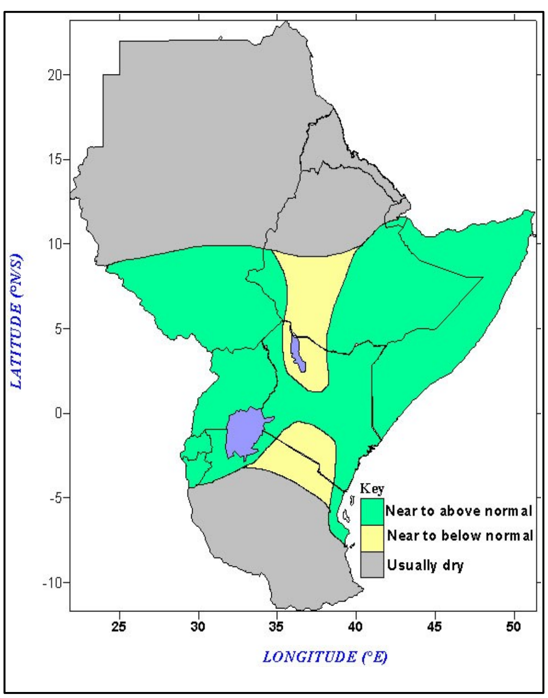
Various approaches have been developed for the verification of such systems such as economic value (Wilks, 2001), new types of correlation analysis (Wei and Toth, 2003), minimum spanning trees (Wilks, 2004) and new reliability measures (Atger, 2004).

Probabilistic forecasts derived from the ensemble, including spread and reliability measures, are evaluated using a variety of standard probabilistic verification scores including the Brier Skill Score (BSS), Ranked Probability Skill Score (RPS), Relative Operating Characteristics (ROC), and Economic Value of forecasts (Richardson, 2000). The BSS can be partitioned into three terms accounting respectively for reliability, resolution, and uncertainty. The BSS is sensitive to the frequency of the event: the rarer the event, the easier it is to get a good Brier Scorer without having any real skill. The Ranked Probability Score measures the sum of squared differences in cumulative probability space for a multi-category probabilistic forecast. ROC describes how a forecast system can meet simultaneously the needs of various user categories.

Zhang and Casey (2000) discuss a variation of reducing a probability forecast to binary forecast by forecasting an event if the probability exceeds some threshold. They categorize the forecasts into three groups, rather than two, using the forecast probability.

Franz (2001) described and applied probabilistic forecast evaluation methods at a simulated National Weather Service (NWS) Ensemble Stream flow Prediction (ESP) water supply outlooks for Colorado River basin. Three types of probabilistic verification methods were successfully applied to the forecasts: ranked probability score (RPS), ranked probability skill score (RPSS) and discrimination and reliability

Hartmann *et al*. (2002) also discuss verification of probability forecasts from the users perspective. They concentrate on graphical representations of the quality of forecasts, giving imaginative displays of conventional metrics such as the Brier score,



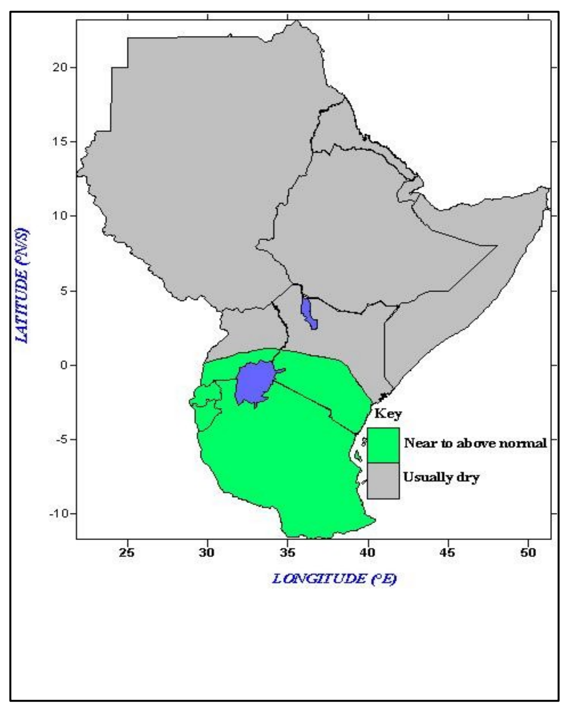


Fig. 1: Forecasts showing (a) average three-category tercile forecast (b) two categories forecasts (Source: *Drought Monitoring Centre-Nairobi, 2007*)

but also presenting descriptive but informative plots of forecasts and observations.

Zhang and Casey (2000) conducted a probabilistic weather forecasting verification of an Australian seasonal rainfall forecast model hindcasts for the winter and summer seasons over the period 1900 to 1995. Two evaluation methods were used. One was to use some measure of the departure between forecasts and observations and the other was to do a conversion from the probabilistic form to a binary yes/no form and use a contingency table to score hit rates against misses and false alarms. They observed that each method provided valuable information about the skill of the probability model forecast.

Since the mainstream of verification methods were primarily devised to answer the needs of model developers, it is not surprising that a common concern in the literature on the subject is to monitor and improve a forecast system following requirements posed by atmospheric scientists, rather than the needs of specific end-users who are more interested in the performance of a set of forecasts relative to their own specific demands (Glahn, 2004).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the study area

Tanzania lies roughly between 1° N and 10°S and from 29°E to 41° E (Figure 2). Two main patterns of diurnal variation of rainfall dominate (Mpeta and Mhita, 1993). The first is maritime type with maximum of precipitation during the night or early morning, and a continental type with an afternoon maximum. In both patterns, the time of maximum precipitation is related to the time of maximum convection and/or cloudiness. These variations are also depicted in the distribution of rainfall event starting times as shown by Kihupi *et al*. (2005) for the case of Morogoro station. For both the short and long rains, there is a low probability of rains starting between 0600 and 1400 hours, but there are higher chances of a rain starting between 1600 and 2200 hours and between 0200 and 0600 hours which corresponds, respectively, with the continental and maritime diurnal variations.

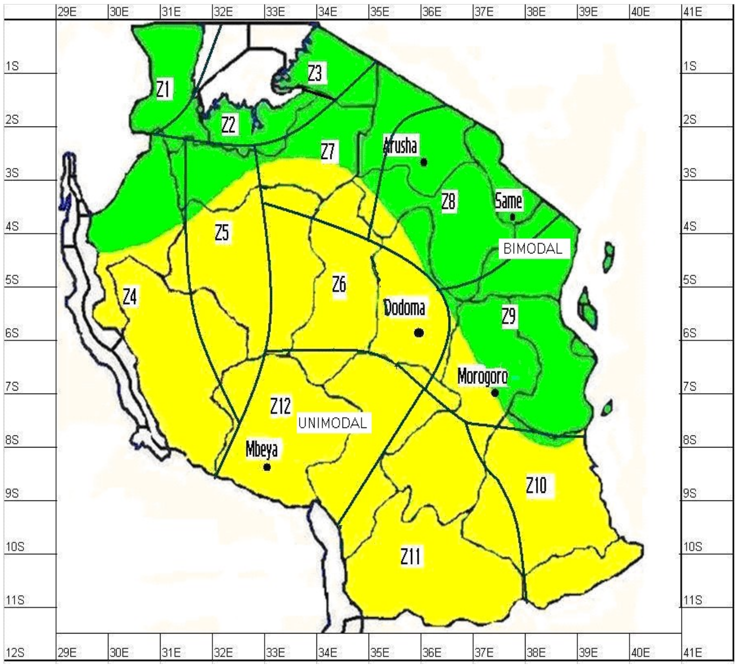


Figure 2: Map of Tanzania showing location of homogeneous zones, bimodal and unimodal rainfall regimes (Source: *TMA,2003)*

The country's climate has been described in detail by many authors such as (Thompson, 1965) and (Niewolt, 1979). In summary, Tanzania has two distinct seasonal rainfall patterns, namely bimodal and unimodal rainfall regimes. Bimodal behaviour exists over northern Tanzania and unimodal rainfall over western, central and southern Tanzania. The bimodal rainfall is characterized by two annual maxima i.e. the short rainfall season between October-December and the long rains in March-May. The March-May and October-December constitute the so called long rains locally known as '*Masika'* and short rains locally known as *'vuli'* respectively. The unimodal rainfall is characterized by a single annual maximum experienced between December and March. Further studies Ogallo (1986) and Mutoni (2001) have split the bimodal and unimodal regimes into several homogeneous zones. The homogeneous zones over the bimodal areas include northern coast areas, northern areas, north eastern highlands and Lake Victoria basin. For the unimodal areas they are western, central, south-western highlands and southern areas (Mhita *et al*., 2003). The annual rainfall for Dodoma ranges from 500 to 800mm with a relative high degree of unreliability. The southern and western areas and the southwestern highlands including Mbeya are the ones which receive large amounts of annual rainfall ranging between 800 to 2000mm.

The rainfall is driven by the seasonal movement of the Inter Topical Convergence Zone (ITCZ), but is highly modified by orography, large inland water bodies and seasonal influxes of moist low-level westerlies (Ogallo 1988). Stations near the coast at low elevations exhibit more distinct wet and dry seasons, although yearly rainfall totals are lower than would be expected for stations at these latitudes.

3.2 Data source

Data was collected from the following sources:

1) NCEP decadal weather forecasts.
2) Decadal weather forecasts from TMA.
3) Decadal weather forecasts from Accuweather.
4) ICPAC decadal weather forecasts.
5) Observed 10-day accumulations of precipitation in each of the five stations from the Tanzania Meteorological Agency.

3.2.1 NCEP weather forecasts

Medium-range forecasts of 10 days for Tanzania from March-May and October-December 2006 and January-May 2007 were obtained from the US National Centre for Environmental Prediction (NCEP, 2006/07).

Forecast products produced by NCEP were all issued in deterministic format (quantitative precipitation forecast). A Sample forecast product for NCEP is as shown in Figure 3 and a complete set of forecast products used in this study is presented in Appendix A.

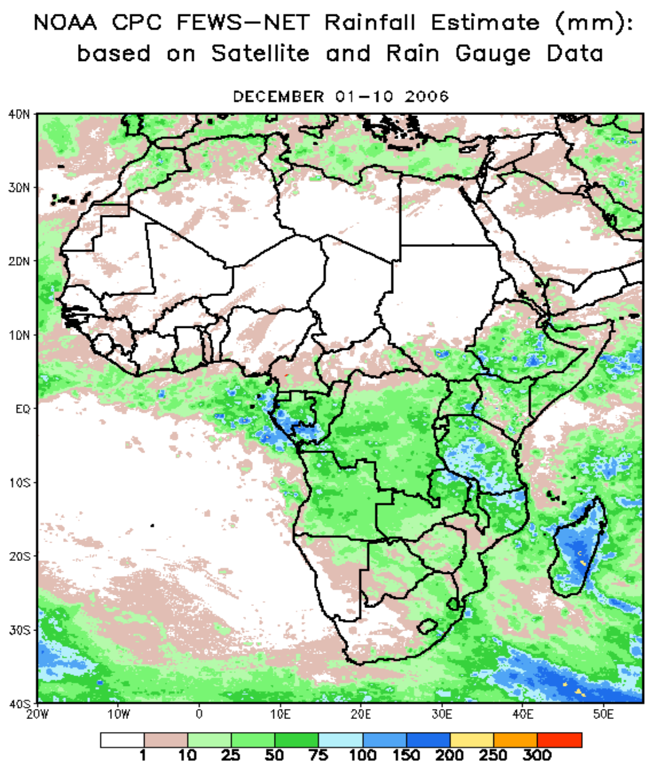


Figure 3: Sample forecast product for NCEP (Source: ***NCEP, 2007*****)**

3.2.2.1 ICPAC weather products

Decadal weather forecasts from March–May and October–December 2006 and January-May 2007 were obtained from the Intergovernmental Authority on Development (IGAD) Climate Prediction and Application Centre (ICPAC), formally known as Drought Monitoring Centre (DMC)–Nairobi (ICPAC, 2006/07). This range of forecasts (2006/07) was only used due to limitations in getting the data.

Ten day forecast products produced by ICPAC issued in three-categorical tercile forecasts, were downscaled by interpolating them into the map of Tanzania so that comparison could be done with the observed rainfall (Atheru and Ambenje, 2002). A Sample forecast product for ICPAC is shown in Figure 4 and a complete set of forecast products used in this study is given in Appendix C.

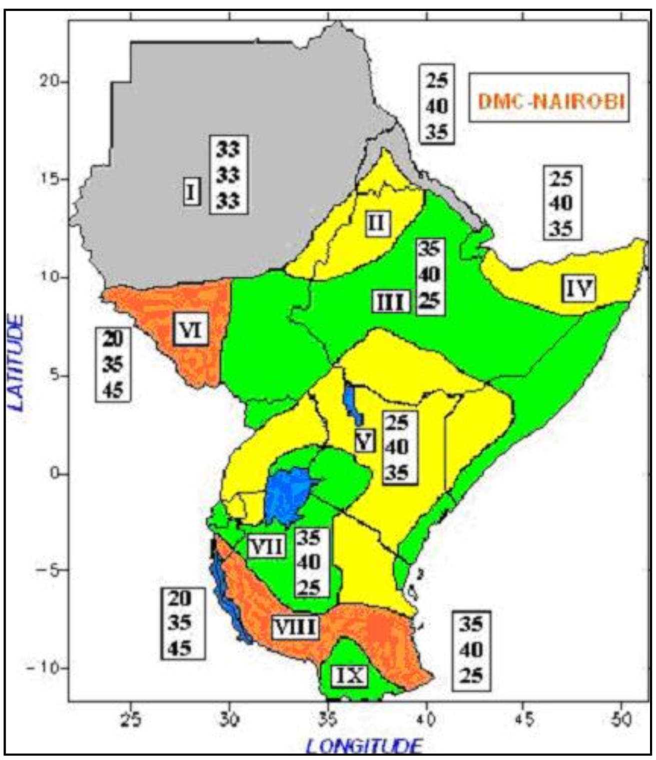


Figure 4: Sample forecast product for ICPAC (Source: *ICPAC, 2007***)**

3.2.3 Accuweather Weather Forecasts

Decadal weather forecasts from March–May and October–December 2006 and January-May 2007 were obtained from Accuweather website (Accuweather, 2006/07). Forecast products produced by Accuweather were all issued in deterministic format (quantitative precipitation forecast). A Sample forecast products is shown in Box 1 and a complete set of forecast products used in this study is presented in Appendix E.

Box 1: Sample forecast product for Accuweather (Source: *Accuweather, 2006*)

Same, Tanzania Expected rain in the next 10 days starting from Thursday, 21 December 2006 Rain Total: 26mm. Occurring: Dec 21; Dec 22; Dec 24; Dec 26

3.2.4 TMA weather forecast

Medium-range forecasts of 10 days for Tanzania from March-May and October-December 2006 and January-May 2007 were obtained from the TMA. The forecasts were for October-November-December (OND) and March-April-May (MAM) for bimodal stations (Morogoro, Same and Arusha) and December-March for unimodal stations (Mbeya and Dodoma). A sample forecast product for TMA is as shown in Box 2 and a complete set of forecast products is presented in Appendix G.

Box 2: Sample forecast product for TMA *(*Sourc***e*****:** *TMA*, *2007*).

> **No. 23 2006/07 Cropping Season**
>
> **March 1-10, 2007**
>
> "Areas with the unimodal rainfall pattern are expected to experience rainfall increase. The southern, southern coastal belt, southwestern highlands, western areas, and central areas, Lake Victoria basin will experience cloudy conditions with thundershowers over some areas and sunny intervals. Northeastern highlands and northern coast will experience partly cloudy conditions with thundershowers over few areas with sunny periods. The rest of the country is expected to feature partly cloudy conditions with sunny periods".

Other forecasts obtained had gaps in their series especially NCEP, ICPAC and Accuweather due to communication problems in getting the data (Table 1). Those forecast products with gaps were excluded from the analysis and this makes the sample size for some of the time periods smaller than others. For example, forecast products from the NCEP especially during OND had only 2 forecasts. In this case therefore, only forecasts during MAM were considered for the evaluation.

Table 1: Forecasts with missing data

Forecasting Agency	Stations	Period with missing data
Accuweather	Morogoro	Dekad 8,11,15,28,30,31,35 (2006)
	Same	Dekad 8,32,33,36 (2006) and 7,9,10,13(2007)
	Mbeya	Dekad 36 (2006),4,6,7 (2007)
ICPAC	Morogoro, Arusha, Same	Dekad 15,28,30,33,35 (2006)
	Mbeya, Dodoma	Dekad 28,33,35(2006); 1 and 6 (2007)
NCEP	Mbeya	Dekad 1,3 and 4 (2007)
	Dodoma	Dekad 1,3 and 4 (2007)

Only those dekads for which forecasts were obtained from all the sources were used.

3.3 Data analyses

3.3.1 NCEP Forecast Products

The NCEP products were for the period 1 March 2006 to 31 May 2007. For stations which experience a unimodal rainfall pattern (Dodoma and Mbeya), the analysis was limited to the rainy season. Bimodal stations were analyzed in both short and long rains. The rainy seasons analyzed were March-April-May (MAM) starting from 1-8 March 2007 to 10-17 May 2007 for Morogoro, Arusha, and Same stations. For unimodal stations (Mbeya and Dodoma) 8 dekads for each station during that particular rainy season December-March (DM) starting from 11-17 December 2006 to 21-28 March 2007 were analyzed.

The products were downscaled by interpolating them into the map of Tanzania so that comparison could be done with the observed rainfall. Each station was located on the map of forecast stations and the quantitative precipitation at that station was obtained for every dekad. For instance, if the Outlook indicated a 10-25mm chance of rainfall, then the forecast at that particular station was for between 10-25mm of rainfall. For every dekad forecast, average forecast values were compared with observed rainfall values, matched with the long-term rainfall values along with their lower and upper bound limits.

A categorical table of forecasts versus observed rainfall is usually expressed in terms of terciles. Terciles are three ranges, or intervals of values of a variable that are defined to describe the lower, middle, and upper thirds of the climatologically expected distribution of values. Without any forecast clues, the chance that any of the three outcomes will occur is one-third, or 33%, which means that if the situation could be rerun many times, each outcome would occur one of the three times. The forecasted decadal rainfall values from NCEP were then ranked and expressed in one of the three terciles of Above Normal (AN), Normal (N), and Below Normal (BN) categories. The above normal values (AN) were obtained using the following expression:

$$AN = LRA\left(\frac{66}{50}\right) \qquad \text{……………………………………………………(4)}$$

Below normal category value BN is given by:

$$BN = LRA\left(\frac{33}{50}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where AN is the above normal value in tercile, BN is the below normal value tercile, and LRA is the long term rainfall average.

The observed decadal rainfall amounts for each station were also ranked and expressed in either 3 equal terciles similar to the forecasted decadal rainfall amounts above. Contents of the resulting terciles are presented in Appendix B. Results from the classification based on the observed rainfall and forecasts were then matched to obtain hits, misses, false alarms, and correct. For example, if the forecast for one particular dekad was for above normal (AN) category and the corresponding observed tercile was normal (N), then the evaluation for this case was a false alarm. If below normal was the forecast and the corresponding observation was above normal, in this case a miss was the evaluation. If above normal was the forecast and the corresponding observation was above normal, in this case a hit was the evaluation. If below normal was the forecast and the corresponding observation was below normal, in this case correct negative was the evaluation. The resulting four combinations of forecasts (yes or no) and observations (yes or no) were then used to obtain the categorization numbers for proper construction of a 2x2 contingency table. The contents of the resulting contingency table are given in Table 2. The contingency table was then used to compute for the Accuracy, Bias and Heidke skill score (HSS) (Cohen's K). The resulting accuracy, bias and HSS indices were then used to evaluate the accuracy and skills of the forecasts.

Table 2: General 2x2 contingency table

	observed yes	observed no
Forecast yes	hits	false alarms
Forecast no	misses	correct negatives

Where hits represents the number of event forecasts that were predicted to occur, and did occur, misses represents the number of event forecasts that were predicted not to occur, but did occur, false alarms represents the number of event forecasts that were predicted to occur, but did not occur and correct negatives represents the number of event forecasts that were predicted not to occur, and did not occur.

3.3.2 ICPAC Forecast Products

The ICPAC products were for the period of March 2006 to April 2007. For stations which experience a unimodal rainfall pattern (Dodoma and Mbeya), the analysis was limited to the rainy season. Bimodal stations were analyzed in both short and long rains. The rainy seasons analyzed were October-November-December (OND) and March-April-May (MAM) for bimodal stations (Morogoro, Arusha, and Same). In total, 13 dekads were analyzed in the season. Other dekads could not be obtained from the website due to the reason previously explained. For unimodal stations (Mbeya and Dodoma) 16 dekads for each station during December-March (DJFM) starting from 11-17 December 2006 to 21-28 March 2007 was analyzed.

Each station under study was located in the forecast map and the corresponding three-category tercile forecasts were assigned for every dekad. Long-term rainfall averages for every dekad were used to obtain the corresponding lower and upper bound limits. Contents of the resulting terciles are presented in Appendix D.

Evaluation was then performed to get hits, misses, false alarms, and correct negatives based on the forecasts and the observations. For example, if the forecast for one particular dekad was for above normal (AN) category and the corresponding observed rainfall amount (67.9) lay between the lower (54.5) and upper (109) bound limit, then this dekad was considered as a miss (Table 3).

Table 3: Categorization of observed rainfall

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
21-31/3 06	9	61.6	A	99.4	40.7	81.3	h
1-10/4/06	10	82.6	A	67.9	54.5	109	m

The resulting four combinations of forecasts (yes or no) and observations (yes or no) were then used to obtain the categorization numbers for proper construction of a 2x2 contingency table. The contents of the resulting contingency table are as given in Table 2.

3.3.3 Accuweather Forecast Products

The same procedure of analysis as it was done for NCEP forecast products to compute for the Accuracy, Bias and Heidke skill score (HSS) (Cohen’s K) using Equations 3, 4 and 5 was repeated for Accuweather data. The resulting accuracy, bias and HSS indices were then used to evaluate the accuracy and skills of the forecasts. Contents and description of the resulting contingency table are as in appendix F.

Accuweather forecast products were for the period March 2006 to May 2007. The rainy seasons analyzed were October-November-December (OND) and March-April-May (MAM) starting from 1-10 March 2006 to 21-31 March 2007 for Morogoro and from 1-10 March 2006 to 21-31 May 2007 for Same (bimodal_stations). The rainy seasons analyzed were December-March (DM) starting from 1-10 March 2006 to 21-31 March 2007 for Mbeya (unimodal station).

For every dekad forecast amount, the observed rainfall amounts were matched with the long term averages along with their lower and upper bound limits to obtain the four combinations of forecast (yes or no) and observations (yes and no). Contents of the resulting upper and lower bound limits are presented in Appendix F. The resulting four combinations of forecasts (yes or no) and observations (yes or no) were then used to obtain the categorization numbers for proper construction of a 2 x 2 contingency. The contents of the resulting contingency table are as given in Table 2.

The same procedure of analysis for Accuweather was repeated from the contingency table as it was done for NCEP and ICPAC forecast products to compute for the Accuracy, Bias and Heidke skill score (HSS) (Cohen’s K) using Equations 3, 4 and 5. The resulting accuracy, bias and HSS indices were again used to evaluate the accuracy and skills of the forecasts. Contents and description of the resulting contingency table are as in Table 2.

3.3.4 TMA Forecast Products

TMA forecast products were for the period March 2006 to May 2007. The rainy seasons analyzed were October-November-December starting from 1-10 October 2006 to 31 December 2006 (OND) and March-April-May (MAM) starting from 1-10 March 2006 to 21-31 March 2007 for Morogoro, Same and Arusha. On the other hand, the rainy seasons analyzed were December-March (DM) starting from 1-10 December 2006 to 21-31 March 2007 for Mbeya and Dodoma (unimodal stations).

