Benchmark Report

for

Enhancing the Livestock Early Warning System (LEWS) with NASA Earth-Sun Science Data, GPS and RANET Technologies

September 1, 2010

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Executive Summary

The Horn of Africa contains the largest grouping of pastoralists in the world. The Sudan, Somalia and Ethiopia are at the top of the list of countries having the highest pastoralist percentage globally. The extremely patchy nature of forage resources in the rangelands of the region means that pasture must be exploited opportunistically, often leading to conflicts amongst different pastoral communities. This project addresses three of NASA's priority application areas: Homeland Security, Disaster Management and Ecological Forecasting and would consequently maintain sustainable ecosystem and stability in the region.

Since 1978, communities of researchers from US Land Grant Universities have been working in collaboration with federal agencies (USAID & USDA) and International agencies to transfer livestock research outputs and applications from the livestock farmers and associated industries in *developed* countries to those in *developing* countries under the *Global Livestock Collaborative Research Support Program (GL-CRSP).* The GL-CRSP program paved the way for the development of a prototype Decision Support System (DSS) - *Livestock Early Warning Decision Support System (LEWS DSS)* – that focused on pastoral communities in East Africa. Over the past six years, LEWS DSS has evolved from a GL-CRSP prototype activity to an operational geospatial monitoring system for characterizing forage conditions and identifying areas of forage degradation as a potential conflict indicator. Decision makers within the US are provided updates through assessment reports and online decision support resources.

The *Enhanced* LEWS DSS is built on the achievements of the existing LEWS DSS to improve its performance and efficiency using additional NASA data. The grant secured from NASA Earth-Sun System Division was used to enhance the existing LEWS DSS by adding water resource monitoring tools to the DSS using NASA data. The location and hydrologic regime of important waterholes were characterized in the study area using Advanced Space borne Thermal Emission and Reflection radiometer (ASTER), Shuttle Radar Topographic Mission (SRTM) and Tropical Rainfall Measuring Mission (TRMM) data, employing a combination of image classification, hydrologic modeling and remote sensing techniques.

Benchmarking is a process by which a product (e.g. the water monitoring tools developed as part of *Enhanced* LEWS DSS: http://watermon.tamu.edu/) is measured or judged. This benchmarking process is required to support adoption of innovative solutions into operational environments that affect life and property. In this report, detailed information collected on the status of the present conditions in the study area is provided. A thorough description of the benchmarking activities taken up under this project and also other ongoing activities is given. Data collected as part of user interaction surveys and user feedback is analyzed and the products of the *Enhanced* LEWS DSS are rated against them. One of methods of performing benchmark is to provide feedback/letters received from the direct stakeholders. Such letters/feedback often showcases the advantages and credibility of the project. Such letters received from the direct stakeholders are also presented in this report as a part of benchmarking. The website statistics that provide the popularity and usage of the NASA DSS products is also presented. Apart from the above, some direct advantages of the project are also presented.

2.0 Introduction

2.1 NASA Mission Traceability

The enhancement to the LEWS DSS is heavily based on sensors from several of NASA missions (TRMM, ASTER, MODIS, SRTM, and TOPEX/Jason-1). As shown in the Evaluation report (Senay et al. 2007), detailed technical requirements of the Enhanced LEWS DSS are matched by the capabilities of NASA technological inputs (Table 1). NASA inputs were used in monitoring and characterization of water resources, mapping forage baseline and seasonal migration patterns to develop a sound and efficient DSS in the region. In so doing, the Enhanced LEWS DSS is designed to solve multiple problems in the region from drought to floods, to conflicts, to land degradation and also play a key role in regional stability of an area known for frequent hostilities.

Table1. Description of NASA EOS inputs and their requirements for the DSS

Sl. No	DSS Required Observation & Predictions	NASA Inputs	Requirements
1	Baseline Forage Characterization to make up-to-date pasture inventory and description	MODIS-VCF	Improve spatial characterization of baseline forage conditions and (to avoid field checks)
2	Introduce new water resource monitoring tool	TRMM	Daily water level changes monitoring, daily rainfall estimates, catchment runoff modeling
3	Mapping and delineation of > ~30 m diameter waterholes	ASTER	Mapping waterholes using 15m ASTER VNIR
4	Watershed delineation	SRTM	Watershed delineation tools using 90m SRTM.
5	Water Level Monitoring	NASA Reservoir level tool (satellite altimeter)	Poor resolution for small ponds – Surrogate data from Lake Turkana measurements are evaluated to validate the general trends of a regional water balance model results
6	Monitoring Flooding along Migration routes	TRMM	Uses TRMM as input into the GeoSFM (Stream Flow Model) of USGS/FEWS NET
7	Tracking migration in real time	GPS	GPS adequate for taking position fixes for tracking livestock migration patterns. Perceived limitations are the skill required by the herder to operate the GPS, including maintenance requirements.

