Linking Ground, Space and Knowledge: The Role of Weather Forecasting in Pastoralists' Decision-Making

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Abstract

Changing weather patterns and decreasing land availability continue to challenge the livelihood of the pastoralists in northern Tanzania. The increasing variability of expected rains has complicated livestock management, often jeopardizing household resilience. Drought Early Warning Systems are being set up to contribute to decision-making processes at national and international levels. Nevertheless, due to the large spatial- and temporal resolution of these systems and their high uncertainties, these systems have limited value at a pastoral household level.

Therefore, this paper explores what type of weather and climate information is deemed valuable for pastoral households in Longido District, Tanzania. It is based on an ethnographic study, conducted over a period of four months. It explores what weather information would be useful, the necessary scale of desired information, the required lead time of communication and, lastly, the most effective method of communicating forecast information. Following on this data, the study assessed the status of remote sensing and weather forecast modelling, exploring the question, the desired weather information can be forecast with enough skill and at a scale that is relevant to pastoral households in Longido? The ECMWF weather model was used in the assessment, revealing some optimism and scepticism concerning the status of existing information and technologies.

Technological recommendations include verification of rainfall data, further research on the rainfall threshold concept, and exploring the model skill of embedded models in Tanzania. At the level of implementation , recommendations include discussing the adverse impacts of actions taken based on the forecasts and forming an implementation advisory group, which includes a comprehensive breadth of stakeholders, such as knowledgeable community members, village leaders, traditional leaders and also professionals from the field of climate sciences, rangeland ecology and anthropology.

Introduction

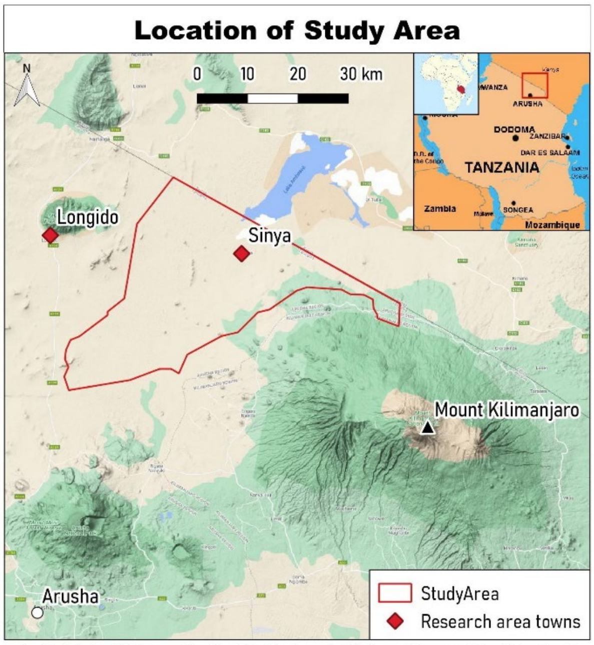
"In June [2009] people started moving with their livestock. In August no one remained. Those who did, their livestock died."– Maasai elder from Sinya, Tanzania

In the Northern-Tanzanian semi-arid rangelands, droughts occur frequently, rainfall patterns are shifting and increasingly variable, and water resources are shrinking (Msangi et al., 2014; United Republic of Tanzania, 2012). For semi-nomadic pastoral Maasai communities in Northern Tanzania, the changing precipitation patterns and increasing droughts form great challenges to their livelihood. These periods of little rainfall and grass scarcity are called *alamei* in Maa, the Maasai language. Moving their livestock over vast distances across semi-arid rangelands is one of the main strategies for many Maasai households to cope with *alamei* (Goldman and Riosmena, 2013). However, due to land privatization in Southern-Kenya, expansion of agriculture especially around Mount Kilimanjaro, and changing policies on grazing in conservation areas, the available lands for grazing in times of *alamei* are decreasing, making it increasingly challenging for the Maasai pastoralists to cope with *alamei* (Goldman and Riosmena, 2013; Miller et al., 2014). As part of climate change mitigation and adaptation projects, and increasing livelihood resilience, satellite data and climate models are used in many areas of the world to monitor and predict droughts (AghaKouchak et al., 2015; Bijaber et al., 2018; Boschetti et al., 2013; Vrieling et al., 2016). For the heavily under-resourced district, and a country with a limited number of weather stations, these macro technologies may provide valuable data for *alamei*-related weather predictions in Longido District, Tanzania. However, for such weather predictions to be valuable, it is essential that these predictions are tailored to the needs of the pastoral households living in these areas.