For every dekad forecast, the observed rainfall amounts were matched with the long term averages along with their lower and upper bound limits to obtain the 3 equal terciles of AN, N and BN. The classification based on the observed rainfall and forecasts could not be matched to obtain hits, misses, false alarms, and correct negatives due to the format of TMA's forecasts. For example, if the forecast for one particular dekad was 'cloudy conditions at times with showers and thunderstorms over few areas' and the corresponding observed rainfall amount lay between the lower and upper bound limit, then it was not possible for this forecast to be specified in one of the four distributions namely; hits, misses, false alarms and correct negatives.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This section presents results of the evaluation of forecast products by NCEP, Accuwearher, DMC and TMA for Same, Morogoro, Arusha, Mbeya and Dodoma stations.

4.1 NCEP forecast products

This sub-section presents evaluation results of deterministic forecast products (non-probabilistic precipitation forecast) produced by NCEP. The forecast products were used to evaluate the short, long and seasonal rainy seasons.

4.1.1 Short/seasonal rains

The rainy season in these products were the short rains covering October-November-December (OND) for the bimodal stations and seasonal rains covering December-January-February-March for the unimodal. Table 4 and Appendices B show evaluation of NCEP 10-day forecasts for the five stations. The accuracy score values for Mbeya and Dodoma stations are presented. The results show that both stations scored accuracy values of 0.38 signifying that less than 40% of all forecast cases were correct. Mills *et al.* (1997) and Barnitz (2001) argue that the accuracy is greatly influenced by the most common category.

Table 4: Verification indices obtained between actual and predicted short, long and seasonal rainy season for the NCEP

Rain season	**Stations**	**Short rains**			**Long rains**		
		Accuracy	Bias	HSS	Accuracy	Bias	HSS

Bimodal	Same	-	-	-	0.25	1.67	-0.41
	Morogoro	-	-	-	0.25	2.00	-0.50
	Arusha	-	-	-	0.37	2.00	-0.11
Unimodal	Mbeya	0.37	0.50	-0.11	-	-	-
	Dodoma	0.37	0.167	0.09	-	-	-

The bias scores remained fairly low especially over Dodoma station with only 0.17 as compared to Mbeya with a score of 0.50 (Table 4). This indicates that rainfall events were forecasted less than it was observed since all the bias values are less than 1. During these months the ITCZ is typically displaced to the north of the equator.

The Heidke skill scores results in the unimodal areas (Mbeya and Dodoma) from December 2006 to March 2007 showed no skill. HSS for Mbeya station was -0.11 while for Dodoma it was 0.09. This could be attributed by the reason that, in summer the predictability of the weather seems to be lower, due to the fact that highly-convective rain events can be driven by small changes in the weather pattern, so that small errors in the flow can lead to large errors of the skill scores of the forecasts (Doswell and Flueck, 1990).

4.1.2 Long rains

Verification indices obtained between actual and predicted MAM 2007 10-day rainfall over Same, Morogoro and Arusha are presented in Table 4. From the table results show that generally, there is less accuracy from the forecasting system since most of the figures are relatively small. The accuracy ranged between 0.25 – 0.38. These figures indicate that less than 40% of forecast cases were correct.

Results (Table 4) show that the bias of the NCEP forecast was high for all the stations reaching a value of 2 over Morogoro and Arusha stations. The bias over Same rainfall forecast was also quite high (1.67). Generally, this indicates that, NCEP had slight tendency of over forecasting in this particular rainy season. The bias score, however, does not reflect whether this forecasting systems has been able to produce the right forecast frequency of 'yes' events compared to the observed frequency of 'yes' events. An answer to this point can be obtained from the Heidke skill scores, which are shown in Table 4.

Results for the Heidke skill score values obtained from the long rainy season from March 2007 to May 2007 with a total of 8 dekads forecasts evaluated, show that all scores were negative (Table 4). This is a standard way of computing the forecast skill scores Mesinger and Black (1992) and it provides statistically significant results given the size of the sample. Negative scores are possible, and occur when the number of hits is lower than would be expected by chance (Ebert, 2002).

4.2 Accuweather forecast products

This sub-section presents evaluation of deterministic forecast products (quantitative precipitation forecasts) produced by Accuweather for Same, Morogoro and Mbeya based on 2006 and 2007 forecasts.

4.2.1 Short/seasonal rains

Table 5 shows the verification indices obtained between actual and predicted rainfall for various stations. Comparing the accuracy between the two different rainy seasons, the accuracy skill was noticed over Same (bimodal) than over Mbeya (unimodal). Same scored 0.83 signifying that 83% of all forecasts were correct. Scores over Morogoro and Mbeya were 0.40 and 0.45 respectively.

Table 5: Verification indices obtained between actual and predicted long, short and seasonal rains for the Accuweather

Rain season	**Stations**	**Short/seasonal rains**			**Long rains**		
		Accuracy	Bias	HSS	Accuracy	Bias	HSS
Bimodal	Same	0.83	0.67	0.67	0.57	0.75	0.16
	Morogoro	0.40	0.67	-0.15	0.62	0.62	0.00
Unimodal	Mbeya	0.45	0.33	-0.03	-	-	-

Table 5 also shows the verification indices obtained between actual and predicted long rainy seasonal rainfall for Same and Morogoro.

In the above table, accuracy score value was 0.83 over Same indicating that 83% of all the forecasts were correct. Morogoro and Mbeya had accuracy score values of 0.40 and 0.45 respectively indicating that in roughly less than a half of the forecasts were accurate.

It can be seen from the table that bias values were between 0 and 1 (Same and Morogoro, 0.67 each and 0.33 for Mbeya). The results signify a general tendency for Accuweather to under-forecast for both rainy seasons.

Same had the highest value of HSS (0.67) during the short rainy season. The HSS skill over Morogoro was -0.15 and over Mbeya was -0.03 meaning that the forecasts were worse than random chance (Table 5). Negative values for HSS over Morogoro and Mbeya mean that the number of hits was lower than would be expected by chance.

4.2.2 Long rains

Table 5 also shows accuracy and skill for long rains. Comparing the accuracy between the two stations both in the bimodal areas, it can be noted that there was slight skill of accuracy for both stations. Same station scored 0.57, indicating that 57% of all forecasts were correct and Morogoro station scored 0.63 indicating that 63% of all forecast cases were correct.

Both stations had relatively high values of bias (Same, 0.57 and Morogoro, 0.62). However, these results still signify a general tendency for Accuweather to under-forecast similar to those in the short rainy season.

Heidke skill scores displayed poor skill for Accuweather in predicting rainfall events with 0.16 for Same and 0 for Morogoro signifying that the forecasts were random.

4.3 ICPAC forecast products

This sub-section presents evaluation of three-categorical tercile forecasts produced by ICPAC for Morogoro, Arusha, Same, Dodoma and Mbeya.

Forecast products produced by ICPAC which are issued in three-categorical tercile forecasts were evaluated. The evaluations were for the short, long and seasonal rainy seasons.

4.3.1 Short/seasonal rains

Comparing the accuracy of the forecasts between these two different rainy seasons (short/seasonal and long rains), it can be noted that the accuracy was slight close to 0.60 over Morogoro indicating that 60% of all forecast cases were correct. Mbeya and Dodoma were next in performance with a slight similar range of scores close to 50%. Same and Arusha stations both in the bimodal rainy season were less accurate with a score of 20% each. Generally, the accuracy skill scores over Morogoro were better compared to other bimodal stations. This is probably due to the orographic effect in the adjacent areas.

The bias for the ICPAC forecast (Table 6) results show that values were 0.50 and above for all stations with values greater than 1 in the unimodal rainy season areas (Mbeya and Dodoma), both stations scoring 1.33 and 1.30 respectively as compared to the bimodal rainy season areas. In the bimodal rainy season, the score ranged between 0.5 - 0.6. This indicates that the forecast system has a tendency to under-forecast in the bimodal and over-forecasts in the unimodal rainy seasons.

Table 6: Verification indices obtained between actual and predicted long, short and seasonal rains for the ICPAC

Rainy season	**Stations**	**Short/seasonal rains**			**Long rains**		
		Accuracy	Bias	HSS	Accuracy	Bias	HSS
Bimodal	Same	0.20	0.50	-0.42	0.12	1.25	-0.75
	Morogoro	0.60	0.60	0.00	0.25	0.67	-0.20
	Arusha	0.20	0.50	-0.43	0.75	1.00	-0.14
Unimodal	Mbeya	0.47	1.33	-0.08	-	-	-
	Dodoma	0.47	1.30	-0.09	-	-	-

The Heidke skill scores for ICPAC results displayed poor skill in predicting rainfall events (Table 6). The evaluations in the short rainy season generally had lower HSS values (Same, -0.42, Morogoro, 0, Arusha, -0.43, Mbeya, -0.08 and Dodoma, -0.09) signifying that all forecasts in the season were worse than random chance.

4.3.2 Long rains

Comparing the accuracy between three stations (Same, Morogoro, and Arusha) all in the long rainy season, the results (Table 6) show that the accuracy for ICPAC was skillful over Arusha than over the other two stations (Same and Morogoro).

Results (Table 6) show that the bias for the ICPAC forecast was high over Same station with values greater than 1 indicating that the forecast system has a tendency to over-forecast. The score value over Arusha was 1 meaning that the forecasts were perfect in the season while over Morogoro the score was 0.67.

The Heidke skill scores of the ICPAC forecast during the long rainy season indicated that there was no skill for all stations with scores having negative values meaning that the forecasts were worse than the reference forecast (Table 6).

4.4 TMA forecast products

This sub-section presents evaluation of qualitative forecasts produced by TMA for Morogoro, Arusha, Same, Dodoma and Mbeya stations.

The format in which the forecasts are issued is text (narrative). The forecast as it stands is not quantitative or even deterministic. A forecaster might predict “cloudy conditions at times with showers and thunderstorms especially towards the end of the dekad”. With such statement, it is not quite clear how one should grade statistically accuracy or skill in that case (Table 7). Consequently, the data for TMA forecast products could not be evaluated.

Table 7: Classification of decadal rainfall and forecasts for TMA

Date	Dekad	Long term rainfall (mm)	Lower	Upper	Forecast	Observed (mm)	Observed tercile category

1-10/3/2006	7	24.7	16	33	No information	51.8	AN
11-20/3/2006	8	41.5	27	55	No information	89	AN
21-31/3/2006	9	61.6	41	81	Cloudy conditions at times with showers and thunderstorms especially towards the end of the dekad	99.4	AN
1-10/4/2006	10	82.6	55	109	Cloudy conditions at times with showers and thunderstorms over few areas	67.9	N

Based on the above results Accuweather forecast products appeared to perform better in the long rainy season (OND) than in the short rainy season (MAM) with respect to accuracy. Similarly, the ICPAC forecasts products appeared to perform better in the OND than in MAM season. These results agree with those of other workers (e.g. Mwano, 2006) who observed that GHACOF forecast products appeared to perform better in the OND than in the MAM season.

The bias for ICPAC forecast products appeared to have relative values close to 1 in the MAM season than in the OND season. Accuweather forecast products generally appeared to under-forecast occurrences of the rain events in both rainy seasons.

All the three forecasting systems (NCEP, Accuweather and ICPAC) skill scores were negative signifying that all forecasts are worse than the reference forecast. This is not surprising because, at lead times of over 7 days, there is only small amount of skill in weather forecasts (Stanski *et al.*, 1989; Palmer *et al*., 2005).

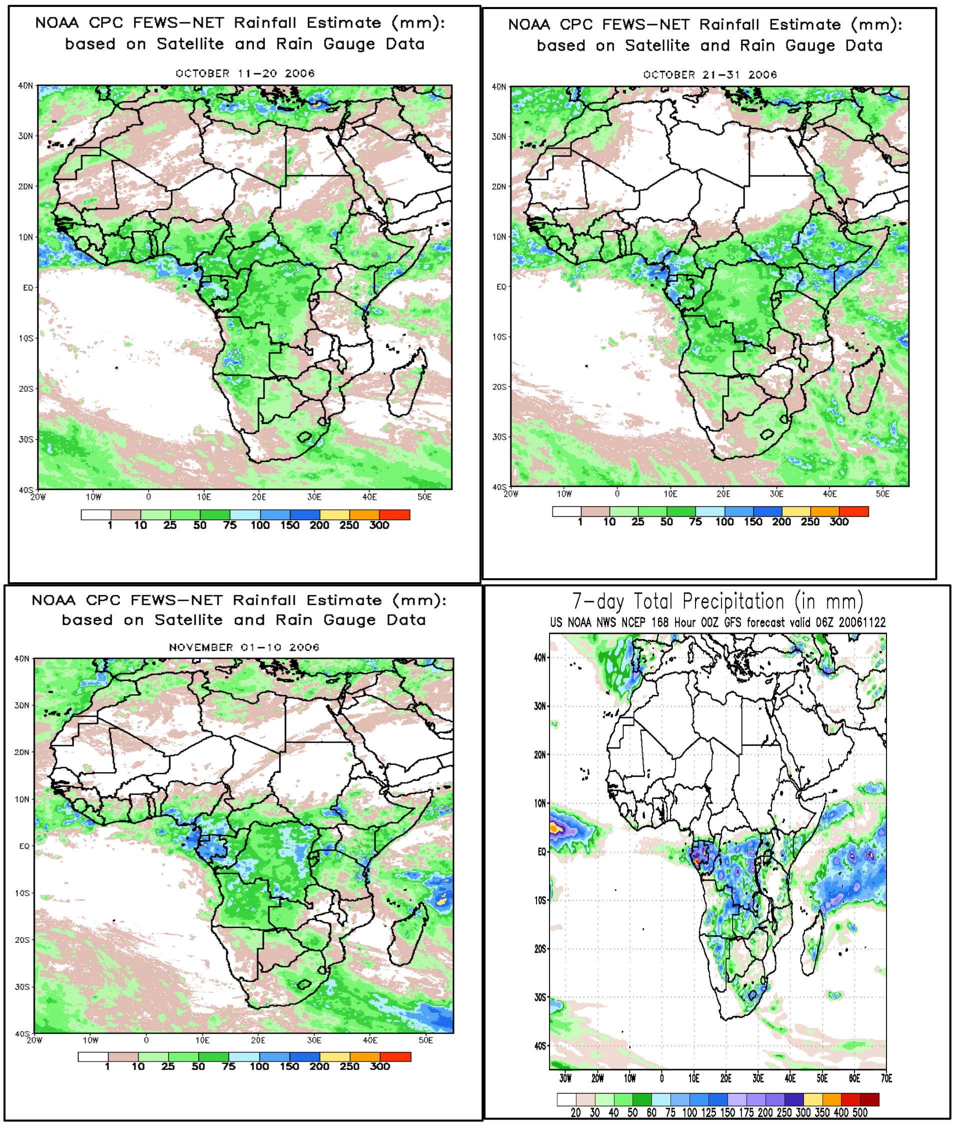
The format in which the TMA's forecasts are issued is text (narrative) as previously stated. Such forecast presentations are often aimed at a general audience (Jolliffe and Jolliffe, 1997). Technical definitions and their corresponding statistical manipulations underlying worded forecasts are not yet available implying that worded forecasts will remain difficult to verify (Jolliffe and Stephenson, 2003).

The results indicate that, although none of the forecasting systems were able to produce a perfect forecast (bias, accuracy and HSS, = 1), ICPAC generally produced the best forecasts in most of the long rainy season and seasonal rain of the unimodal areas based on the bias results**.**

These results naturally lead to questions as to why one forecasting system performs better than others. The answers to these questions are not straightforward. Several factors, including formulation and assumptions made in the schemes, can be responsible for producing different results. Moreover, different schemes may respond in different ways to a given combination of horizontal and vertical resolutions of the model.

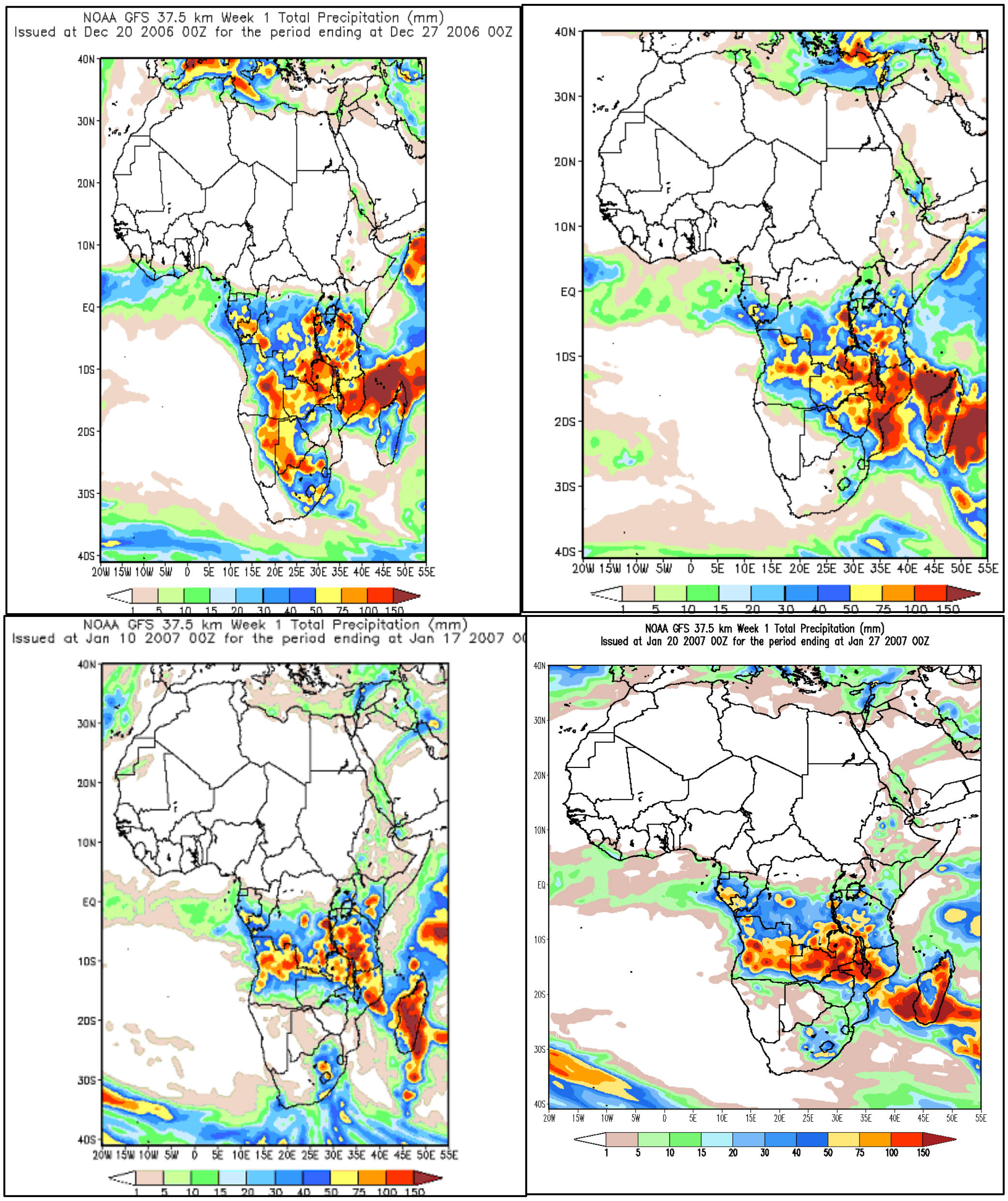
LIST OF APPENDICES

Appendix A1: NCEP Climate Forecasts Products



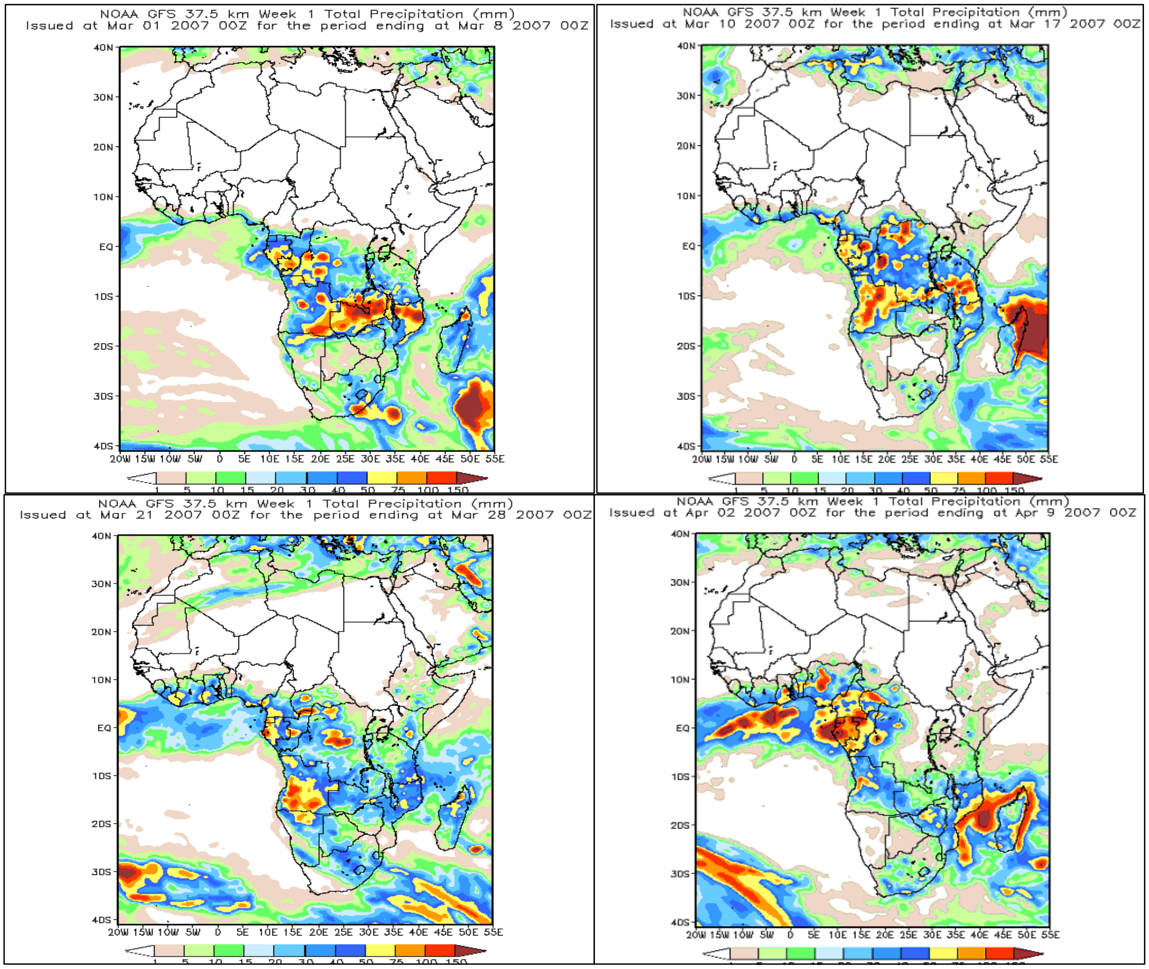
Climate outlook in the respective order top left to bottom a) 11-20 Oct 2006, b) 1-7 Nov, 06, c) 11-20 Nov, 06 and d) 21-27 Nov

Appendix A2: NCEP Climate Forecasts Products



Climate outlook in the respective order top left to bottom right a) 1-8 March 200, b) 10-17 March 200 7, c) 21-27 March 2007 and d) 1-10 April 2007

Appendix A3: NCEP Climate Forecasts Products



Climate outlook in the respective order top left to bottom right a) 1-9 April 2007 b) 11-17 April 2007 c) 21-28 Feb 2007 and d) 11-18 Feb 2007