Therefore, the goal of this research is to explore if weather forecasts and remote sensing data can be tailored to existing coping and decision-making strategies adopted by pastoralist households. Furthermore, it is assessed if this tailored information provides enough skill to effectively complement local knowledge and drought management strategies. The study generated important methodological and theoretical findings, both of which have practical implications for policy and technological development.

Methods and Study Site

The study area entails the Ward of Sinya in Longido District in Tanzania (Figure 1). The study area is situated in a semi-arid, hot ecosystem in which 300-600mm of rain falls on average annually (Longido District Council, 2018). The area is characterized by bimodal rainfall patterns in which the short rains usually occur in November till January and the long rains in February till May (Miller et al., 2014). The rainfall is very patchy and the average temperatures are between 15 and 30 °C (Longido District Council, 2018; Western and Finch, 1986).



Credits: Made in qGIS. Basemap: OpenStreetMap. Map Tanzania: http://www.infolaso.com/. Map Africa: https://commons.wikimedia.org/

Figure 1 Location of Study Area

Fieldwork

In the first phase of this study the current *alamei* strategies, available knowledge and information on weather predictions were explored. This phase initiated the design of an *alamei*-related weather information system. The fieldwork was conducted over a period of 4 months in February-April 2019 and August 2019. The goal of the fieldwork was to determine (1) current *alamei* management strategies applied by the households in Sinya, (2) local knowledge on weather predictions, (3) access to technology-based weather predictions by community members in Sinya, and (4) valuable weather information for households in addition to the existing *alamei* management strategies. After having obtained information on these topics, the design of a potential system, which provides this required weather information, was discussed, focusing on what area the information should be on, how far in advance the information is required and how this information can be effectively communicated to reach as many households in Sinya as possible. Data was gathered through key-informant interviews, focus group discussions and a 'family portrait' strategy (Cochrane et al., 2005; Serneels et al., 2009), which included in-depth discussions with a case-study family. In total, more than 30 formal and informal interviews were conducted, and 12 focus group session were held, with a total of over 45 people participating. The family, for which a livelihood strategy portrait was made, was visited 4 times, across 6 months.

Model skill determination

The main findings of the fieldwork were the elements which were identified by the participants as being essential for a valuable forecast. These results were then used, to understand whether the seasonal forecasts of the European Centre for Medium-Range Weather Forecasts (ECMWF) model can predict these with enough skill. These identified elements are provided in the results section and the model skill determination method is described below.

The precipitation reanalysis data[1] (1993 - June 2019) of the ECMWF was compared with the forecasted data[2] (1993 - June 2019). For this comparison, for both datasets the 5-day cumulative rainfall was determined for each day of the selected month. It was determined whether a given threshold is not exceeded at any point during the month of interest for both the reanalysis and the forecasted data, based on the 5-day cumulative

[1] *ERA5 hourly data on single levels from 1979 to present* dataset retrieved from: https://cds.climate.copernicus.eu/
[2] ECMWF's meteorological archive: https://confluence.ecmwf.int/display/UDOC/MARS+user+documentation

data. This threshold non-exceedance determination was conducted for all 25 to 51 ensemble members. From the threshold non-exceedance data, the amount of hits, misses, false alarms (FA) and correct negatives (CN) were determined. A hit is defined as both the forecast data and the reanalysis data indicated that the threshold is not being exceeded. A false alarm is when the threshold was exceeded in the reanalysis data, but not in the forecast data. The hit-rate and false-alarm rate were computed using the following relationship:

$$Hit_{rate} = \frac{Hit}{Hit+Miss} \qquad FalseAlarm_{rate} = \frac{FA}{FA+CN}$$

Finally, a Receiver Operating Characteristic (ROC) curve was constructed per given threshold, to identify the model skill.