Appendix B: Terciles, contingency table and indices for NCEP

Dodoma

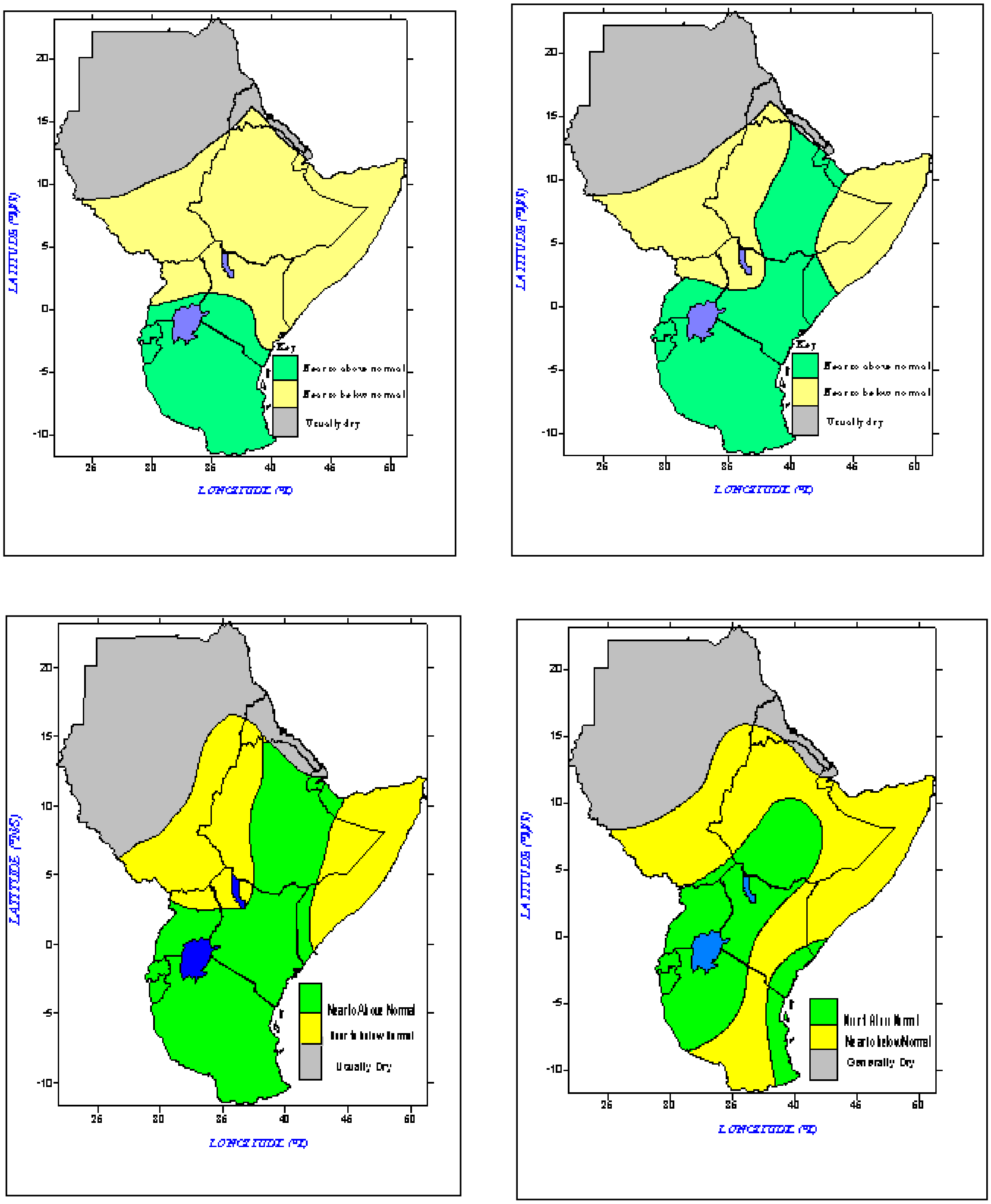
Dates	dekad	long term	lower	upper	forecast	af	observed	ft	obsered tercile	evaluation
11-17/12/06	35	43.3	28.6	57.2	30-40	35.0	64.7	N	A	m
20-27/12/06	36	45.1	29.8	59.5	10-15	12.5	34.8	B	N	m
10-17/1/07	2	48.8	32.2	64.4	75-100	87.5	60.3	A	N	m
20-27/1/07	3	41.1	27.1	54.3	50-75	62.5	113.9	A	A	h
21-28/2/07	6	27.5	18.2	36.3	20-30	25.0	49.2	N	A	m
1-8/3/07	7	35	23.1	46.2	5-10	7.5	12	B	B	cn
10-17/3/07	8	42.2	27.9	55.7	20-30	25.0	34.6	B	N	m
21-28/3/07	9	38.8	25.6	51.2	10-15	12.5	4.9	B	B	cn

af – Average forecast
ft – forecast tercile

forecasted	observed		
	yes	no	total
yes	1	0	1
no	5	2	7
total	6	2	8

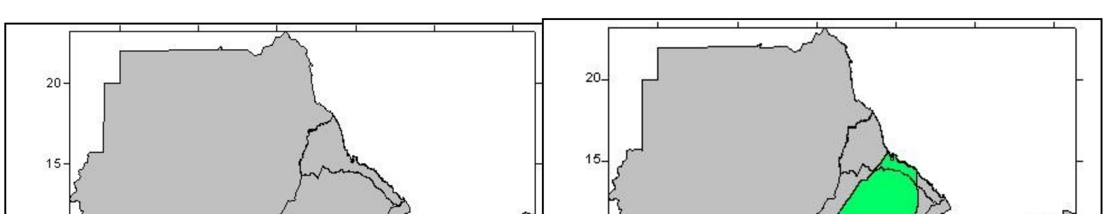
Accuracy	0.38
Bias	0.17
HSS	0.09

Appendix C1: ICPAC Climate Outlook

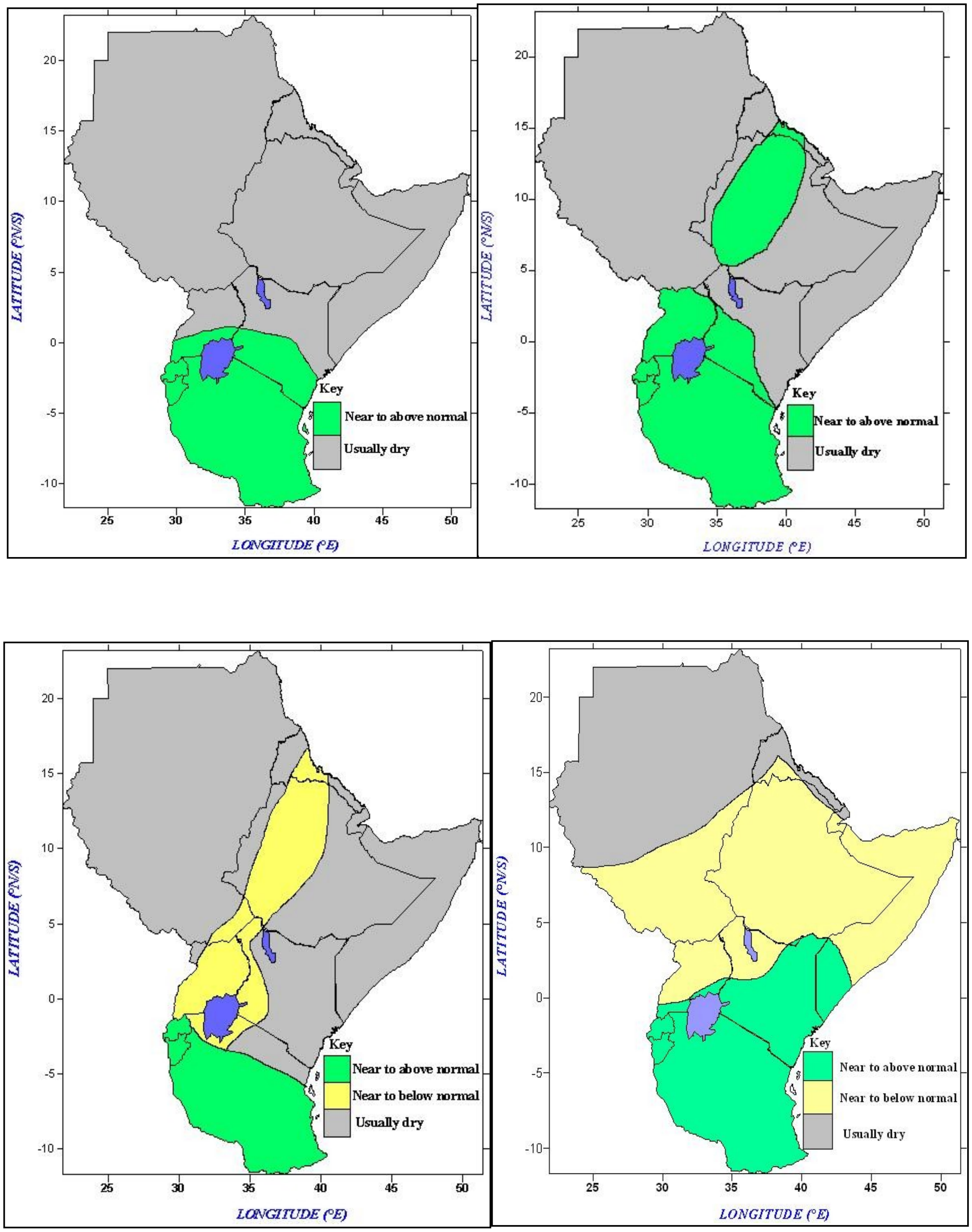


Climate outlook in the respective order top left to bottom right a) dekad 9 (21-31 April) 2006; b) dekad 10 (11-20 April 2006; c) dekad 11 (21-30) April 2006 and d) dekad 12 (21-30 April) 2006

Appendix C2: ICPAC Climate Outlook



Appendix C2: ICPAC Climate Outlook



Climate outlook in the respective order top left to bottom right a) dekad 2 (10-20 Jan) 2007; b) dekad 4 (1-10 Feb 2007; c) dekad 5 (11-20Feb) 2007 and d) dekad11 (1-10 Apr 2007

Appendix C3:ICPACClimate Outlook

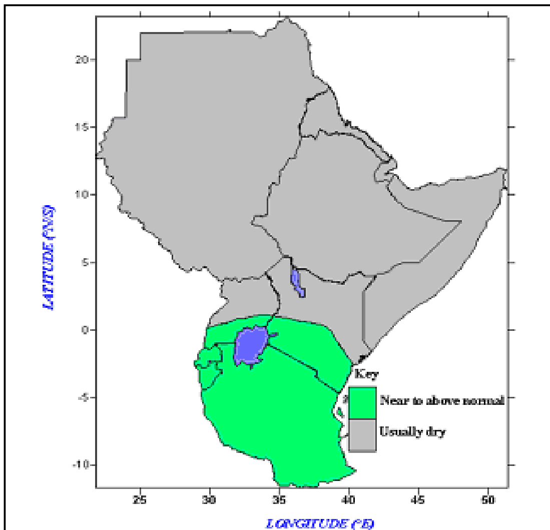
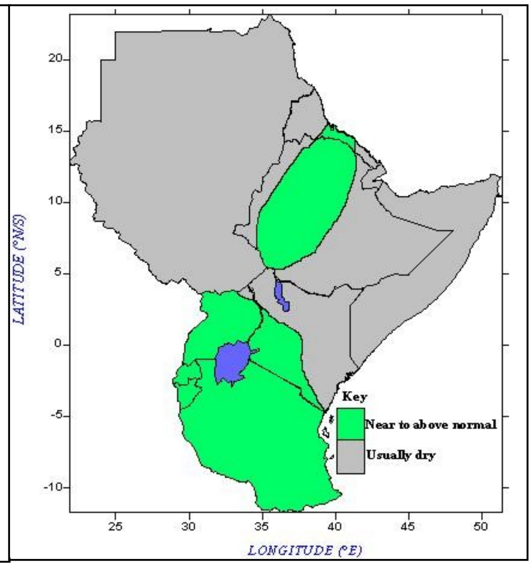


Figure 5: Climate outlook for dekad 03 (21-31 January) 2007



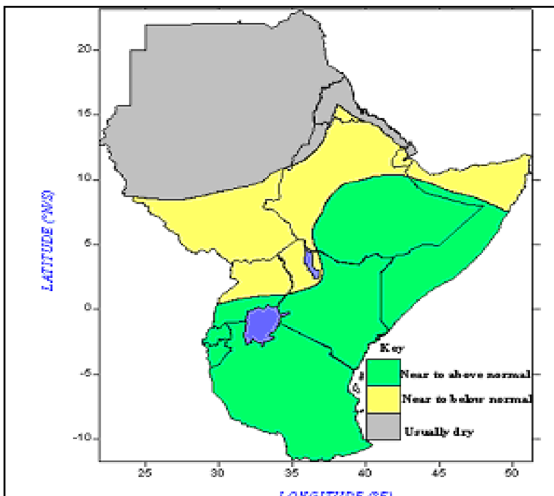
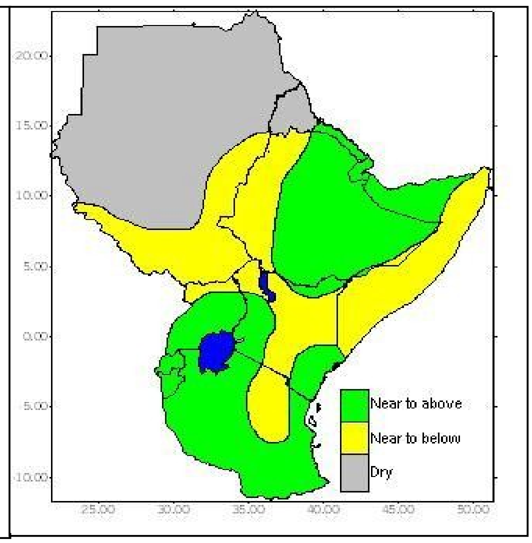
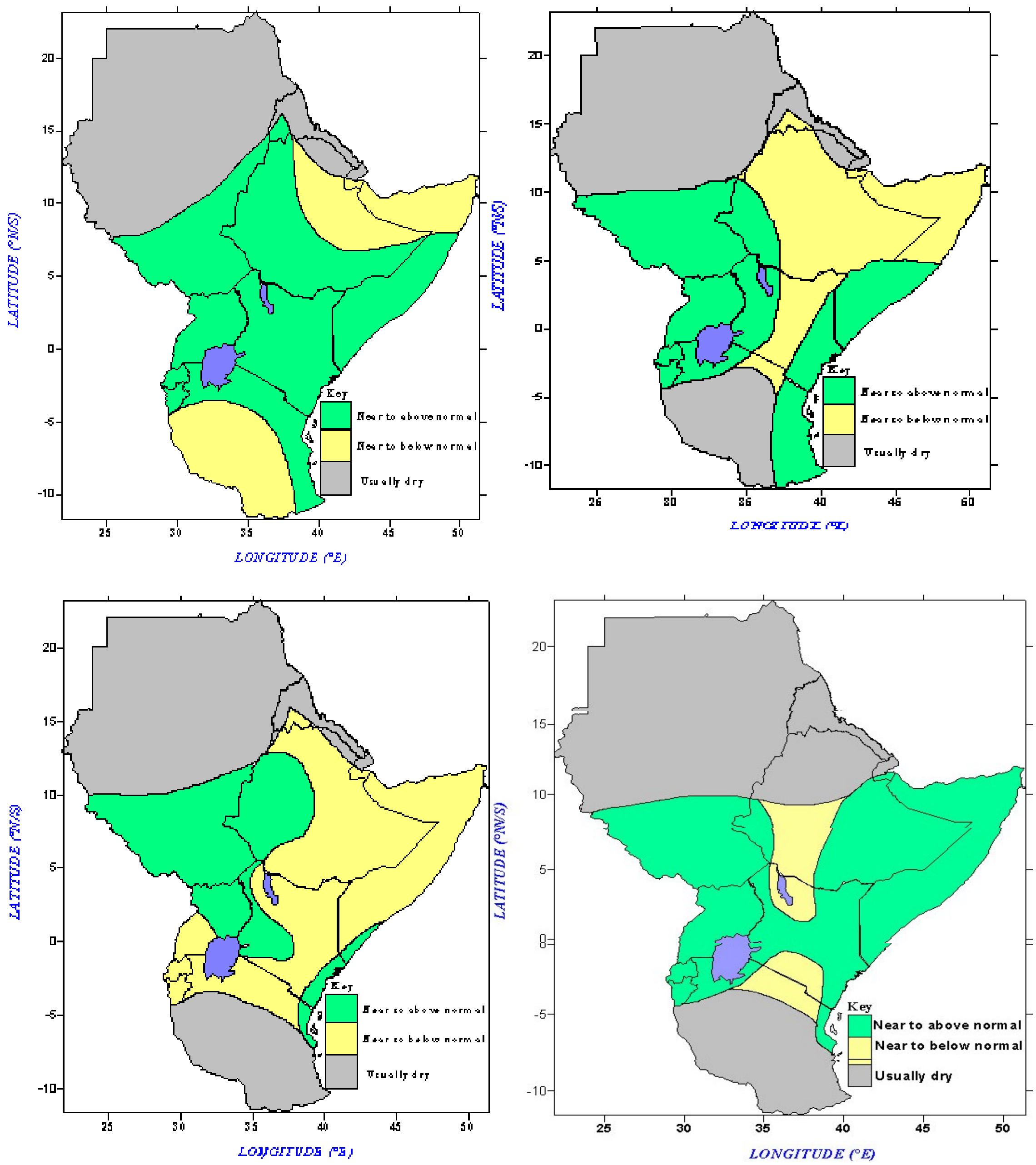


Figure 4: Climate outlook for dekad 09 (21-31 March) 2007



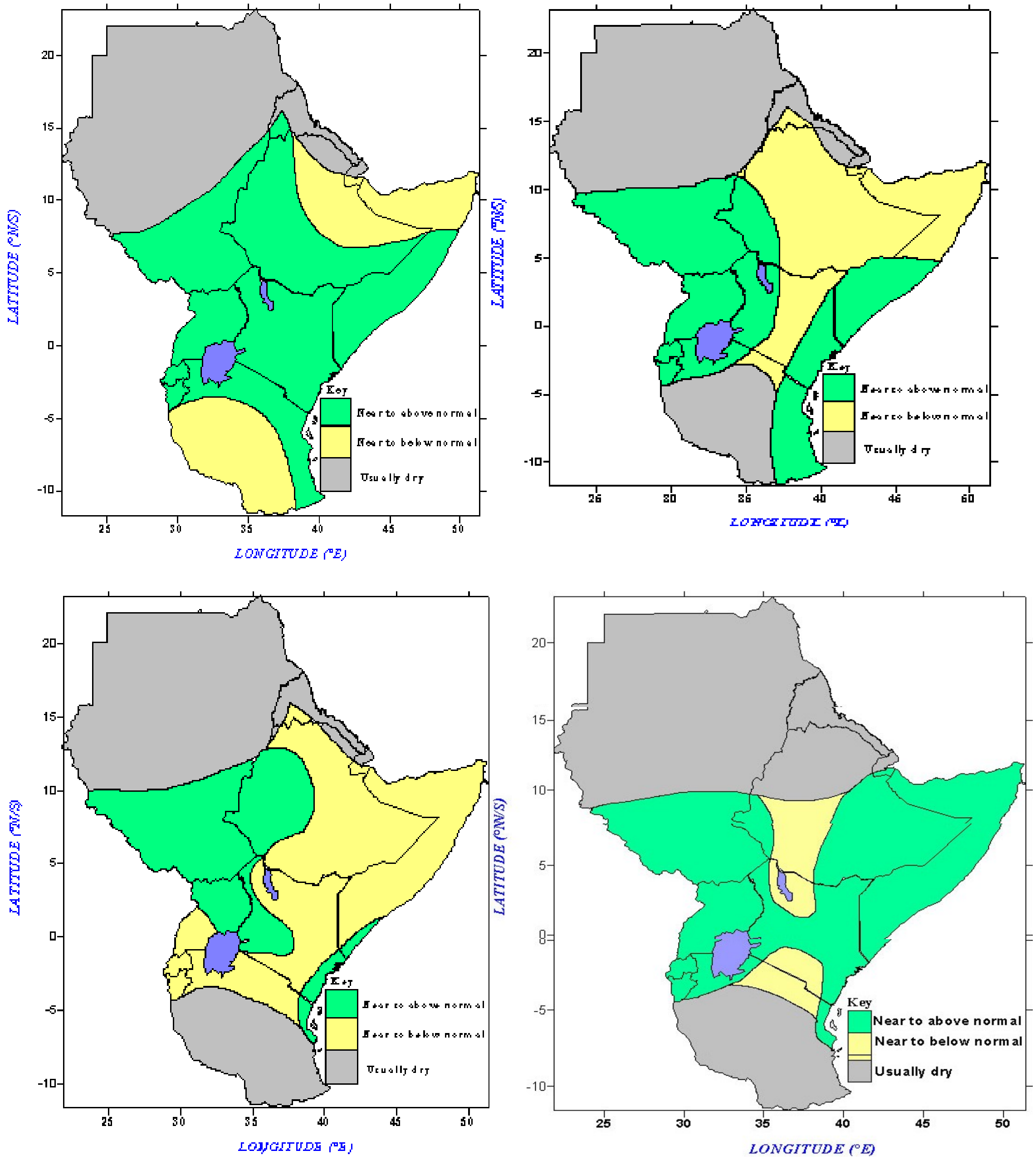
Climate outlook in the respective order top left to bottom left *a) dekad 3 (21 -31Jan) 2007 b) dekad 4 (1-10 Feb) 2007 and c) dekad 9 (21-31 Mar) 2007*