Results

Fieldwork

The *alamei* management strategies differ between households and are not completely generalizable. The major factor which influences these differences is the availability of labour power to look after the cattle when they stay far away from home. However, for all the households who took part in this research, transhumance and selling some livestock to buy food, are the most prominent strategies in times of *alamei.* The decisions on moving and selling are influenced largely by grass availability, expected grass depletion rates and expected rains. However, these rains do not always occur according to these expectations and the patterns have been highly unpredictable. Therefore, when grasses are scarce, and a decision on moving and selling needs to be made, it is considered valuable to receive a prediction on whether these rains will come and provide enough precipitation for the grasses to regrow. Though local knowledge exists on weather predictions, the ones who have this knowledge are often hesitant to share it and cannot predict with enough certainty to encourage action. Weather information from other sources such as the Tanzanian Meteorological Agency, do not provide the required information at a small enough scale. The forecasts are often incorrect for Sinya and, when available, the information is by many not received due to lack of internet, tv's and radios.

These findings resulted in the idea to provide *alamei*-related weather information during key decision junctures. This weather information would be complementary to a larger system of *alamei* drivers and of knowledge on *alamei* management in Sinya. The remainder of this study (phase 2) focusses on one specific decision juncture prior to the long rains in March and April. For this decision period two types of forecast information were considered important: (1) whether the expected long rains in March and April are predicted to arrive and (2) if predicted, will the rains provide enough precipitation for the grasses to regrow over an area the size of Enduimet Division (1282 km^2), which encompasses Sinya's core grazing areas. This can best be communicated through a group of trained volunteers through a meeting or a phone call chain, who learn how to communicate this information so that the uncertainties become clear.

Model skill

In the research the skill of the ECMWF model to forecast the above dimensions was analysed. The seasonal forecasts from this model were used to predict whether the 5-day accumulated rainfall would stay below a threshold in the upcoming month. After applying a quantile-to-quantile mapping technique to correct for the bias the forecasting skill was determined. To understand the impact of scale, the skill was determined both for the Enduimet Division (LON 36.7 by 37.4, LAT. -2.6 by -3) and for an extended area (LON 32.0 by 40.0, LAT 0.0 by -6.0) which comprises the whole of Maasailand (Table 1).

Table 1 Overview of the ROC-scores indicating the ECMWF model skill to determine the 5-day precipitation threshold exceedance for Enduimet Division and the Extended area of Maasailand. A ROC-score of 1 means perfect model skill (all predictions correct), the score of 0.5 means half of the predictions are correct, and less than 0.5 means one can better flip a coin than use the model.

Data extraction Area	ROC-score March	ROC Score-April
Forecast (FC) & reanalysis (RE) small Enduimet area	0.78	0.59
FC extended area Maasailand RE Enduimet area	0.78	0.79
FC & RE extended area Maasailand	0.84	0.76

Discussion [Conclusions/Implications]

Through an in-depth engagement with semi-nomadic pastoralists in Longido, this study has identified weather information which can provide value to the drought management strategies of the Maasai communities in the area, in addition to the current knowledge and available information. However, the skill of these predictions can still be improved. This can be done through (1) validating the reanalysis data with ground measurements,

(2) conducting more research on the rainfall threshold and other potential factors which may play a role in grass regrowth, and (3) running the model at levels, to detect the scale with the best balance between model skill versus usability for pastoralists.

In addition to the improvement of the skill, the way of communication is of importance to prevent misinterpretation and assure the receiving group can make an informed decision on how to use the information in their *alamei* management strategies. To prevent adverse impacts as much as possible, it is recommended to set up a support committee who discusses how this information can best be communicated, not only in terms of medium (as discussed in the results) but also on how to explain the concept of probability to ensure the expectations of the users match the capability of the forecasts.

Through *careful* implementation of the weather prediction information provision which is obtained in this research, valuable lessons can be learned on both communication of this information as well as which additional predictions can support this information. As satellite resolution and model performance continue to improve, these communication systems can continuously be updated and grow alongside with the technology. This will assure pastoralists in these remote areas benefit from these technological resources too, in times of increasing uncertainty of precipitation patterns and drought occurrence.

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