Appendix C4: ICPAC Climate Outlook



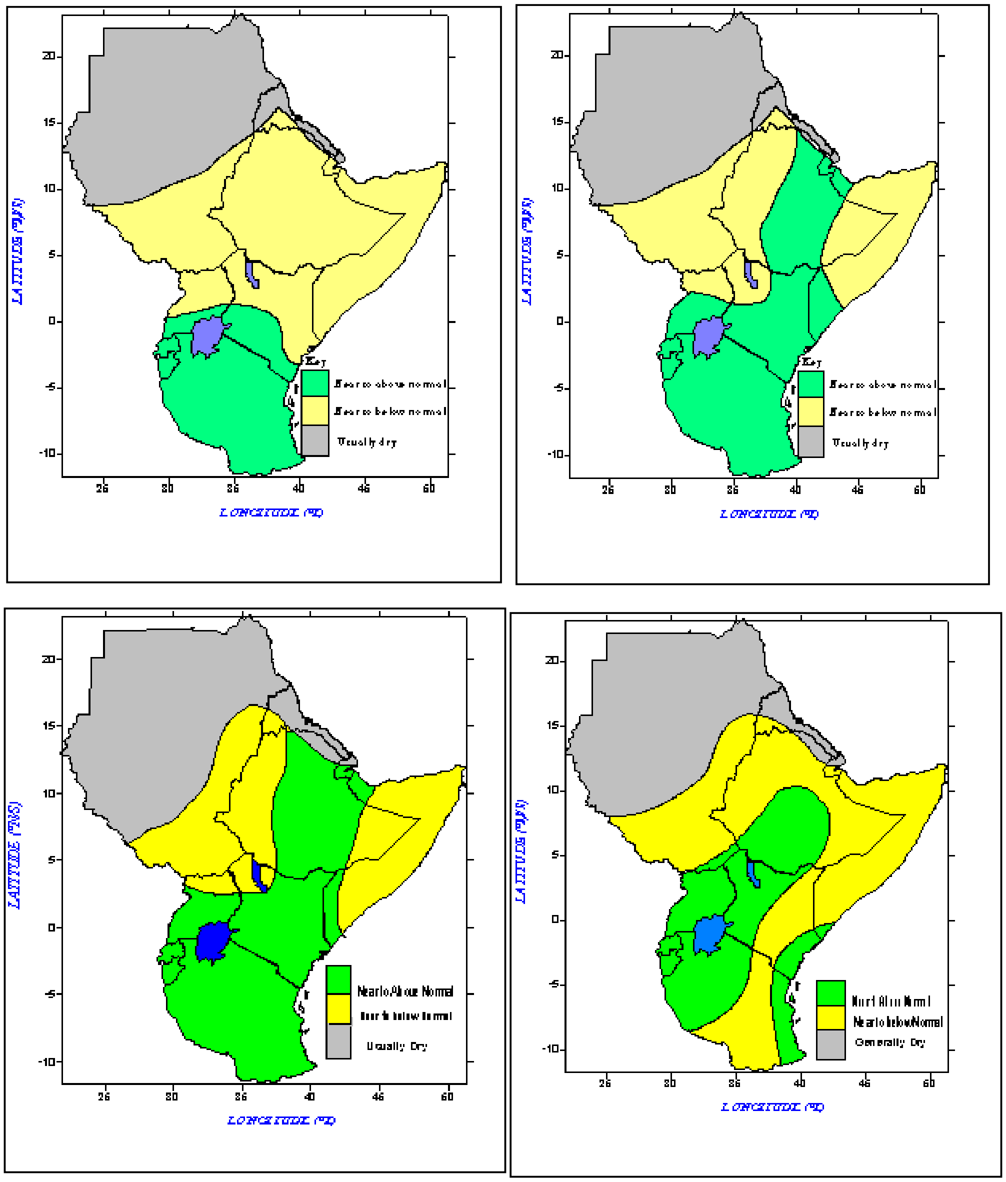
Climate outlook in the respective order top left to bottom right a) dekad 13 (1 -10 May) 2007 b) dekad 11 (11 -20 April) 2007 and c) dekad 12 (21-30 April) 2007

Appendix C5: ICPAC Climate Outlook



Climate outlook in the respective order top left to bottom right a) dekad 13 (1 -10 May) 2006 b) dekad 14 (11 -20 May) 2006 c) dekad 15 (21 -31 May) 2006 and dekad 29 (11 -20 October) 2006

Appendix C6: ICPAC Climate Outlook



Climate outlook in the respective order top left to bottom right a) dekad 9 (21-31 March) 2006; b) dekad 10 (1-10 April) 2006; c) dekad 11 (11-20 April) 2006 and d) dekad 12 (21-30 April) 2006

Appendix D1: Terciles, contingency table and indices for ICPAC

Arusha

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
21-31/3 06	9	61.6	A	99.4	40.7	81.3	h
1-10/4/06	10	82.6	A	67.9	54.5	109	m
11-20/4/06	11	73.8	A	127	48.7	97.4	h
21-30/4/06	12	67.3	N	71.1	44.4	88.8	h
1-10/5/06	13	37.6	A	84.1	24.8	49.6	h
11-20/5/06	14	28.3	N	26.2	18.7	37.4	h
11-20/10/06	29	6.5	N	14	4.3	8.6	m
1-10/11/06	31	23.9	A	154.3	15.8	31.5	h
11-20/11/06	32	38.9	N	4.3	25.7	51.3	m
1-10/12/06	34	35.7	N	21.8	23.6	47.1	fa
21-31/12/06	36	32.9	N	118.9	21.7	43.4	m
21-31/3/07	9	61.6	A	96.2	40.7	81.3	h
1-10/4/07	10	82.6	A	13.8	54.5	109	fa

OND

		observed		
		yes	no	total
forecasted	yes	1	1	2
	no	3	0	3
	total	4	1	5

Accuracy	0.2
Bias	0.5
HSS	-0.43

MAM

		observed		
		yes	no	total
forecasted	yes	6	1	7
	no	1	0	1
	total	7	1	8

Accuracy	0.75
Bias	1
HSS	-0.14

Appendix D2

Dodoma

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
21-31/3/06	9	59.7	A	26	39.4	78.8	fa
1-10/4/06	10	49.8	A	89.3	32.9	65.7	h

11-20/4/06	11	34.2	A	65.3	22.6	45.1	h
21-30/4/06	12	22.1	N	76	14.6	29.2	m
1-10/5/06	13	11.5	N	5.4	7.6	15.2	fa
11-20/5/06	14	4.2	B	55.1	2.8	5.5	m
11-20/10/06	29	4	B	0	2.6	5.3	cn
1-10/11/06	31	11.1	A	17.3	7.3	14.7	h
11-20/11/06	32	28.1	B	13.6	18.5	37.1	cn
1-10/12/06	34	23.2	B	95	15.3	30.6	m
21-31/12/06	36	41.3	A	117.2	27.3	54.5	h
11-20/1/07	2	73.1	A	130.4	48.2	96.5	h
21-31/1/07	3	66.4	A	66.7	43.8	87.6	fa
1-10/2/07	4	66.7	A	124	44.0	88.0	h
11-20/2/07	5	66.3	A	71.1	43.8	87.5	fa
21-31/3/07	9	57.3	A	35.3	37.8	75.6	fa

		observed		
		yes	no	total
forecasted	yes	6	6	12
	no	3	2	5
	total	9	8	17

Accuracy	0.47
Bias	1.33
HSS	-0.09

Appendix D3

Mbeya

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
21-31/3/06	9	59.7	A	26	39.4	78.8	fa
1-10/4/06	10	49.8	A	89.3	32.9	65.7	h
11-20/4/06	11	34.2	A	65.3	22.6	45.1	h
21-30/4/06	12	22.1	N	76	14.6	29.2	m
1-10/5/06	13	11.5	N	5.4	7.6	15.2	fa

11-20/5/06	14	4.2	B	55.1	2.8	5.5	m
11-20/10/06	29	4	B	0	2.6	5.3	cn
1-10/11/06	31	11.1	A	17.3	7.3	14.7	h
11-20/11/06	32	28.1	B	13.6	18.5	37.1	cn
1-10/12/06	34	23.2	B	95	15.3	30.6	m
21-31/12/06	36	41.3	A	117.2	27.3	54.5	h
11-20/1/07	2	73.1	A	130.4	48.2	96.5	h
21-31/1/07	3	66.4	A	66.7	43.8	87.6	fa
1-10/2/07	4	66.7	A	124	44.0	88.0	h
11-20/2/07	5	66.3	A	71.1	43.8	87.5	fa
21-31/3/07	9	57.3	A	35.3	37.8	75.6	fa

		observed		
		yes	no	total
forecasted	yes	6	6	12
	no	3	2	5
	total	9	8	17

Accuracy	0.47
Bias	1.33
HSS	-0.09

Appendix D4

Morogoro

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
21-31/3/ 06	9	93	A	106.2	61.4	122.8	h
1-10/4/06	10	69.1	A	70.2	45.6	91.2	m
11-20/4/06	11	65.9	A	70.3	43.5	87.0	m
21-30/4/06	12	59.7	A	84.1	39.4	78.8	h
1-10/5/06	13	45.7	A	51.6	30.2	60.3	m
11-20/5/06	14	24.1	A	1	15.9	31.8	m
11-20/10/06	29	6.7	A	39.9	4.4	8.8	h

1-10/11/06	31	11.1	A	54.7	7.3	14.7	h
11-20/11/06	32	28.1	A	27.4	18.5	37.1	m
1-10/12/06	34	23.2	B	56.1	15.3	30.6	m
21-31/12/06	36	41.3	A	101.1	27.3	54.5	h
21-31/3/07	9	58	A	35.9	38.3	76.6	fa
1-10/4/07	10	69.1	A	43.2	45.6	91.2	fa

OND

		observed		
		yes	no	total
forecasted	yes	3	0	3
	no	2	0	2
	total	5	0	5

Accuracy	0.6
Bias	0.6
HSS	0

MAM

		observed		
		yes	no	total
forecasted	yes	2	2	4
	no	4	0	0
	total	6	2	8

Accuracy	0.25
Bias	0.67
HSS	-0.2

Appendix D 5

Same

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
21-31/3/06	9	34.2	A	24.4	22.6	45.1	m
1-10/4/06	10	43.1	A	77.4	28.4	56.9	h
11-20/4/06	11	41.3	A	48.6	27.3	54.5	m
21-30/4/06	12	35.1	N	76	23.2	46.3	m
1-10/5/06	13	34.2	A	22.3	22.6	45.1	fa
11-20/5/06	14	20.6	N	3.5	13.6	27.2	fa
11-20/10/06	29	7.2	N	40.2	4.8	9.5	m
1-10/11/06	31	10.6	A	30.7	7.0	14.0	h
11-20/11/06	32	18.8	N	34.3	12.4	24.8	m

1-10/12/06	34	24	N	15.6	15.8	31.7	fa
21-31/12/06	36	20.3	N	138	13.4	26.8	m
21-31/3/07	9	59.7	A	9.6	39.4	78.8	fa
1-10/4/07	10	43.1	A	3.9	28.4	56.9	fa

OND

		observed		
		yes	no	total
forecasted	yes	1	1	2
	no	3	0	3
	total	4	1	5

Accuracy	0.2
Bias	0.5
HSS	-0.43

MAM

		observed		
		yes	no	total
forecasted	yes	1	4	5
	no	3	0	3
	total	4	4	8

Accuracy	0.125
Bias	1.25
HSS	-0.75

Appendix E1: Accuweather Forecasts for Mbeya

Thursday, March 1, 2006 Rain Total: 33.1 Occurring: Mar 1 | Mar 2 | Mar3 | | Mar 5

March 11, 2006 Rain Total: 7.1 Occurring: Mar13 | Mar17 | Mar 18 | Mar 19

March 22, 2006 Rain Total: 7.8 Occurring: Mar22 | Mar24 | 26|

October 1, 2006 Rain Total: 9.7 Occurring: Oct 1 | Oct 2 | Oct 3

November 1, 2006 Rain Total: 11.9 Occurring: Nov 1 | Nov 2 | Nov 3 | Nov 4

November 21, 2006 Rain Total: 11.7 Occurring: Nov 21 | Nov 22 | Nov 23

December 1 Rain Total: 97 Occurring: Dec 1 | Dec 2 | Dec 4 | Dec 6 Dec 7 | Dec 9

December 11 Rain Total: 11.9 Occurring: Dec 11 | Dec 12 | Dec 14 | Dec 15

Thursday, January 1, 2007 Rain Total: 22.4 Occurring: Jan 1 | Jan 2 | Jan 3 | Jan 4 | Jan 5

Thursday, January 11, 2007 Rain Total: 28.1 Occurring: Jan 11 | Jan 12 | Jan 13 | Jan 15

January 21, 2007 Rain Total: 116.8 Occurring: Jan 21 | Jan 22 | Jan 23 | Jan 24 | Jan 25

February 12, 2007Rain Total: 43.4 Occurring: Feb 12 | Feb1 4 | Feb1 5

March 11, 2007 Rain Total: 13.5 Occurring: Mar 12 | Mar 14 | Mar 15

March 22, 2006 Rain Total: 2.5 Occurring: Mar 22 | Mar 24

Appendix E2: Morogoro

March 1, 2006 Rain; Total: 32.5 Occurring: Mar 2 | Mar 3 | Mar 4 | Mar 5 | Mar 6

March 21, 2006; Rain Total: 19.6 Occurring: Mar21 | Mar 23

April 2, 2006 Rain Total: 16.7 Occurring: Apr 2 | Apr 3 |Apr 5 | Apr 8 |

April 11, 2006 Rain Total: 24.8 Occurring: Apr 12 | Apr 13 | Apr14 | Apr 15

April 21, 2006 Rain Total: 3.8 Occurring: Apr 22 | Apr 23 |

May 1, 2006 Rain Total: 3.8 Occurring: May1 | May 3 |

October 11, 2006 Rain Total: 8.6 Occurring: Oct 12 | Oct 13 | Oct 14 |

November 11, 2006 Rain Total: 3.1 Occurring: Nov 12 | Nov13 |

November 21, 2006 Rain Total: 6.1 Occurring: Nov 22 | Nov 23 |

December 1, 2006 Rain Total: 4.8 Occurring: Dec 1 | Dec 2 | Dec 3

December 12, 2006 Rain Total: 18.2 Occurring: Dec 12 | Dec 13 | Dec 14 | Dec 15 | Dec 16

Thursday, March 01, 2007 Rain Total: 5.3 Occurring: Mar 1 | Mar 2|

March 11, 2007Rain Total: 19.6 Occurring: Mar 11 | Mar 12 | Mar 13 | Mar 14 | Mar 15

March 22, 2007 Rain Total: 6.7 Occurring: Mar 22 | Mar 23 | Mar 24 | Mar 25 | Mar 26

April 11, 2007 Rain Total: 19 Occurring: Apr 12 | Apr 13 | Apr 14 | Apr 15

Appendix E3: Same

March 1, 2006Rain Total: 28.2 Occurring: Mar 5 | Mar7 | Mar 8| Mar 9

March 21, 2006 Rain Total: 7.7 Occurring: Mar 21 | Mar 22 | Mar 23

October 1, 2006 Rain Total: 2.3 Occurring: Oct 1 | Oct 2

October 11, 2006 Rain Total: 2.0 Occurring: Oct 11

November 1, 2006 Rain Total: 8.7 Occurring: Nov 1 | Nov 2| Nov 4

November 21, 2006 Rain Total: 22.2 Occurring: Nov 21 | Nov 22 | Nov 23

December 1, 2006 Rain Total: 2.6 Occurring: Dec 1 | Dec 2

December 11, 2006 Rain Total: 14.9 Occurring: Dec 12 | Dec 13 | Dec 14 | Dec 15 | Dec 16

March 11, 2007 Rain Total: 2.1 Occurring: Mar 11 | Mar 12

March 21, 2007 Rain Total: 1.3 Occurring: Mar 21|

April 11, 2007 Rain Total: 4.7 Occurring: Apr 11 | Apr 12

April 21, 2007 Rain Total: 8.5 Occurring: Apr 21 | Apr 22 | Apr 23 |

May 11, 2007 Rain Total: 26.1 Occurring: May 12 | May 13 | May 14 |

May 21, 2007 Rain Total: 1.8 Occurring: May 21|

Appendix F1: Tercile, contingency table and indices for Accuweather

Mbeya

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
1-10/3/06	7	57.8	33.1	56.5	38.1	76.3	m
11-20/3/06	8	57.3	7.1	31.6	37.8	75.6	cn
21-31/3/06	9	59.7	7.8	26	39.4	78.8	cn
1-10/12/06	34	44.1	97	102.3	29.1	58.2	h
11-20/12/06	35	63.8	11.9	62.4	42.1	84.2	m
1-10/1/07	1	67.3	22.4	41.9	44.4	88.8	cn
11-20/1/07	2	73.1	28.1	130.4	48.2	96.5	m
21-31/1/07	3	66.4	116.8	49.1	43.8	87.6	fa
11-20/2/07	5	66.3	43.4	55.8	43.8	87.5	m
11-20/3/07	8	57.3	13.5	65.3	37.8	75.6	m
21-31/3/07	9	59.7	2.5	33.3	39.4	78.8	cn

observed

		yes	no	total
forecasted	yes	1	1	2
	no	5	4	9
	total	6	5	11

Accuracy	0.45
Bias	0.33
HSS	-0.33

Appendix F2

Morogoro

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
1-10/3/06	7	30.4	32.5	50	20.1	40.1	h
21-31/3/06	9	58	19.6	93.1	38.3	76.6	m
1-10/4/06	10	69.1	24.8	70.2	45.6	91.2	m
21-30/4/06	12	59.7	3.8	84.1	39.4	78.8	m
1-10/5/06	13	45.7	3.8	51.6	30.2	60.3	m
11-20/10/06	29	6.7	8.6	8.9	4.4	8.8	h
11-20/11/06	32	28.1	3.1	18.8	18.5	37.1	m
21-30/11/06	33	19	6.1	67.7	12.5	25.1	m
1-10/12/06	34	23.2	4.8	55.4	15.3	30.6	fa
11-20/12/06	35	42.9	18.2	22.7	28.3	56.6	cn
1-10/3/07	7	30.4	5.3	5	20.1	40.1	cn
11-20/3/07	8	43	19.6	83.9	28.4	56.8	m
21-31/3/07	9	58	6.7	61.5	38.3	76.6	m

OND

		observed		
		yes	no	total

Accuracy	0.4

forecasted	yes	1	1	2		Bias	0.67
	no	2	1	3		HSS	-0.15
	total	3	2	5			

MAM

		observed					
		yes	no	total		Accuracy	0.63
forecasted	yes	5	0	5		Bias	0.63
	no	3	0	3		HSS	0
	total	8	0	8			

Appendix F3

Same

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
1-10/3/06	6	19.3	28.2	114.1	12.7	25.5	h
21-31/3/06	9	34.2	7.7	25	22.6	45.1	m
1-10/10/06	28	7.6	2.3	0	5.0	10.0	cn
11-20/10/06	29	7.2	2	71.8	4.8	9.5	m
1-10/11/06	31	10.7	8.7	30.7	7.1	14.1	h
21-31/11/06	33	33.5	22.2	102	22.1	44.2	h
1-10/12/06	34	44.1	2.6	13.2	29.1	58.2	cn
11-20/12/06	35	63.8	14.9	11	42.1	84.2	cn
11-20/3/07	8	57.3	2.1	22.9	37.8	75.6	cn
11-20/41/07	11	34.2	4.7	49	22.6	45.1	m
21-30/4/07	12	22.1	8.5	6.9	14.6	29.2	cn
11-20/5/07	14	4.2	26.1	23.7	2.8	5.5	fa
21-31/5/07	15	1.4	1.8	12.2	0.9	1.8	h

OND

		observed					
		yes	no	total		Accuracy	0.83
forecasted	yes	2	0	2		Bias	0.67
	no	1	3	4		HSS	0.67
	total	3	3	6			

MAM

		observed		
		yes	no	total
forecasted	yes	2	1	3
	no	2	2	4
	total	4	3	7

Accuracy	0.57
Bias	0.75
HSS	0.16

Appendix G: TMA 10-day forecasts

Box 1: Expected weather during March 01 – 10, 2006

Western areas (Kigoma and Tabora regions) and central (Dodoma and Singida regions) are expected to feature partly cloudy to cloudy conditions with showers and thunderstorms from mid towards the end of the dekad. The Lake Victoria basin (Mwanza Mara and Kagera region) will experience cloudy conditions with showers and thunderstorms over most areas especially at the beginning of the dekad breaking to partly cloudy conditions with showers and thunderstorms over few areas at the end of the dekad. Southernwestern highlands (Mbeya, Rukwa and parts of southern Iringa and Ruvuma regions) will feature partly cloudy to cloudy conditions at times with showers and thunderstorms over most areas. Northern coast (Dar es Salaam, Coast, Tanga), southern coast (Mtwara and Lindi regions) and the Islands of Zanzibar and Pemba will feature partly cloudy to cloudy conditions with showers and thunderstorms at times and sunny intervals.

Box 2: Expected weather during March 11 – 20, 2006

Western areas (Kigoma and Tabora regions) and central (Dodoma and Singida regions) are expected to feature partly cloudy to cloudy conditions with showers and thunderstorms from mid towards the end of the dekad. The Lake Victoria basin (Mwanza Mara and Kagera region) will experience cloudy conditions with showers and thunderstorms over most areas especially at the beginning of the dekad breaking to partly cloudy conditions with showers and thunderstorms over few areas at the end of the dekad. Southernwestern highlands (Mbeya, Rukwa and parts of southern Iringa and Ruvuma regions) will feature partly cloudy to cloudy conditions at times with showers and thunderstorms over most areas. Northern coast (Dar es Salaam, Coast, Tanga), southern coast (Mtwara and Lindi regions) and the Islands of Zanzibar and Pemba will feature partly cloudy to cloudy conditions with showers and thunderstorms at times and sunny intervals.

Box 3: Expected weather during March 21 – 31, 2006

The Lake Victoria basin, (Mwanza, Mara and Kagera regions) will experience partly to cloudy conditions with showers and thunderstorms over few areas. Southwestern highlands (Mbeya, Rukwa and parts of southern Iringa and Ruvuma regions) will feature partly cloudy conditions with showers and thunderstorms over few areas. Northern coast (Dar es Salaam, Coast and Tanga regions), Southern coast (Mtwara and Lindi regions) and the Islands of Zanzibar and Pemba will feature partly cloudy to cloudy conditions with showers and thunderstorms at times. Northeastern highlands areas (Arusha, Manyara and Kilimanjaro regions) will experience cloudy conditions at times with showers and thunderstorms especially towards the end of the dekad. Western areas (Kigoma and Tabora regions) and central areas (Dodoma and Singida regions) are expected to feature partly cloudy conditions with showers and thunderstorms over few areas.

Box 4: Expected weather during April 01 – 10, 2006

Northern coast (Dar es Salaam, Coast and Tanga regions), southern coast (Mtwara and Lindi regions) and the Islands of Zanzibar and Pemba will feature partly cloudy to cloudy conditions with showers and thunderstorms at times and sunny intervals over few areas. Northeastern highlands (Arusha, Kilimanjaro and Manyara regions) areas will experience cloudy conditions at times with showers and thunderstorms over few areas. Western areas (Kigoma and Tabora regions) and central areas (Dodoma, and Singida regions) are expected to feature partly cloudy conditions with showers and thunderstorms over few areas and sunny periods. Lake Victoria basin, (Mwanza, Mara and Kagera regions) will experience partly cloudy to cloudy conditions with showers and thunderstorms over few areas. Southwestern highlands (Mbeya, Rukwa and parts of southern Iringa regions) and Ruvuma region will be partly cloudy with showers and thunderstorms at times over few areas although most of the areas will be dominated by sunny periods.

Box 5: Expected weather during April 11 – 20, 2006

The Lake Victoria basin, (Mwanza, Mara and Kagera regions) will experience partly cloudy to cloudy conditions with showers and thunderstorms over most areas at the beginning of the dekad and over few areas towards the end of the period. Northern coast (Dar es Salaam, Coast and Tanga regions and Islands of Zanzibar and Pemba) will feature cloudy conditions with showers over most areas and thunderstorms over few areas and sunny intervals. Northeastern highlands (Arusha, Kilimanjaro and Manyara regions) will experience cloudy conditions at times with showers and thunderstorms over few areas. Western areas (Kigoma and Tabora regions) are expected to feature partly cloudy conditions with showers and thunderstorms over few areas and sunny periods. Southwestern highlands (parts of southern Iringa, Mbeya and Rukwa regions), central areas (Dodoma and Singida regions) and southern (Ruvuma region) will feature partly cloudy conditions with showers and few thunderstorms at times over few areas although most of the areas will be dominated by sunny periods.

Box 6: Expected weather during April 21 – 300, 2006

Lake Victoria basin (Mwanza, Mara and Kagera region) will experience partly cloudy to cloudy conditions with showers and thunderstorms over most areas at the beginning of the dekad and over few areas towards the end of the dekad. Northern coast (Dar es Salaam, Coast and Tanga regions, and Islands of Zanzibar and Pemba) will feature partly cloudy to cloudy conditions with showers over most areas and thunderstorms over few areas and sunny periods. Northeastern highlands (Arusha, Manyara and Kilimanjaro regions) will experience cloudy conditions at times with showers and thunderstorms over most areas. Western areas (Kigoma and Tabora regions) are expected to feature cloudy conditions with showers and thunderstorms over few areas and sunny periods. Southwestern highlands (Mbeya and Rukwa regions), southern (Ruvuma region) and central areas (Dodoma, Singida and Iringa regions) will feature partly cloudy conditions with light showers and light thunderstorms at times over few areas and sunny periods. Most of the southern region, southwestern highlands and parts of central areas will be dominated by sunny periods over most areas.

Box 7: Expected weather during May 01 – 10, 2006

Lake Victoria basin, (Mwanza, Mara and Kagera regions) will continue experience partly cloudy to cloudy conditions at times with showers over most areas and thunderstorms over few areas. Northern coast (Dar es Salaam, Coast and Tanga regions) and the Islands of Zanzibar and Pemba will feature partly cloudy conditions with light showers over few areas and thunderstorms at times over few areas and sunny periods. Northeastern highlands (Arusha, Kilimanjaro and Manyara regions) areas will experience partly cloudy to cloudy conditions at times with showers over most areas and thunderstorms over few areas and sunny periods. Western areas (Kigoma region) are expected to feature partly cloudy conditions with showers and thunderstorms over few areas and sunny periods. Southwestern highlands (Iringa, Mbeya, Rukwa and Tabora regions), central areas (Dodoma and Singida regions) and southern areas (Ruvuma region) will feature partly cloudy with light rains at times over few areas and long sunny periods. Most of the southern, southwestern highlands and parts of central areas will be dominated by sunny periods over most areas and chilly temperatures at night and early morning.

Box 8: Expected weather during May 11 – 20, 2006

Lake Victoria basin (Mwanza, Mara and Kagera regions) and northeastern highlands (Arusha, Kilimanjaro and Manyara regions) will continue experiencing partly cloudy to cloudy conditions at times with showers over most areas and thunderstorms over few areas. Northern coast (Dar es Salaam, Coast and Tanga regions, and Islands of Zanzibar and Pemba) will feature partly cloudy conditions with light rains over few areas and sunny periods. Western areas (Kigoma region) are expected to feature partly cloudy conditions with showers and thunderstorms over few areas and sunny periods. Southwestern highlands (Mbeya, Rukwa and Tabora regions), central areas (Dodoma, Singida and Iringa regions) and southern (Ruvuma region) will feature partly cloudy with light rains at times over few areas and long sunny periods. Most of the southern region, southwestern highlands and parts of central areas will be dominated by sunny periods over most areas and chilly temperatures at night and early morning hours.

Box 9: Expected weather during May 21 – 31, 2006

Lake Victoria basin, (Mwanza, Mara and Kagera regions) will experience partly cloudy to cloudy conditions at times with showers and thunderstorms over few areas and sunny periods. Northern coast (Dar es Salaam, Coast and Tanga regions, and Islands of Zanzibar and Pemba) will feature partly cloudy conditions with light morning rains over few areas and sunny periods. Northeastern highlands (Arusha, Kilimanjaro and Manyara regions) will experience partly cloudy with occasional light showers over few areas and sunny periods. Western areas (Kigoma region) are expected to feature partly cloudy conditions with showers and thunderstorms over few areas at the beginning of the period and sunny periods. Southwestern highlands (Mbeya, Rukwa and Tabora regions), central areas (Dodoma, Singida and Iringa regions) and southern sector (Ruvuma region) will feature partly cloudy conditions with light rains at times over few areas and long sunny periods. Most of the southern region, southwestern highlands and parts of central areas will start observing minimum temperatures associated with chilly weather at night and early morning hours followed by long sunny periods in the afternoon.

Box 10: Expected weather during October 11 – 20, 2006

Lake Victoria basin and western areas (Kigoma region) will experience partly cloudy to cloudy conditions with thundershowers mainly over the western parts of the lake and sunny periods. The Northern coast (Tanga and Dar es Salaam regions, and Islands of Zanzibar and Pemba) will feature partly cloudy to cloudy conditions at times with showers over few areas and sunny periods. Northeastern highlands (Arusha, Kilimanjaro and Manyara regions) will feature partly cloudy to cloudy conditions at times with rainshowers mainly over high grounds and sunny periods. Southern, southwestern and central regions will experience partly cloudy conditions and sunny periods. Southern, southern coast, southwestern highlands, western, the central area and Lake Victoria basin will experience cloudy conditions with thundershowers over few areas and sunny intervals. Northeastern highlands and northern coast will experience partly cloudy conditions with thundershowers over few areas with sunny periods. The rest will feature partly cloud conditions with sunny periods.

Box 11: Expected weather during October 21 – 31, 2006

The Northern coast and the Islands of Zanzibar and Pemba will feature cloudy conditions with showers over few areas and sunny periods mainly towards the end of the dekad. Lake Victoria basin and western areas (Kigoma region) will experience cloudy conditions with thundershowers mainly over the western parts of the lake and sunny periods. Northeastern highlands will feature partly cloudy to cloudy conditions at times with rainshowers mainly over high grounds and sunny periods. Southern, southwestern highlands, central regions will experience partly cloudy conditions with occasional light rainshowers towards the end of the dekad and sunny periods.

Box 12: Expected weather during October 21 – 31, 2006

Areas with the unimodal rainfall pattern are expected to experience rainfall increase. The southern, southern coastal belt, southwestern highlands, western areas, and central areas, Lake Victoria basin will experience cloudy conditions with thundershowers over some areas and sunny intervals. Northeastern highlands and northern coast will experience partly cloudy conditions with thundershowers over few areas with sunny periods. The rest of the country is expected to partly cloud conditions with sunny periods.

Box 13: Expected weather during March 01 – 10, 2007

Southern region and southern coast, and southwestern and northeastern highlands will feature partly cloudy to cloudy conditions with thundershowers over few areas and sunny periods. Western, central, Lake Victoria basin, and northern coast including Islands of Zanzibar and Pemba are expected to experience cloudy conditions with thundershowers over some areas and sunny intervals.

Box 14: Expected weather during March 21 – 31, 2007

Southern region, southwestern highlands, central and western areas will feature partly cloudy conditions with rain showers over few areas and sunny periods. Lake Victoria basin and northeastern highlands will feature partly cloudy conditions with thundershowers over few areas and sunny periods. Southern coast, northern coast and ts hinterlands will feature partly cloudy to cloudy conditions with rain showers and isolated thunderstorms with sunny intervals.

Box 15: Expected weather during April 11 – 20, 2007

Southern coast, southern region, southwestern highlands, central areas and western areas are expected to feature partly cloudy conditions with rain showers over few areas and sunny periods. Areas over Lake Victoria basin are expected to experience partly cloudy conditions with thundershowers mainly over western areas. Northeastern highlands and northern coast and its hinterlands are expected to feature partly cloudy to cloudy conditions with thundershowers over some areas and sunny intervals.

Box 16: Expected weather during April 21– 30, 2007

Western areas and Lake Victoria basin will have partly cloudy conditions with thundershowers over few areas. Northern coast and northeastern highlands will have partly cloudy to cloudy conditions with showers and thunder activities over few areas and sunny intervals.

Box 17: Expected weather during May 1 – 10, 2007

Western areas and Lake Victoria basin are expected to feature partly cloudy conditions with thundershowers over few areas and sunny periods. Northern coast and Northeastern highlands are expected to experience partly cloudy to cloudy conditions with showers over few areas and sunny periods. Southwestern highlands are expected to feature partly cloudy conditions with few cases of isolated showers mainly over high ground and sunny periods. The dryness over southern coast, central areas towards Shinyanga and Tabora regions is expected to persist.

Box 18: Expected weather during May 11-20, 2007

Lake Victoria basin is expected to feature thundershowers over few areas and sunny periods. Northern coast and northeastern highlands are expected to have isolated to widespread showers and sunny periods. Southwestern highlands are expected to feature few cases of isolated showers mainly over high ground and sunny periods. Further reduction of rainfall activities is expected over southern coast, southern region, central and western areas including Shinyanga region.

Box 19: expected weather during May 21-31, 2007

Lake Victoria basin (Kagera, Mwanza, Mara and Shinyanga regions) is expected to feature thundershowers over few areas and sunny periods. Northern coast (Dar es Salaam, Morogoro, and Tanga regions, and Islands of Zanzibar and Pemba) and northeastern highlands (Arusha, Kilimanjaro, and Manyara regions) are expected to feature isolated to widespread showers and sunny periods.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMENDATIONS

5.1 Conclusions

This study evaluated medium range forecast products over Tanzania. The study had three objectives. The first objective evaluated medium-range rainfall forecasts in selected bimodal and unimodal areas of Tanzania. The second objective identified the most important verification indicators on rainfall forecast accuracy relevant to agriculture. The last objective was to compare forecasted rainfall amounts by various forecasting systems with actual rainfall amounts as recorded by TMA for some selected stations. A summary of conclusions is follows.

Generally, most of the forecasting systems had poor forecast performance.
Accuweather forecast products generally appear to under-forecasting of occurrences of the rain events in both rainy seasons than any other forecast systems under study.

1. Based on accuracy scores Accuweather and ICPAC forecast products appear to perform better in the short rainy season (OND) than in the long rainy season (MAM).

    3. Results indicate that, none of the all the three forecasting systems (NCEP, Accuweather and ICPAC) were able to produce a perfect forecast (HSS = 1). However, HSS alone does

not reflect whether a particular forecasting system has been able to produce the perfect forecast at the right location (Glahn, 2004).

4. Forecasts in text form are more difficult to verify compared with forecasts in numerical or probabilistic form.

5.2.Recommendations

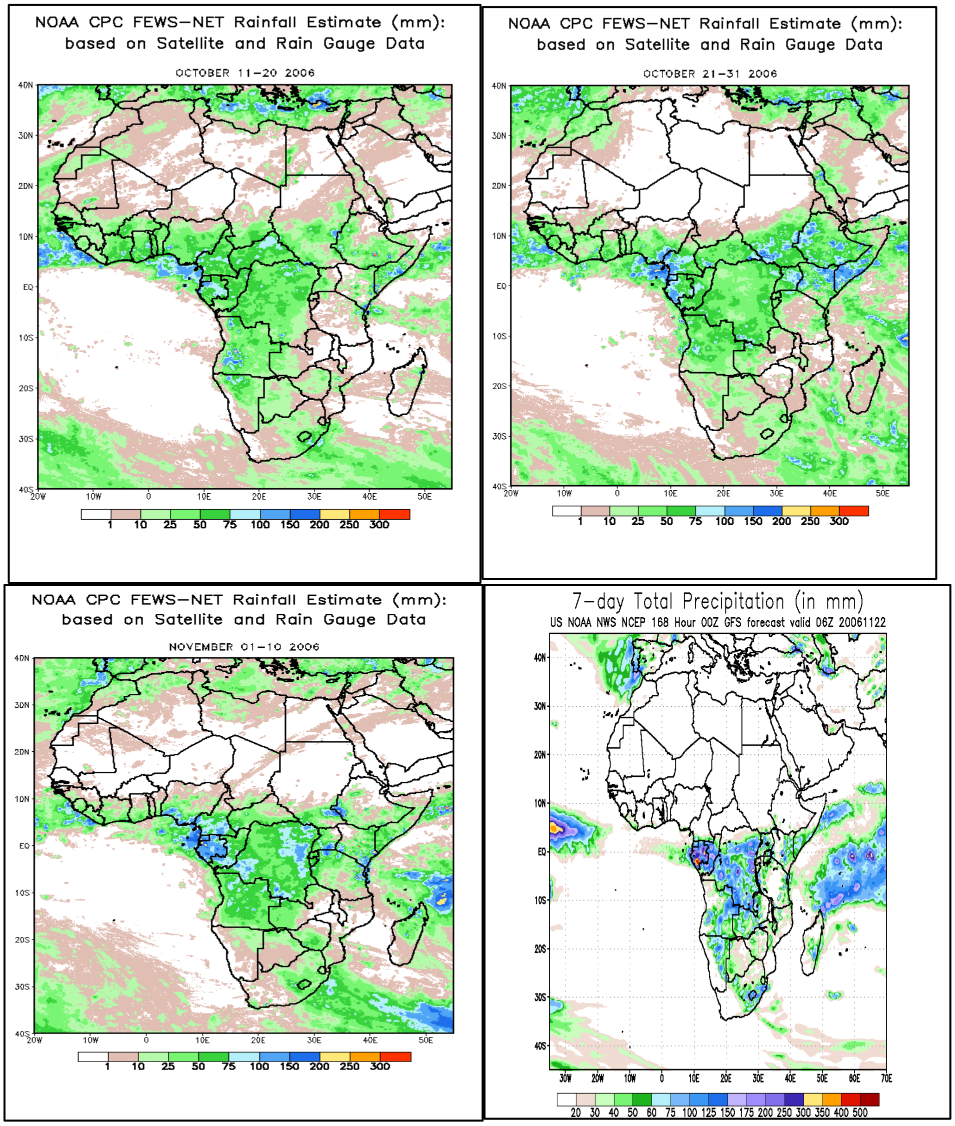
From this study the following recommendations can be made.

1. There is a need to carry out further studies that would cover many stations in the country.

2. Further studies should be done on other meteorological parameters such as temperatures, which are very important in the day-to day agricultural practices.
3. Forecasts should be presented in formats that are amenable to objective quality assessment. General qualitative terms should be avoided wherever feasible, and any claim for skill of narrative forecasts should be treated with caution.
4. The methodology on the dissemination and accessibility of the forecasts should be carefully chosen so as to produce information that is meaningful to the user. A two-way dialogue is necessary to ensure that the users get what they want.

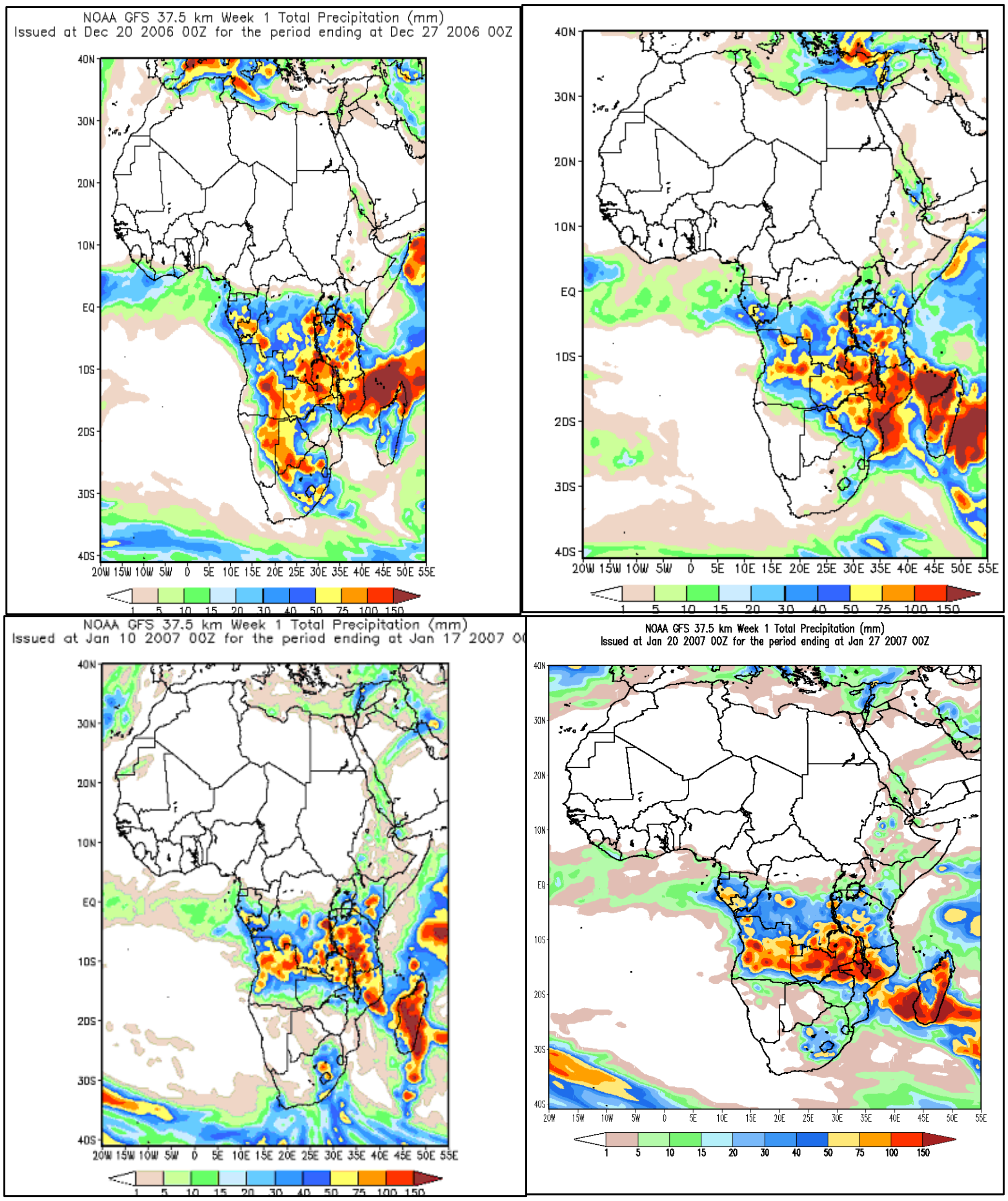
LIST OF APPENDICES

Appendix A1: NCEP Climate Forecasts Products



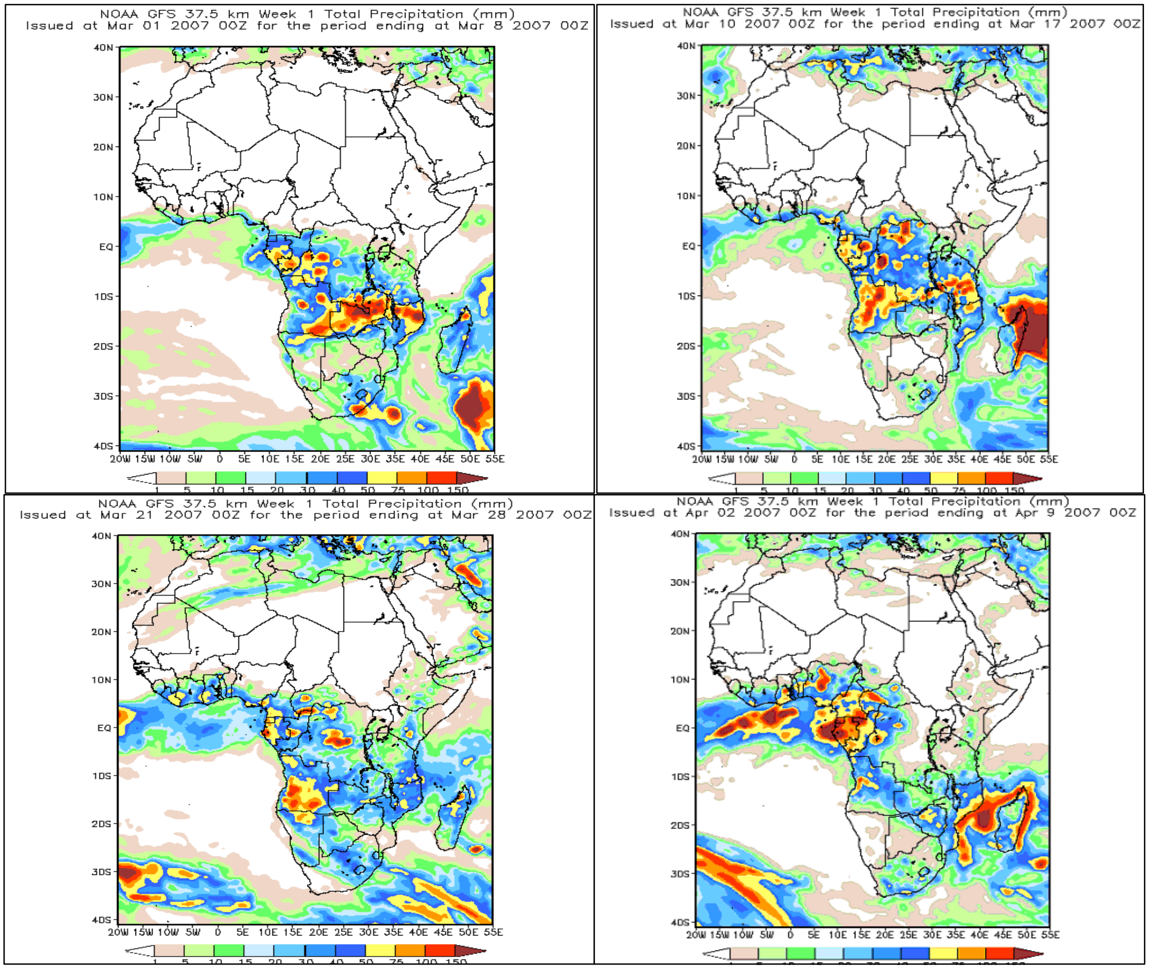
Climate outlook in the respective order top left to bottom a) 11-20 Oct 2006, b) 1-7 Nov, 06, c) 11-20 Nov, 06 and d) 21-27 Nov

Appendix A2: NCEP Climate Forecasts Products



Climate outlook in the respective order top left to bottom right a) 1-8 March 200, b) 10-17 March 200 7, c) 21-27 March 2007 and d) 1-10 April 2007

Appendix A3: NCEP Climate Forecasts Products



Climate outlook in the respective order top left to bottom right a) 1-9 April 2007 b) 11-17 April 2007 c) 21-28 Feb 2007 and d) 11-18 Feb 2007

Appendix B: Terciles, contingency table and indices for NCEP

Dodoma

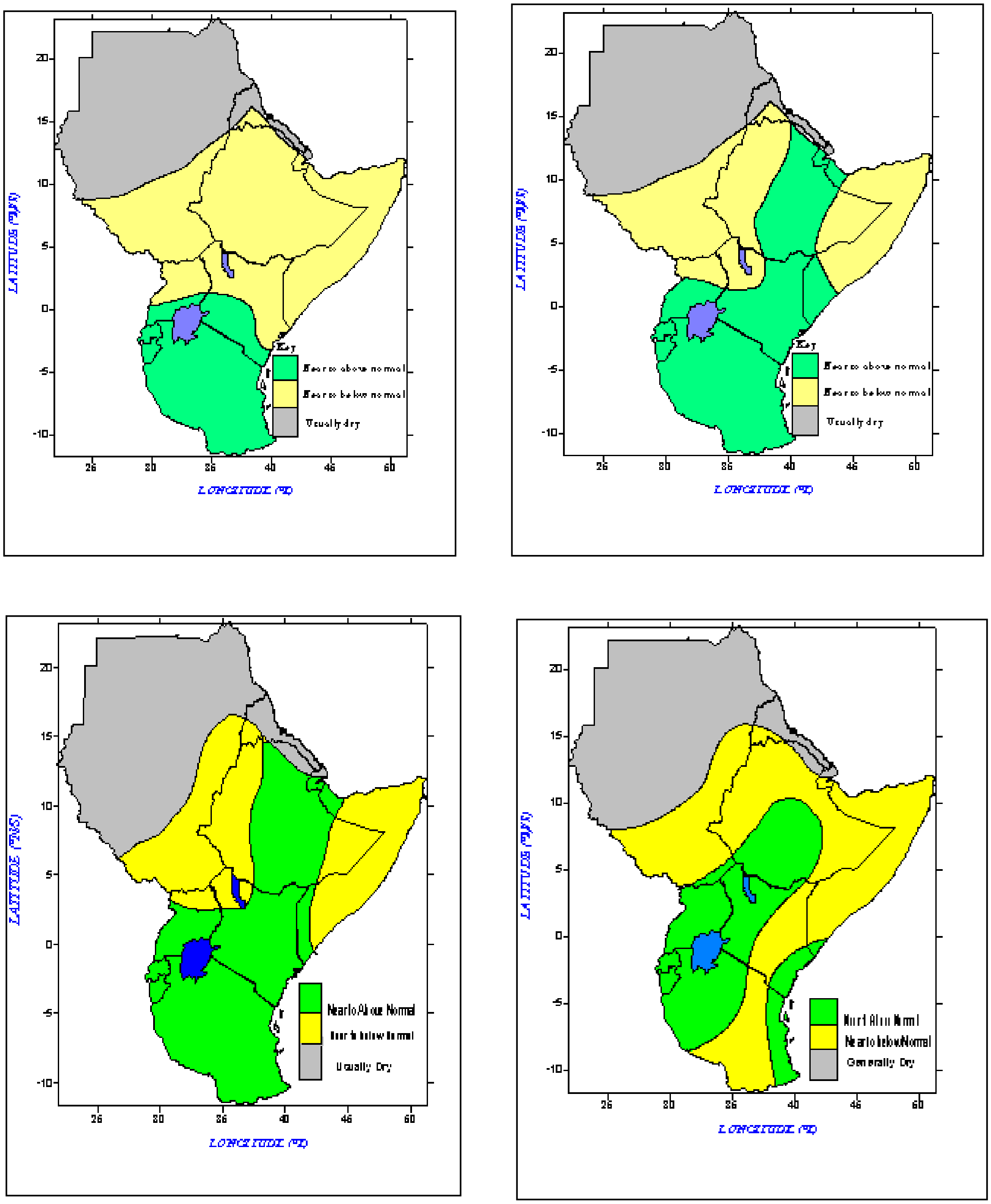
Dates	dekad	long term	lower	upper	forecast	af	observed	ft	obsered tercile	evaluation
11-17/12/06	35	43.3	28.6	57.2	30-40	35.0	64.7	N	A	m
20-27/12/06	36	45.1	29.8	59.5	10-15	12.5	34.8	B	N	m
10-17/1/07	2	48.8	32.2	64.4	75-100	87.5	60.3	A	N	m
20-27/1/07	3	41.1	27.1	54.3	50-75	62.5	113.9	A	A	h
21-28/2/07	6	27.5	18.2	36.3	20-30	25.0	49.2	N	A	m
1-8/3/07	7	35	23.1	46.2	5-10	7.5	12	B	B	cn
10-17/3/07	8	42.2	27.9	55.7	20-30	25.0	34.6	B	N	m
21-28/3/07	9	38.8	25.6	51.2	10-15	12.5	4.9	B	B	cn

af – Average forecast
ft – forecast tercile

forecasted	observed		
	yes	no	total
yes	1	0	1
no	5	2	7
total	6	2	8

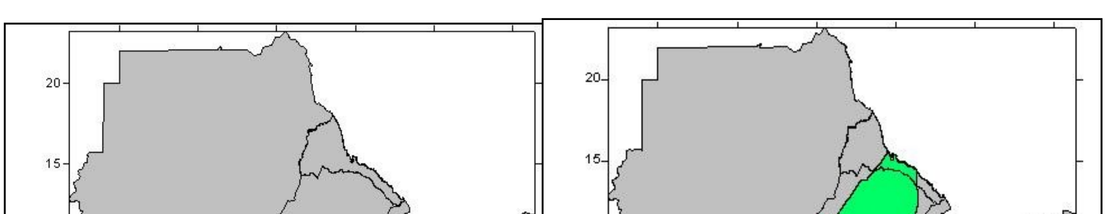
Accuracy	0.38
Bias	0.17
HSS	0.09

Appendix C1: ICPAC Climate Outlook

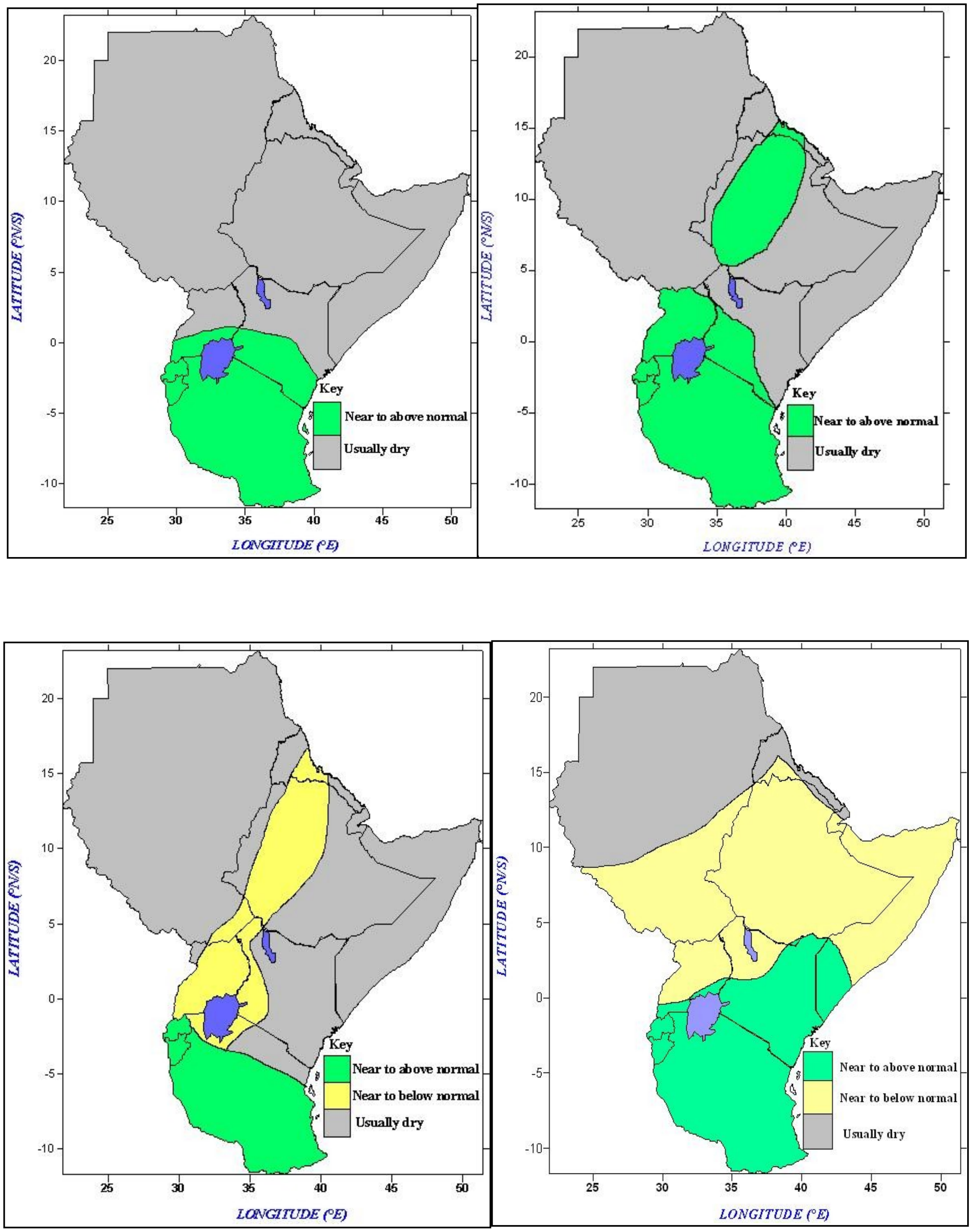


Climate outlook in the respective order top left to bottom right a) dekad 9 (21-31 April) 2006; b) dekad 10 (11-20 April 2006; c) dekad 11 (21-30) April 2006 and d) dekad 12 (21-30 April) 2006

Appendix C2: ICPAC Climate Outlook



Appendix C2: ICPAC Climate Outlook



Climate outlook in the respective order top left to bottom right a) dekad 2 (10-20 Jan) 2007; b) dekad 4 (1-10 Feb 2007; c) dekad 5 (11-20Feb) 2007 and d) dekad11 (1-10 Apr 2007

Appendix C3:ICPACClimate Outlook

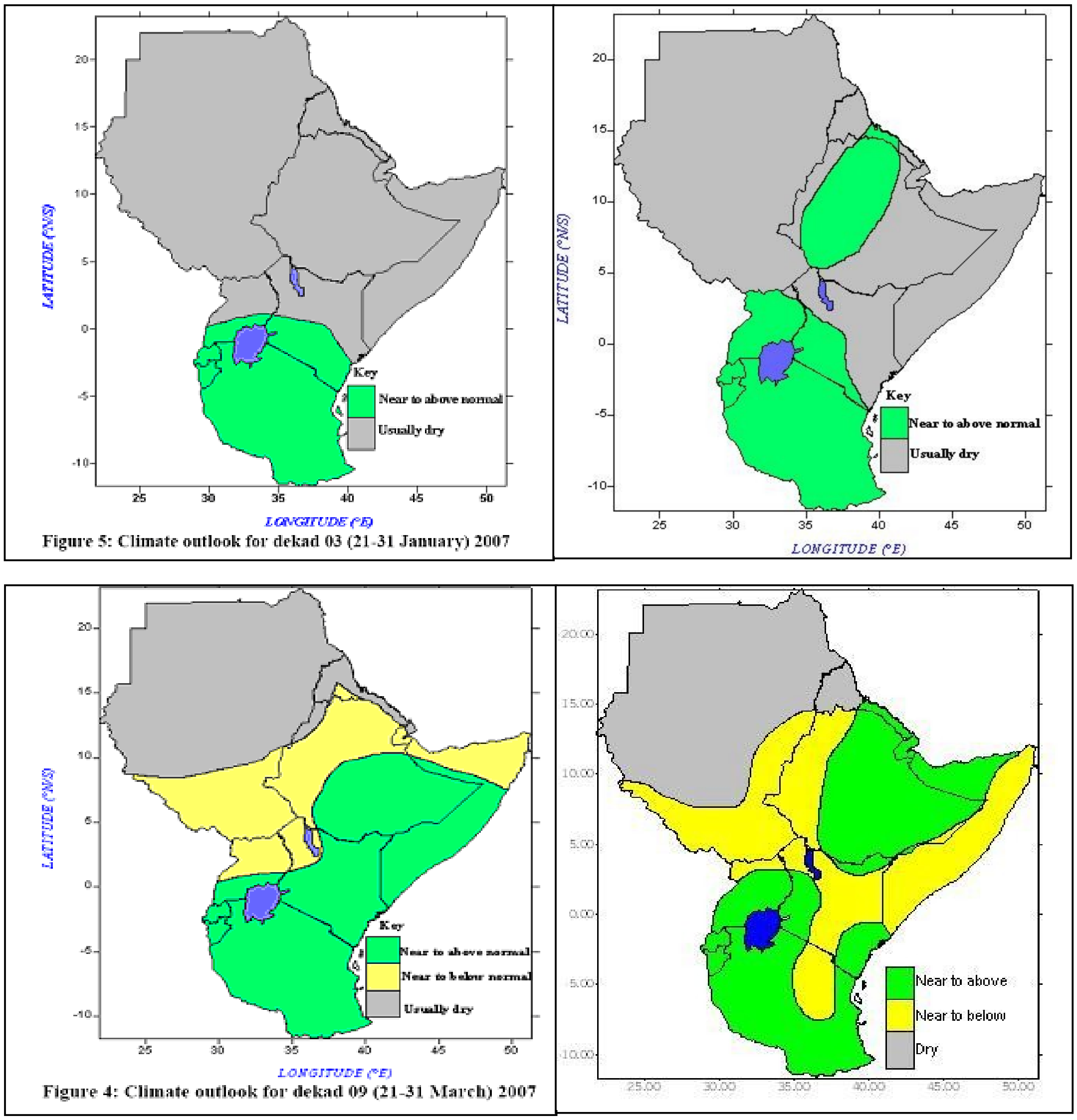
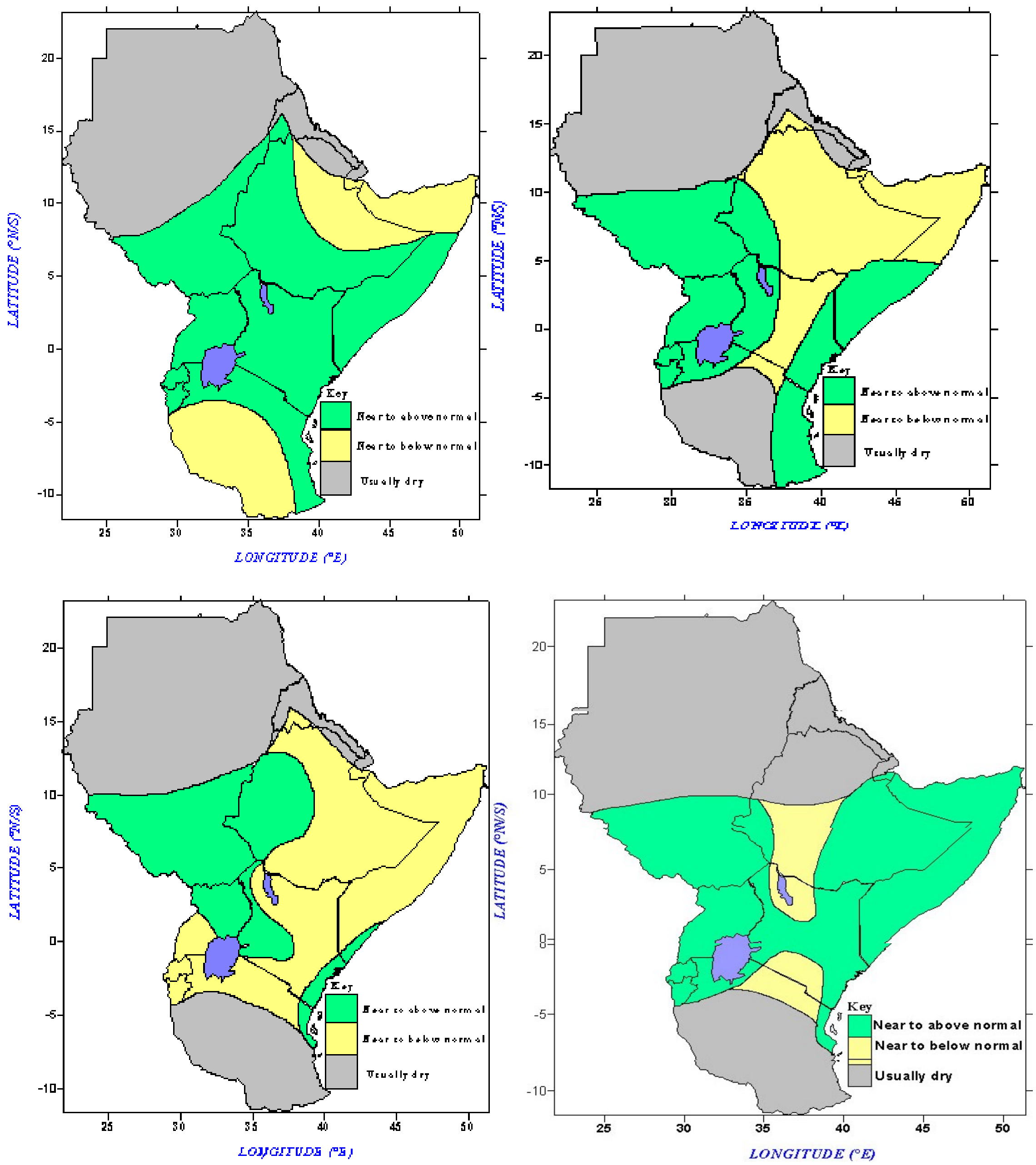


Figure 5: Climate outlook for dekad 03 (21-31 January) 2007

Figure 4: Climate outlook for dekad 09 (21-31 March) 2007

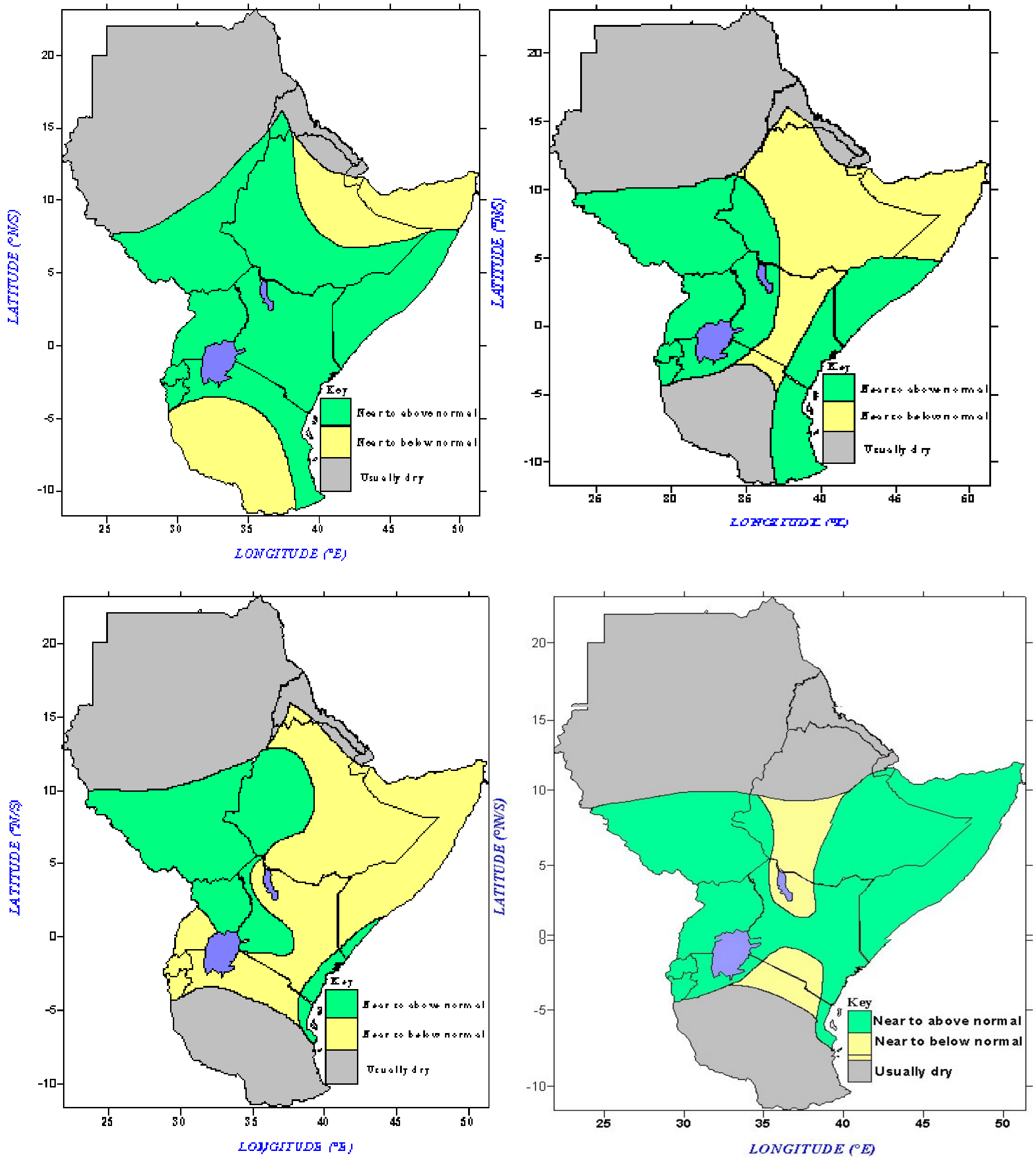
Climate outlook in the respective order top left to bottom left *a) dekad 3 (21 -31Jan) 2007 b) dekad 4 (1-10 Feb) 2007 and c) dekad 9 (21-31 Mar) 2007*

Appendix C4: ICPAC Climate Outlook



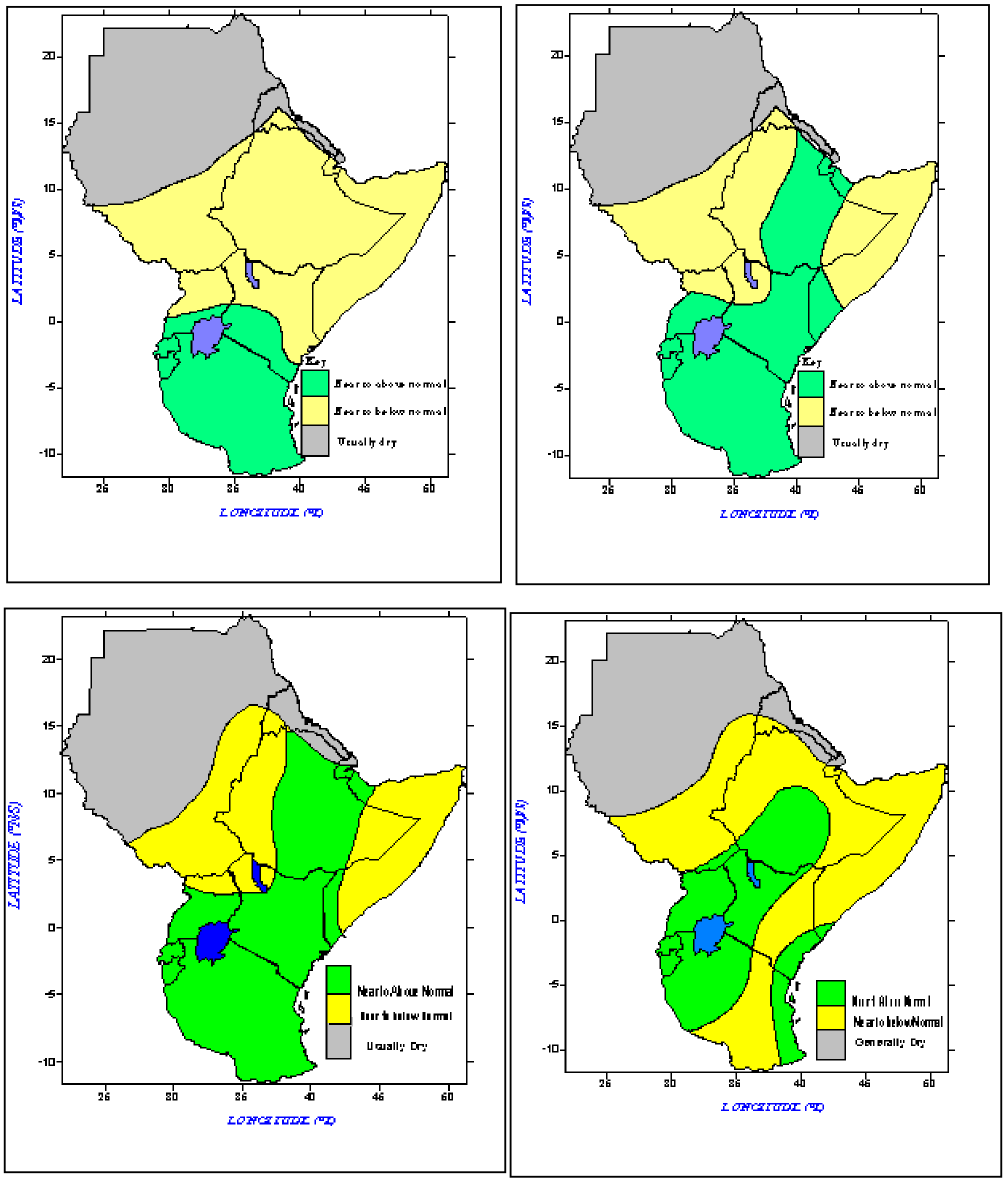
Climate outlook in the respective order top left to bottom right a) dekad 13 (1 -10 May) 2007 b) dekad 11 (11 -20 April) 2007 and c) dekad 12 (21-30 April) 2007

Appendix C5: ICPAC Climate Outlook



Climate outlook in the respective order top left to bottom right a) dekad 13 (1 -10 May) 2006 b) dekad 14 (11 -20 May) 2006 c) dekad 15 (21 -31 May) 2006 and dekad 29 (11 - 20 October) 2006

Appendix C6: ICPAC Climate Outlook



Climate outlook in the respective order top left to bottom right a) 9 -31 March) 2006; b) dekad 10 (1-10 April) 2006; c) dekad 11 (11 - 20 April) 2006 and d) dekad 12 (21-30 April) 2006

Appendix D1: Terciles, contingency table and indices for ICPAC

Arusha

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
21-31/3 06	9	61.6	A	99.4	40.7	81.3	h
1-10/4/06	10	82.6	A	67.9	54.5	109	m
11-20/4/06	11	73.8	A	127	48.7	97.4	h
21-30/4/06	12	67.3	N	71.1	44.4	88.8	h
1-10/5/06	13	37.6	A	84.1	24.8	49.6	h
11-20/5/06	14	28.3	N	26.2	18.7	37.4	h
11-20/10/06	29	6.5	N	14	4.3	8.6	m
1-10/11/06	31	23.9	A	154.3	15.8	31.5	h
11-20/11/06	32	38.9	N	4.3	25.7	51.3	m
1-10/12/06	34	35.7	N	21.8	23.6	47.1	fa
21-31/12/06	36	32.9	N	118.9	21.7	43.4	m
21-31/3/07	9	61.6	A	96.2	40.7	81.3	h
1-10/4/07	10	82.6	A	13.8	54.5	109	fa

OND

		observed		
		yes	no	total
forecasted	yes	1	1	2
	no	3	0	3
	total	4	1	5

Accuracy	0.2
Bias	0.5
HSS	-0.43

MAM

		observed		
		yes	no	total
forecasted	yes	6	1	7
	no	1	0	1
	total	7	1	8

Accuracy	0.75
Bias	1
HSS	-0.14

Appendix D2

Dodoma

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
21-31/3/06	9	59.7	A	26	39.4	78.8	fa
1-10/4/06	10	49.8	A	89.3	32.9	65.7	h
11-20/4/06	11	34.2	A	65.3	22.6	45.1	h
21-30/4/06	12	22.1	N	76	14.6	29.2	m
1-10/5/06	13	11.5	N	5.4	7.6	15.2	fa
11-20/5/06	14	4.2	B	55.1	2.8	5.5	m
11-20/10/06	29	4	B	0	2.6	5.3	cn
1-10/11/06	31	11.1	A	17.3	7.3	14.7	h
11-20/11/06	32	28.1	B	13.6	18.5	37.1	cn
1-10/12/06	34	23.2	B	95	15.3	30.6	m
21-31/12/06	36	41.3	A	117.2	27.3	54.5	h
11-20/1/07	2	73.1	A	130.4	48.2	96.5	h
21-31/1/07	3	66.4	A	66.7	43.8	87.6	fa
1-10/2/07	4	66.7	A	124	44.0	88.0	h
11-20/2/07	5	66.3	A	71.1	43.8	87.5	fa
21-31/3/07	9	57.3	A	35.3	37.8	75.6	fa

		observed		
		yes	no	total
forecasted	yes	6	6	12
	no	3	2	5
	total	9	8	17

Accuracy	0.47
Bias	1.33
HSS	-0.09

Appendix D3

Mbeya

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
21-31/3/06	9	59.7	A	26	39.4	78.8	fa
1-10/4/06	10	49.8	A	89.3	32.9	65.7	h
11-20/4/06	11	34.2	A	65.3	22.6	45.1	h
21-30/4/06	12	22.1	N	76	14.6	29.2	m
1-10/5/06	13	11.5	N	5.4	7.6	15.2	fa
11-20/5/06	14	4.2	B	55.1	2.8	5.5	m

11-20/10/06	29	4	B	0	2.6	5.3	cn
1-10/11/06	31	11.1	A	17.3	7.3	14.7	h
11-20/11/06	32	28.1	B	13.6	18.5	37.1	cn
1-10/12/06	34	23.2	B	95	15.3	30.6	m
21-31/12/06	36	41.3	A	117.2	27.3	54.5	h
11-20/1/07	2	73.1	A	130.4	48.2	96.5	h
21-31/1/07	3	66.4	A	66.7	43.8	87.6	fa
1-10/2/07	4	66.7	A	124	44.0	88.0	h
11-20/2/07	5	66.3	A	71.1	43.8	87.5	fa
21-31/3/07	9	57.3	A	35.3	37.8	75.6	fa

		observed		
		yes	no	total
forecasted	yes	6	6	12
	no	3	2	5
	total	9	8	17

Accuracy	0.47
Bias	1.33
HSS	-0.09

Appendix D4

Morogoro

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
21-31/3/ 06	9	93	A	106.2	61.4	122.8	h
1-10/4/06	10	69.1	A	70.2	45.6	91.2	m
11-20/4/06	11	65.9	A	70.3	43.5	87.0	m
21-30/4/06	12	59.7	A	84.1	39.4	78.8	h
1-10/5/06	13	45.7	A	51.6	30.2	60.3	m
11-20/5/06	14	24.1	A	1	15.9	31.8	m
11-20/10/06	29	6.7	A	39.9	4.4	8.8	h
1-10/11/06	31	11.1	A	54.7	7.3	14.7	h
11-20/11/06	32	28.1	A	27.4	18.5	37.1	m
1-10/12/06	34	23.2	B	56.1	15.3	30.6	m
21-31/12/06	36	41.3	A	101.1	27.3	54.5	h
21-31/3/07	9	58	A	35.9	38.3	76.6	fa
1-10/4/07	10	69.1	A	43.2	45.6	91.2	fa

OND

		observed		
		yes	no	total
forecasted	yes	3	0	3
	no	2	0	2
	total	5	0	5

Accuracy	0.6
Bias	0.6
HSS	0

MAM

		observed		
		yes	no	total
forecasted	yes	2	2	4
	no	4	0	0
	total	6	2	8

Accuracy	0.25
Bias	0.67
HSS	-0.2

Appendix D 5

Same

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
21-31/3/06	9	34.2	A	24.4	22.6	45.1	m
1-10/4/06	10	43.1	A	77.4	28.4	56.9	h
11-20/4/06	11	41.3	A	48.6	27.3	54.5	m
21-30/4/06	12	35.1	N	76	23.2	46.3	m
1-10/5/06	13	34.2	A	22.3	22.6	45.1	fa
11-20/5/06	14	20.6	N	3.5	13.6	27.2	fa
11-20/10/06	29	7.2	N	40.2	4.8	9.5	m
1-10/11/06	31	10.6	A	30.7	7.0	14.0	h
11-20/11/06	32	18.8	N	34.3	12.4	24.8	m
1-10/12/06	34	24	N	15.6	15.8	31.7	fa
21-31/12/06	36	20.3	N	138	13.4	26.8	m
21-31/3/07	9	59.7	A	9.6	39.4	78.8	fa
1-10/4/07	10	43.1	A	3.9	28.4	56.9	fa

OND

		observed		
		yes	no	total
forecasted	yes	1	1	2
	no	3	0	3
	total	4	1	5

Accuracy	0.2
Bias	0.5
HSS	-0.43

MAM

		observed		
		yes	no	total
forecasted	yes	1	4	5
	no	3	0	3
	total	4	4	8

Accuracy	0.125
Bias	1.25
HSS	-0.75

Appendix E1: Accuweather Forecasts for Mbeya

Thursday, March 1, 2006 Rain Total: 33.1 Occurring: Mar 1 | Mar 2 | Mar3 | | Mar 5

March 11, 2006 Rain Total: 7.1 Occurring: Mar13 | Mar17 | Mar 18 | Mar 19

March 22, 2006 Rain Total: 7.8 Occurring: Mar22 | Mar24 | 26|

October 1, 2006 Rain Total: 9.7 Occurring: Oct 1 | Oct 2 | Oct 3

November 1, 2006 Rain Total: 11.9 Occurring: Nov 1 | Nov 2 | Nov 3 | Nov 4

November 21, 2006 Rain Total: 11.7 Occurring: Nov 21 | Nov 22 | Nov 23

December 1 Rain Total: 97 Occurring: Dec 1 | Dec 2 | Dec 4 | Dec 6 Dec 7 | Dec 9

December 11 Rain Total: 11.9 Occurring: Dec 11 | Dec 12 | Dec 14 | Dec 15

Thursday, January 1, 2007 Rain Total: 22.4 Occurring: Jan 1 | Jan 2 | Jan 3 | Jan 4 | Jan 5

Thursday, January 11, 2007 Rain Total: 28.1 Occurring: Jan 11 | Jan 12 | Jan 13 | Jan 15

January 21, 2007 Rain Total: 116.8 Occurring: Jan 21 | Jan 22 | Jan 23 | Jan 24 | Jan 25

February 12, 2007Rain Total: 43.4 Occurring: Feb 12 | Feb1 4 | Feb1 5

March 11, 2007 Rain Total: 13.5 Occurring: Mar 12 | Mar 14 | Mar 15

March 22, 2006 Rain Total: 2.5 Occurring: Mar 22 | Mar 24

Appendix E2: Morogoro

March 1, 2006 Rain; Total: 32.5 Occurring: Mar 2 | Mar 3 | Mar 4 | Mar 5 | Mar 6

March 21, 2006; Rain Total: 19.6 Occurring: Mar21 | Mar 23

April 2, 2006 Rain Total: 16.7 Occurring: Apr 2 | Apr 3 |Apr 5 | Apr 8 |

April 11, 2006 Rain Total: 24.8 Occurring: Apr 12 | Apr 13 | Apr14 | Apr 15

April 21, 2006 Rain Total: 3.8 Occurring: Apr 22 | Apr 23 |

May 1, 2006 Rain Total: 3.8 Occurring: May1 | May 3 |

October 11, 2006 Rain Total: 8.6 Occurring: Oct 12 | Oct 13 | Oct 14 |

November 11, 2006 Rain Total: 3.1 Occurring: Nov 12 | Nov13 |

November 21, 2006 Rain Total: 6.1 Occurring: Nov 22 | Nov 23 |

December 1, 2006 Rain Total: 4.8 Occurring: Dec 1 | Dec 2 | Dec 3

December 12, 2006 Rain Total: 18.2 Occurring: Dec 12 | Dec 13 | Dec 14 | Dec 15 | Dec 16

Thursday, March 01, 2007 Rain Total: 5.3 Occurring: Mar 1 | Mar 2|

March 11, 2007Rain Total: 19.6 Occurring: Mar 11 | Mar 12 | Mar 13 | Mar 14 | Mar 15

March 22, 2007 Rain Total: 6.7 Occurring: Mar 22 | Mar 23 | Mar 24 | Mar 25 | Mar 26

April 11, 2007 Rain Total: 19 Occurring: Apr 12 | Apr 13 | Apr 14 | Apr 15

Appendix E3: Same

March 1, 2006Rain Total: 28.2 Occurring: Mar 5 | Mar7 | Mar 8| Mar 9

March 21, 2006 Rain Total: 7.7 Occurring: Mar 21 | Mar 22 | Mar 23

October 1, 2006 Rain Total: 2.3 Occurring: Oct 1 | Oct 2

October 11, 2006 Rain Total: 2.0 Occurring: Oct 11

November 1, 2006 Rain Total: 8.7 Occurring: Nov 1 | Nov 2| Nov 4

November 21, 2006 Rain Total: 22.2 Occurring: Nov 21 | Nov 22 | Nov 23

December 1, 2006 Rain Total: 2.6 Occurring: Dec 1 | Dec 2

December 11, 2006 Rain Total: 14.9 Occurring: Dec 12 | Dec 13 | Dec 14 | Dec 15 | Dec 16

March 11, 2007 Rain Total: 2.1 Occurring: Mar 11 | Mar 12

March 21, 2007 Rain Total: 1.3 Occurring: Mar 21|

April 11, 2007 Rain Total: 4.7 Occurring: Apr 11 | Apr 12

April 21, 2007 Rain Total: 8.5 Occurring: Apr 21 | Apr 22 | Apr 23 |

May 11, 2007 Rain Total: 26.1 Occurring: May 12 | May 13 | May 14 |

May 21, 2007 Rain Total: 1.8 Occurring: May 21|

Appendix F1: Tercile, contingency table and indices for Accuweather

Mbeya

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
1-10/3/06	7	57.8	33.1	56.5	38.1	76.3	m
11-20/3/06	8	57.3	7.1	31.6	37.8	75.6	cn
21-31/3/06	9	59.7	7.8	26	39.4	78.8	cn
1-10/12/06	34	44.1	97	102.3	29.1	58.2	h
11-20/12/06	35	63.8	11.9	62.4	42.1	84.2	m
1-10/1/07	1	67.3	22.4	41.9	44.4	88.8	cn
11-20/1/07	2	73.1	28.1	130.4	48.2	96.5	m
21-31/1/07	3	66.4	116.8	49.1	43.8	87.6	fa

11-20/2/07	5	66.3	43.4	55.8	43.8	87.5	m
11-20/3/07	8	57.3	13.5	65.3	37.8	75.6	m
21-31/3/07	9	59.7	2.5	33.3	39.4	78.8	cn

		observed		
		yes	no	total
forecasted	yes	1	1	2
	no	5	4	9
	total	6	5	11

Accuracy	0.45
Bias	0.33
HSS	-0.33

Appendix F2

Morogoro

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
1-10/3/06	7	30.4	32.5	50	20.1	40.1	h
21-31/3/06	9	58	19.6	93.1	38.3	76.6	m
1-10/4/06	10	69.1	24.8	70.2	45.6	91.2	m
21-30/4/06	12	59.7	3.8	84.1	39.4	78.8	m
1-10/5/06	13	45.7	3.8	51.6	30.2	60.3	m
11-20/10/06	29	6.7	8.6	8.9	4.4	8.8	h
11-20/11/06	32	28.1	3.1	18.8	18.5	37.1	m
21-30/11/06	33	19	6.1	67.7	12.5	25.1	m
1-10/12/06	34	23.2	4.8	55.4	15.3	30.6	fa
11-20/12/06	35	42.9	18.2	22.7	28.3	56.6	cn
1-10/3/07	7	30.4	5.3	5	20.1	40.1	cn
11-20/3/07	8	43	19.6	83.9	28.4	56.8	m
21-31/3/07	9	58	6.7	61.5	38.3	76.6	m

OND

		observed		
		yes	no	total
forecasted	yes	1	1	2
	no	2	1	3
	total	3	2	5

Accuracy	0.4
Bias	0.67
HSS	-0.15

MAM

		observed				
		yes	no	total	Accuracy	0.63
forecasted	yes	5	0	5	Bias	0.63
	no	3	0	3	HSS	0
	total	8	0	8		

Appendix F3

Same

Dates	dekad	long term	forecast	observed	lower	upper	evaluation
1-10/3/06	6	19.3	28.2	114.1	12.7	25.5	h
21-31/3/06	9	34.2	7.7	25	22.6	45.1	m
1-10/10/06	28	7.6	2.3	0	5.0	10.0	cn
11-20/10/06	29	7.2	2	71.8	4.8	9.5	m
1-10/11/06	31	10.7	8.7	30.7	7.1	14.1	h
21-31/11/06	33	33.5	22.2	102	22.1	44.2	h
1-10/12/06	34	44.1	2.6	13.2	29.1	58.2	cn
11-20/12/06	35	63.8	14.9	11	42.1	84.2	cn
11-20/3/07	8	57.3	2.1	22.9	37.8	75.6	cn
11-20/41/07	11	34.2	4.7	49	22.6	45.1	m
21-30/4/07	12	22.1	8.5	6.9	14.6	29.2	cn
11-20/5/07	14	4.2	26.1	23.7	2.8	5.5	fa
21-31/5/07	15	1.4	1.8	12.2	0.9	1.8	h

OND

		observed				
		yes	no	total	Accuracy	0.83
forecasted	yes	2	0	2	Bias	0.67
	no	1	3	4	HSS	0.67
	total	3	3	6		

MAM

		observed				
		yes	no	total	Accuracy	0.57
forecasted	yes	2	1	3	Bias	0.75
	no	2	2	4	HSS	0.16
	total	4	3	7		

Appendix G: TMA 10-day forecasts

Box 1: Expected weather during March 01 – 10, 2006

Western areas (Kigoma and Tabora regions) and central (Dodoma and Singida regions) are expected to feature partly cloudy to cloudy conditions with showers and thunderstorms from mid towards the end of the dekad. The Lake Victoria basin (Mwanza Mara and Kagera region) will experience cloudy conditions with showers and thunderstorms over most areas especially at the beginning of the dekad breaking to partly cloudy conditions with showers and thunderstorms over few areas at the end of the dekad. Southernwestern highlands (Mbeya, Rukwa and parts of southern Iringa and Ruvuma regions) will feature partly cloudy to cloudy conditions at times with showers and thunderstorms over most areas. Northern coast (Dar es Salaam, Coast, Tanga), southern coast (Mtwara and Lindi regions) and the Islands of Zanzibar and Pemba will feature partly cloudy to cloudy conditions with showers and thunderstorms at times and sunny intervals.

Box 2: Expected weather during March 11 – 20, 2006

Western areas (Kigoma and Tabora regions) and central (Dodoma and Singida regions) are expected to feature partly cloudy to cloudy conditions with showers and thunderstorms from mid towards the end of the dekad. The Lake Victoria basin (Mwanza Mara and Kagera region) will experience cloudy conditions with showers and thunderstorms over most areas especially at the beginning of the dekad breaking to partly cloudy conditions with showers and thunderstorms over few areas at the end of the dekad. Southernwestern highlands (Mbeya, Rukwa and parts of southern Iringa and Ruvuma regions) will feature partly cloudy to cloudy conditions at times with showers and thunderstorms over most areas. Northern coast (Dar es Salaam, Coast, Tanga), southern coast (Mtwara and Lindi regions) and the Islands of Zanzibar and Pemba will feature partly cloudy to cloudy conditions with showers and thunderstorms at times and sunny intervals.

Box 3: Expected weather during March 21 – 31, 2006

The Lake Victoria basin, (Mwanza, Mara and Kagera regions) will experience partly to cloudy conditions with showers and thunderstorms over few areas. Southwestern highlands (Mbeya, Rukwa and parts of southern Iringa and Ruvuma regions) will feature partly cloudy conditions with showers and thunderstorms over few areas. Northern coast (Dar es Salaam, Coast and Tanga regions), Southern coast (Mtwara and Lindi regions) and the Islands of Zanzibar and Pemba will feature partly cloudy to cloudy conditions with showers and thunderstorms at times. Northeastern highlands areas (Arusha, Manyara and Kilimanjaro regions) will experience cloudy conditions at times with showers and thunderstorms especially towards the end of the dekad. Western areas (Kigoma and Tabora regions) and central areas (Dodoma and Singida regions) are expected to feature partly cloudy conditions with showers and thunderstorms over few areas.

Box 4: Expected weather during April 01 – 10, 2006

Northern coast (Dar es Salaam, Coast and Tanga regions), southern coast (Mtwara and Lindi regions) and the Islands of Zanzibar and Pemba will feature partly cloudy to cloudy conditions with showers and thunderstorms at times and sunny intervals over few areas. Northeastern highlands (Arusha, Kilimanjaro and Manyara regions) areas will experience cloudy conditions at times with showers and thunderstorms over few areas. Western areas (Kigoma and Tabora regions) and central areas (Dodoma, and Singida regions) are expected to feature partly cloudy conditions with showers and thunderstorms over few areas and sunny periods. Lake Victoria basin, (Mwanza, Mara and Kagera regions) will experience partly cloudy to cloudy conditions with showers and thunderstorms over few areas. Southwestern highlands (Mbeya, Rukwa and parts of southern Iringa regions) and Ruvuma region will be partly cloudy with showers and thunderstorms at times over few areas although most of the areas will be dominated by sunny periods.

Box 5: Expected weather during April 11 – 20, 2006

The Lake Victoria basin, (Mwanza, Mara and Kagera regions) will experience partly cloudy to cloudy conditions with showers and thunderstorms over most areas at the beginning of the dekad and over few areas towards the end of the period. Northern coast (Dar es Salaam, Coast and Tanga regions and Islands of Zanzibar and Pemba) will feature cloudy conditions with showers over most areas and thunderstorms over few areas and sunny intervals. Northeastern highlands (Arusha, Kilimanjaro and Manyara regions) will experience cloudy conditions at times with showers and thunderstorms over few areas. Western areas (Kigoma and Tabora regions) are expected to feature partly cloudy conditions with showers and thunderstorms over few areas and sunny periods. Southwestern highlands (parts of southern Iringa, Mbeya and Rukwa regions), central areas (Dodoma and Singida regions) and southern (Ruvuma region) will feature partly cloudy conditions with showers and few thunderstorms at times over few areas although most of the areas will be dominated by sunny periods.

Box 6: Expected weather during April 21 – 300, 2006

Lake Victoria Basin (Mwanza, Mara And Kagera Region) Will Experience Partly Cloudy To Cloudy Conditions With Showers And Thunderstorms Over Most Areas At The Beginning Of The Dekad And Over Few Areas Towards The End Of The Dekad. Northern Coast (Dar Es Salaam, Coast And Tanga Regions, And Islands Of Zanzibar And Pemba) Will Feature Partly Cloudy To Cloudy Conditions With Showers Over Most Areas And Thunderstorms Over Few Areas And Sunny Periods. Northeastern Highlands (Arusha, Manyara And Kilimanjaro Regions) Will Experience Cloudy Conditions At Times With Showers And Thunderstorms Over Most Areas. Western Areas (Kigoma And Tabora Regions) Are Expected To Feature Cloudy Conditions With Showers And Thunderstorms Over Few Areas And Sunny Periods. Southwestern Highlands (Mbeya And Rukwa Regions), Southern (Ruvuma Region) And Central Areas (Dodoma, Singida And Iringa Regions) Will Feature Partly Cloudy Conditions With Light Showers And Light Thunderstorms At Times Over Few Areas And Sunny Periods. Most Of The Southern Region, Southwestern Highlands And Parts Of Central Areas Will Be Dominated By Sunny Periods Over Most Areas.

Box 7: Expected weather during May 01 – 10, 2006

Lake Victoria basin, (Mwanza, Mara and Kagera regions) will continue experience partly cloudy to cloudy conditions at times with showers over most areas and thunderstorms over few areas. Northern coast (Dar es Salaam, Coast and Tanga regions) and the Islands of Zanzibar and Pemba will feature partly cloudy conditions with light showers over few areas and thunderstorms at times over few areas and sunny periods. Northeastern highlands (Arusha, Kilimanjaro and Manyara regions) areas will experience partly cloudy to cloudy conditions at times with showers over most areas and thunderstorms over few areas and sunny periods. Western areas (Kigoma region) are expected to feature partly cloudy conditions with showers and thunderstorms over few areas and sunny periods. Southwestern highlands (Iringa, Mbeya, Rukwa and Tabora regions), central areas (Dodoma and Singida regions) and southern areas (Ruvuma region) will feature partly cloudy with light rains at times over few areas and long sunny periods. Most of the southern, southwestern highlands and parts of central areas will be dominated by sunny periods over most areas and chilly temperatures at night and early morning.

Box 8: Expected weather during May 11 – 20, 2006

Lake Victoria basin (Mwanza, Mara and Kagera regions) and northeastern highlands (Arusha, Kilimanjaro and Manyara regions) will continue experiencing partly cloudy to cloudy conditions at times with showers over most areas and thunderstorms over few areas. Northern coast (Dar es Salaam, Coast and Tanga regions, and Islands of Zanzibar and Pemba) will feature partly cloudy conditions with light rains over few areas and sunny periods. Western areas (Kigoma region) are expected to feature partly cloudy conditions with showers and thunderstorms over few areas and sunny periods. Southwestern highlands (Mbeya, Rukwa and Tabora regions), central areas (Dodoma, Singida and Iringa regions) and southern (Ruvuma region) will feature partly cloudy with light rains at times over few areas and long sunny periods. Most of the southern region, southwestern highlands and parts of central areas will be dominated by sunny periods over most areas and chilly temperatures at night and early morning hours.

Box 9: Expected weather during May 21 – 31, 2006

Lake Victoria basin, (Mwanza, Mara and Kagera regions) will experience partly cloudy to cloudy conditions at times with showers and thunderstorms over few areas and sunny periods. Northern coast (Dar es Salaam, Coast and Tanga regions, and Islands of Zanzibar and Pemba) will feature partly cloudy conditions with light morning rains over few areas and sunny periods. Northeastern highlands (Arusha, Kilimanjaro and Manyara regions) will experience partly cloudy with occasional light showers over few areas and sunny periods. Western areas (Kigoma region) are expected to feature partly cloudy conditions with showers and thunderstorms over few areas at the beginning of the period and sunny periods. Southwestern highlands (Mbeya, Rukwa and Tabora regions), central areas (Dodoma, Singida and Iringa regions) and southern sector (Ruvuma region) will feature partly cloudy conditions with light rains at times over few areas and long sunny periods. Most of the southern region, southwestern highlands and parts of central areas will start observing minimum temperatures associated with chilly weather at night and early morning hours followed by long sunny periods in the afternoon.

Box 10: Expected weather during October 11 – 20, 2006

Lake Victoria basin and western areas (Kigoma region) will experience partly cloudy to cloudy conditions with thundershowers mainly over the western parts of the lake and sunny periods. The Northern coast (Tanga and Dar es Salaam regions, and Islands of Zanzibar and Pemba) will feature partly cloudy to cloudy conditions at times with showers over few areas and sunny periods. Northeastern highlands (Arusha, Kilimanjaro and Manyara regions) will feature partly cloudy to cloudy conditions at times with rainshowers mainly over high grounds and sunny periods. Southern, southwestern and central regions will experience partly cloudy conditions and sunny periods. Southern, southern coast, southwestern highlands, western, the central area and Lake Victoria basin will experience cloudy conditions with thundershowers over few areas and sunny intervals. Northeastern highlands and northern coast will experience partly cloudy conditions with thundershowers over few areas with sunny periods. The rest will feature partly cloud conditions with sunny periods.

Box 11: Expected weather during October 21 – 31, 2006

The Northern coast and the Islands of Zanzibar and Pemba will feature cloudy conditions with showers over few areas and sunny periods mainly towards the end of the dekad. Lake Victoria basin and western areas (Kigoma region) will experience cloudy conditions with thundershowers mainly over the western parts of the lake and sunny periods. Northeastern highlands will feature partly cloudy to cloudy conditions at times with rainshowers mainly over high grounds and sunny periods. Southern, southwestern highlands, central regions will experience partly cloudy conditions with occasional light rainshowers towards the end of the dekad and sunny periods.

Box 12: Expected weather during October 21 – 31, 2006

Areas with the unimodal rainfall pattern are expected to experience rainfall increase. The southern, southern coastal belt, southwestern highlands, western areas, and central areas, Lake Victoria basin will experience cloudy conditions with thundershowers over some areas and sunny intervals. Northeastern highlands and northern coast will experience partly cloudy conditions with thundershowers over few areas with sunny periods. The rest of the country is expected to partly cloud conditions with sunny periods.

Box 13: Expected weather during March 01 – 10, 2007

Southern region and southern coast, and southwestern and northeastern highlands will feature partly cloudy to cloudy conditions with thundershowers over few areas and sunny periods. Western, central, Lake Victoria basin, and northern coast including Islands of Zanzibar and Pemba are expected to experience cloudy conditions with thundershowers over some areas and sunny intervals.

Box 14: Expected weather during March 21 – 31, 2007

Southern region, southwestern highlands, central and western areas will feature partly cloudy conditions with rain showers over few areas and sunny periods. Lake Victoria basin and northeastern highlands will feature partly cloudy conditions with thundershowers over few areas and sunny periods. Southern coast, northern coast and ts hinterlands will feature partly cloudy to cloudy conditions with rain showers and isolated thunderstorms with sunny intervals.

Box 15: Expected weather during April 11 – 20, 2007

Southern coast, southern region, southwestern highlands, central areas and western areas are expected to feature partly cloudy conditions with rain showers over few areas and sunny periods. Areas over Lake Victoria basin are expected to experience partly cloudy conditions with thundershowers mainly over western areas. Northeastern highlands and northern coast and its hinterlands are expected to feature partly cloudy to cloudy conditions with thundershowers over some areas and sunny intervals.

Box **16: Expected weather during April 21– 30, 2007**

Western areas and Lake Victoria basin will have partly cloudy conditions with thundershowers over few areas. Northern coast and northeastern highlands will have partly cloudy to cloudy conditions with showers and thunder activities over few areas and sunny intervals.

Box 17: Expected weather during May 1 – 10, 2007

Western areas and Lake Victoria basin are expected to feature partly cloudy conditions with thundershowers over few areas and sunny periods. Northern coast and Northeastern highlands are expected to experience partly cloudy to cloudy conditions with showers over few areas and sunny periods. Southwestern highlands are expected to feature partly cloudy conditions with few cases of isolated showers mainly over high ground and sunny periods. The dryness over southern coast, central areas towards Shinyanga and Tabora regions is expected to persist.

Box 18: Expected weather during May 11-20, 2007

Lake Victoria basin is expected to feature thundershowers over few areas and sunny periods. Northern coast and northeastern highlands are expected to have isolated to widespread showers and sunny periods. Southwestern highlands are expected to feature few cases of isolated showers mainly over high ground and sunny periods. Further reduction of rainfall activities is expected over southern coast, southern region, central and western areas including Shinyanga region.

Box 19: expected weather during May 21-31, 2007

Lake Victoria basin (Kagera, Mwanza, Mara and Shinyanga regions) is expected to feature thundershowers over few areas and sunny periods. Northern coast (Dar es Salaam, Morogoro, and Tanga regions, and Islands of Zanzibar and Pemba) and northeastern highlands (Arusha, Kilimanjaro, and Manyara regions) are expected to feature isolated to widespread showers and sunny periods.

LIST OF REFERENCES

Allen, M.D. Frame, Kettleborough, J. and D. Stainforth (5). Confidence, uncertainty and decision support relevance in climate. [http://www.lse.ac.uk] site visited on 12/2/2008.

Anderson, D.L.T. (2005). Operational seasonal prediction. In Palmer, T. N. and Hagedon, R.., In Palmer editions, *Predictability of Weather and Climate*. Cambridge University Press. 375pp.

Atger, F. (2004). Estimation of the reliability of ensemble-based probabilistic forecasts. Q.J.R. *Bulletin of Meteorological Society*. 130 (597): 627-646.

Atheru, Z.K. and Ambenje, P. (2002). Verification of September-December 2001 Consensus Climate Outlook. pp. 36-41.

Bako, M., I. Niag, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman, R.. Tabo and P. Yanda (2007). Africa, Climate Change 2007. Impacts, Adaptation and Vulnerability. Cambridge University Press, Cambridge UK. pp. 433-467.

Banitz, E. (2001). Evaluation of short-term weather forecasts in South Africa. *Water South Africa*., 27(4): 489-498.

Bessler, D.A. and R. Ruffley, (2004). Prequential analysis stock market returns. *Applied Econ*omy 35(5): 399-412.

Bettge, A.G., D.P. Baumhefner, and R.M. Chervin (1981). On the verification of seasonal climate forecasts. *Bulletin of American Meteorological Society* 62: 1654 -1665.

Bougeault, P., (2003). The WGNE survey of verification methods for numerical prediction of weather elements and severe weather events. [http://www] site visited on 10/8/2006.

Brown, T. J., (2001). Program for climate, Ecosystem and fire Applications. In: *Proceedings of fire and climate workshops, University of Arizona, Institute for study of Planet Earth*, Climate Assessment for the Southwest. 247pp.

Buizza, R. (2005). The ECMWF Ensemble Prediction System. In Palmer editions, Predictability of weather and climate . Cambridge University Press. pp. 534 – 539.

Burton, I. and Van Aalst (2004). Look before you leap: A Risk management Approach for integrated Climate Change Adaptation into World Bank Operations. World Bank Environment Dept. Paper No. 100. World Bank, Washington. 376pp.

Cherubin, T., A. Ghelli, and F. Lalaurette, (2001). Verification of Prediction forecasts over the Alpine Region Using a high-Density Observing Network. *Weather forecasting*, ***17***, *American Meteorological Society. p*p. 238 - 249.

Clewett, J.F. (2002). Seasonal climate forecasts and decisions support systems for drought prone agriculture. A case study based on the development and application of the Rainman Climate analysis software. In "Coping against El Nino for stabilizing Rainfed Agriculture: Lessons from Asia and the Pacific" United Nations, CGPRT Centre Monograph No. 43: pp. 37-55.

Clewett, J.F., Smith, P.G., D.A. Partridge, I.J. and Peacock, A. (1999). Australian Rainman Version 3: an integrated software package of Rainfall Information for

Better Management. Department of Primary Industries Queensland, QI98071. 387pp.

Coelho, C.A.S., Stephenson, D. B., Doblas-Reys, F. J., Balmaseda, M., Guetter, A., van Oldenborough, G. J., (2006). A Bayesian approach for multi-model downscaling: seasonal forecasting of regional rainfall and river flows in South America. *Applied Meteorology*13:73-82.

Colin, J.P. (2002). The value and benefits of using seasonal climate forecasts in making business decisions: a Review. [http://www.longpadlock.gld.au] site visited on 13/2/2008.

Curry, J. (2001). Use of climate information in the greater Horn: assessing the needs of institutional users. New York: International Research Institute for climate Prediction, Columbia University. pp. 132 -141.

Dakey, D.J. and Vere-Jones (2004). Scoring probability forecasts for point process: The entropy score information gain. *Journal Applied Probability*. pp. 297-312.

De Elia, R. and Laprise, E. (2005). Diversity in interpretation of probability: Implications for weather forecasting. *Monthly Weather Review*. 133(5): 1129-1143.

Doswell, C. A., and J.A. Flueck, (2002). Forecasting and verifying in a field research.

Ebert, E.E., (2002) Verifying satellite precipitation estimates for weather and hydrological applications. *1st International Precipitation Working Group (IPWG) Workshop, Madrid, Spain, 23-27 September 2002*. pp 36-47.

ESRL. (2004). Earth System Research Laboratory for assessing the quality of weather forecasts [http://www-ad.fsl.noaa.gov] site visited on 13/3/2008.

Franz, K.J. (2001). Evaluation of National Weather Service Ensemble Stream flow Prediction (ESP) Water Supply Forecasts. *Master's Thesis*, *Department of Hydrology and water Resources*, University of Arizona, Tucson, Arizona. 351pp.

Fredrich, K.. and L.M. Leslie, (1988). Real-time short-term prediction rainfall in the tropics. *Weather Forecasting,* 3: 243-246.

Galvin, K. A., Boone, R.B., Smith, N. M.., & Lynn, S. J. (2001). Impacts of climate variability on East African pastoralists: linking social science and remote sensing. *Climate Research* 19(1): 161-172.

Gelli, A. and F. Lalaurette, (2000). Verifying precipitation forecasts using up-scaled observations. *ECMWF Newsletter* 87: 9-17.

Gneiting, T. , A. E. Raftery, A. H. Westveld (2005). Calibrated probabilistic forecasting using ensemble model output statistics and minimum CRPS estimation. *Monthly Weather Review* 133(5): 1058-1118.

Goddard, L., Barnston, A. and Mason, S. J. (2003). Evaluation of the IRI's "net assessment" seasonal climate forecasts. *Bulletin of American Meteorology*

Goddard, L., Mason, S.J., Zebiak, S.E., Ropelewski, C. F., Basher, R., & Cane, M.A. (2001). Current approaches to seasonal-to-interannual climate predictions. *International Journal of Climatology* 21: 1111-1152.

Hammer, G. L. (2002). Climate and Weather Risk assessment for Agricultural Planning. [http://www.wmo.ch] site visited on 12/2/2008.

Hammer, G. L., Hansen, J. W., Phillips, J. G., Mjelde, J.W., Hill, H., Love, A., & Potgieter, A. (2002). Advances in application of climate prediction in agriculture. *Agricultural Systems* 70: 515-553.

Harte, D. and D. Vere-Jones (2005). The entropy score and its uses in earthquake forecasting. *Pure Applied Geophysics* 162: 1229-1253.

Hatmann, C., T.C. Pagano, S. Soroshanian and R. Bales (2002). Confidence builders. Evaluating seasonal climate forecasts from users perspectives. *Bulletin of American Meteorological Society* 83: 683-698.

Heidke, P., (1926). Berechnung des Erfolges und Gute der Windstarkevorhersagen in Sturmwarnungdienst. *Geography Annual* 8: 310-349.

Hellmuth, M.E., A. Moorhead, M.C. Thomson and J. Williams (2007). Climate risk management in Africa: Learning from practice. [http://64.233. 104] site visited on 18/2/2008.

Holger, M. and S. Roger, (2005). Seasonal and inter-anuual climate forecasting: The new tool for increasing preparedness to climate variability and change in agricultural planning and operations. Increasing Climate variability and change. *Agriculture and Forestry* pp. 221-247.

IPCC (2007). Climate change Impact Report. [http://www.ipcc.ch] site visited on 12/2/2008.

Jagtap, S. S. and A.K. Chan, (2000). Agrometeorological aspects of agriculture in the sub-humid and humid zones and Asia. *Agriculture and Forestry Meteorology*. 103, pp 59-72.

Jilliffe I. T. and N.M. N. Jolliffe, (1997). Assessment of descriptive weather forecasts. *Weather Forecasting* 52: 391-396.

Jolliffe, I. T. and D.B. Stephenson (2003). Forecast verification: A Practioners Guide in Atmospheric Science. John Wiley and sons, 254pp.

Jurry, M. (2002). Economic impacts of climate variability in South Africa and development of resource prediction models. [http://www.isse.ucar.edu] site visited on 12/2/2008.

Kamamistu, M., J. Roads, L. Haan and J. Ritche (2002). ECPC's Mar 2004 Seasonal Forecasts. [http://www.grads.iges.org] site visited on 13/2/2008.

Ken, R. W. (2007). Verification of National Weather Service warning using Geographic Information systems. [http://www.weather.gov] site visited on 12/2/2007

Kihupi, N. I., Dihenga, H. O., and Tarimo, A.K.P.R. (2005). Rainfall disaggregation for stochastic simulation of soil water balance. The Tanzania Engineer 8 (1): 29-36.

Kipkorir, E. C. (2002). Analysis of rainfall climate on the Njemps flats, Baringo District, Kenya. *Journal of Arid Environments* 50: 445-458.

LDCEG, (2003). Selection of examples and exercises drawn from the regional NAPA preparation Workshops, United Nations Framework Convention on Climate Change (UNFCCC), Bonn, Germany. 682pp.

Luciana, S. O. and Maria, G. (2006). Evaluation of weather forecasts made for Rio de Janeiro city. [http://www.gemini.dpi.inipe.br] site visited on 12/2/2008.

Mark, A. R., S. Dickson, and D. Massie (2001). Extended forecast verification at the weather forecast office at Nashville, Tennassee. [http://www.nwas.org] site visited on 23/9/2007.

Mason, I. (1979). On reducing probability forecasts to yes/no forecasts. *Monthly Weather Review* 107: 207-211.

Mason, I. (2004). Binary events. In Jolliffe and Stephenson (2003). 37pp.

Maunder, N. (2003). Climate Information and Prediction Products: Are these Products Meeting the Demands of the Food Security? *In a Report of the First DMCN Experts Meeting on downscaling of climate Information and Prediction Products for Specific Applications in Agriculture and Food Security Sectors, Nairobi, Kenya*. 418pp.

Maunder, W.J., (1971). The value of weather, Methuen and Co, London. 399 pp.

Meghestab, H. (2005). Weather patterns, food security and humanitarian response in sub-Sahara Africa. [http://www.pubmedcentral.nih.gov] site visited on 13/2/2008.

Meinke, H. Baethgen, W. E., Carberry, P.S., Donatelli, M., Hammer, G. L., Selvaraju, R. and Stockle, C.O. (2001). Increasing profits and reducing risks in crop production using participatory systems simulation approaches. *Agricultural Systems* 70: 493-513.

Mhita, M. S., Tibaijuka, P.F. and Tilya, T. (2003). Development of New Seasonal Climate Prediction Tools Through analysis of Onset and Cessation of seasonal Rains associated With El Nino/Lanina Events. *The Report of the Pilot Applications Project*. 13pp.

Mjelde, J. W., Thompson, T.N., Nixon, C. J., Lamb, P.J., (1997). Utilizing a farm-level decision model to help prioritize future climate prediction research needs. *Applied Meteorology*. 4: 162-170.

Molly, E. H., Maarten, K. and D. Ponzi (2007). Come rain or shine. Integrating Climate Risk Management into African Development bank Operations. *Working paper No 89 African development Bank*, Tunis. 127pp.

Mpeta, E. J. and Mhita, M.S. (1993). The diurnal variation of precipitation in Tanzania. *Proceedings of the 3rd Technical Meeting*. pp. 76-78.

Muller, R.H., (1944). Verification of short term-range weather forecasts. *Bulletin American Meteorological Society* 25: 88-95.

Murphy, A. H. (1977). The value of climatological categorical and probabilistic forecasts in the cost-loss ratio situation. *Monthly Weather Review* 105: 803-816.

Murphy, A. H., (1993). What is good forecast? An essay on the nature of goodness in weather forecasting: *Weather and Forecasting* 8: 281-293.

Murphy, A. H., R. Hertwing, and B. Fasolo (2000). " A 30% chance of rain tomorrow". How does the public understand weather forecasts. [http://www.mpib-berlin.mpg.de] site visited on 13/2/2008.

Murphy, a. H., R. L. Winkler, (1987). A general framework for forecast verification. *Monthly Weather Review* 115: 1330-1338.

Murphy, A. H., R.L. Winkler, (1992). Diagnostic verification of probability forecasts. *International Journal Weather Forecasting* 7:1330-1338.

Mwano, M. J., (2006). Evaluation of different seasonal rainfall forecast products and forecasting techniques in various agro-climatic zones of Tanzania. Unpublished Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania, pp. 126-138.

Nicholas, F. (2006). Are accurate forecasts possible? [http://www.ch.oice.co.uk] site visited on 8/2/2007.

Nieuwolt, S., (1973). Rainfall and evaporation in Tanzania. *Land Use Planning Research* 24: 136-142.

Nieuwolt, S., (1979). The East African Monsoons and their effects on agriculture. *Geophysical Journal* 3: 193-200.

ODI, (1999). Seasonal climate Forecasting: Who can use it and how should it be disseminated? 47: 116-123.

Ogallo, L. A., Boulahya, M. S. and Keane, T., (2000). Applications of seasonal to interannual climate prediction in agricultural planning and operations. *Agriculture and forest Meteorology* 103: 159-166.

Ogallo, L.A., (1988). Relationships between seasonal rainfall in East Africa and the Southern Oscillation. *International Journal of Climatology* 8: 31-43.

Owens, D. T., Clarkson, N. M. and Flood, N. (1996). Development of a long-term Daily and Monthly Rainfall Collection for Australia. In “The Impact of weather and climate on agriculture” *Proceedings of the second Australian Conference on agricultural Meteorolog*y. University of Queensland, Brisbane, 1-4 October 1996. pp 235-239.

Palmer, T. N., Shutts, G. J., Hagedorn, R., Doblas-Reyes, F. j., Jung, T., Leutbecher, M., (2005). Representing model uncertainty in weather and climate prediction. *Annual Review Earth Planet. Science. pp.* 163-193.

Patt, A. G., Suarez, P. and Gwata, C. (2005). Effects of seasonal climate forecasts and National Academy of Science of the United Stares of America. 102., 12623. [http://www.people.bu.edu] site visited on 12/2/2008.

Richardson, D. S. and L. A, Smith (2002). Skill and \economic value of the ECWMF Ensemble Prediction system. *Journal Royal Meteorological Society* 126: 649-701.

Roulston, M.S. and L.A. Smith (2002). Evaluating probabilistic forecast using information theory. *Monthly Weather Review* 130 (6): 1653-1660.

Schreck C. J. and Semazzi, F.H. M. (2004). Variabilty of the recent climate of eastern Africa. *International Journal of Climatology*, 24(6): 681-701.

Shukla, P. R., Sharma, S. K. and Ramana, (2002). Climate change and India-issues, concerns and opportunities, Tata McGraw-Hill Publishing Company limited, New Delhi, 317pp.

Siri, E. and E. l. Santiago, (2001). User responses to seasonal climate forecasts in Southern Africa. [http://www.cicero.uio.no] site visited on 8/2/2008.

Sivakumar, P. (2002). Targeting seasonal climate for integration into household level decisions. The case of smallholders farmers in Lesotho. [http://www.questia.com] site visited on 13/2/2008.

Skely, W. C. and A. Henderson-Sellers, (1996). Grid box or grid point: What type of data do GCMs deliver to climate impacts researchers? *International Journal of Society* 84: 1761-1781.

Someshwar, D. (2000). Evaluation and verification of MM5 forecasts over the Indian region. [http://www.mmm.ucar.edu] site visited on 30/1/2008.

Stanski, H. R., L.J. Wilson, and W.R. Burrows., (1989). Survey of common verification methods in meteorology. *World weather Watch Technical. Report 8*., WMO/TD no. 358, 114pp.

Stephenson, D. B. and Doblas-Reyes (2000). Statistical methods for interpreting Monte Carlo ensemble forecasts. *Tellus*, 52(3): 300-322.

Stephenson, D.B. (2000). Use of odds ratio for diagnosing forecast skill. *Weather Forecasting*, 15(2): 221-232.

Thompson, B. J. (1965). Climate of Africa. Oxford University Press. 436pp.

Thorns, J. E., (1996). The quality ands accuracy of a sample of public and commercial weather forecasts in the UK. *Meteorological Application*. 3: 63-74.

TMA (2005). *Tanzania Meteorological Agency bulletin* 5: pp. 21-29.

TMA (2006). *Tanzania Meteorological Agency (January-March 2006) Bulletin* 65: pp. 13-17.

Toth, F. L., T. Hagedorn, T. Palmer, (2003). Predictability of weather and climate. [http://www.cambridge.org] site visited on 13/2/2008.

Trotman, A. (2006). [htpp:www.forecasting.com[site visited on 29/5/2007.

Unganai, L.S., Mano, T. Bandason, and V. Mutikani (2004). Economic benefits of applying seasonal climate forecasts in smallholder farm management: case study for Zimbabwe [http://www.noaa.ogp] site visited on 30/8/2007.

Wald, N. (1999). Verification of March-May 1998 and September-December 1998 Climate Outlook for Eastern Africa. Summaries of the Presentations at the User's Pre-Forum Capacity Building Workshop for period March-May 1999. pp. 14-28.

Wei, A. and R. Toth (2003). New measure of ensemble performance: Perturbation versus correlation analysis (PECA). Monthly weather Review 131 (8): 1549-1565.

Wilks, D.S. (1995). Statistical methods in the atmospheric Sciences: An introduction Academic Press. 467pp.

Wilks, D.S. (2000). On interpretation of probability climate forecasts. *Journal of Climatology* 13: 1965-1971.

Wilks, D.S. (2001). A skill score based on economic value for probability forecasts. *Meteorological. Application* 8: 209-219.

WMO, (2000). Guidelines of performance assessment of public weather services. Document available at [http://www.wmo.ch] site visited on 20/2/2008.

Wolfs, P. and Hubener, R. (1996). Irrigation in the world – the future will not be like the past. *Journal of Agriculture in the Tropics and Sub Tropics*. 97: 185-201.

Zhang, H. and Casey, T. (2000). Verification of categorical probability forecasts. Weather and forecasting. American Meteorological Society 15