2.2 Brief description of *Enhanced* LEWS Decision Support System (DSS)

The *Enhanced* LEWS DSS is made up of four main components: (i) a forage characterization model, (ii) water resources monitoring module (iii) an operational data and product processing module and (iv) a product dissemination system. Figure 2 shows the analytical and communication components of the proposed *Enhanced* LEWS system adapted from LEWS with the addition of new NASA data into the framework.

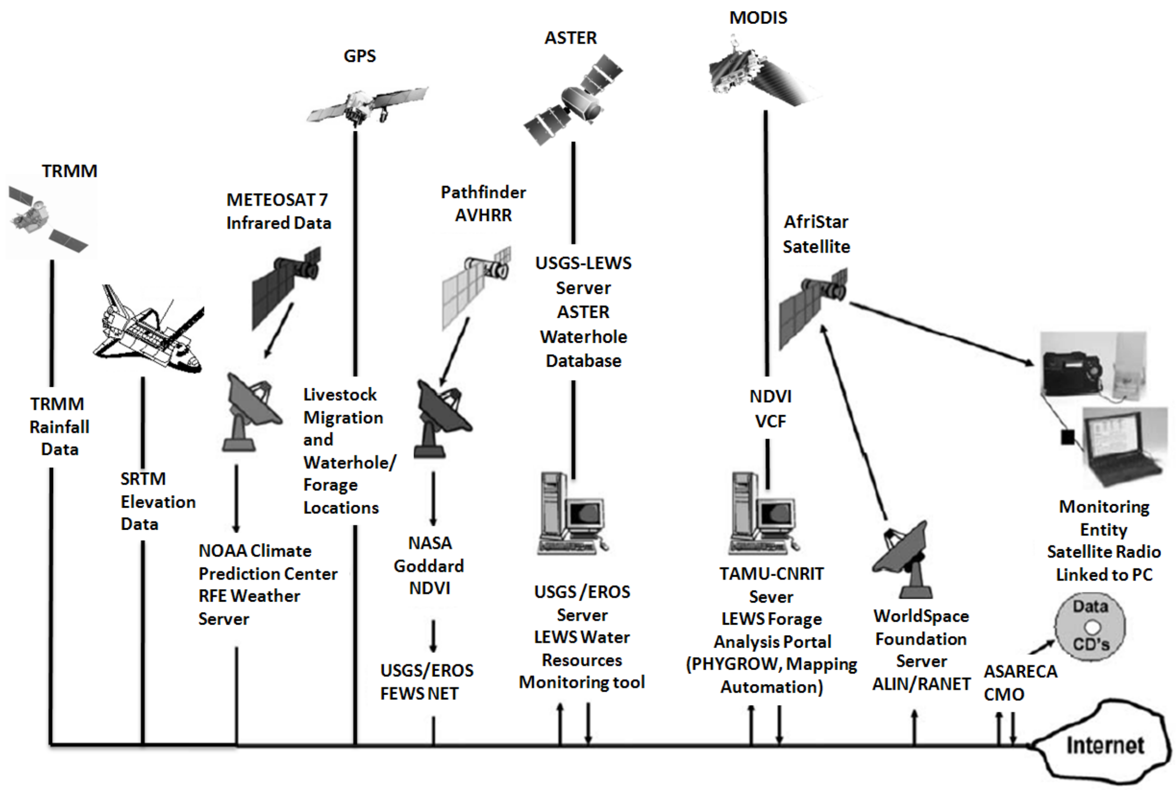

Figure 1. Components of the Enhanced LEWS DSS with NASA inputs[1]

2.2.1 The Forage Characterization module

The basis of forage characterization module is the PHYGROW, a Phytomass Growth Simulator biophysical model. It is a hydrological plant growth model intended to simulate daily available forage. The model has the capability to simulate multi-species or multi-functional plant groups simultaneously across multiple years on daily time steps. This model is used to produce daily estimates of forage conditions and posts the results every 10 days. Forecasts of forage conditions area also generated for lead periods of up to 90 days using current forage estimates, historical forage and phenology based on Normalized Difference Vegetation Index (NDVI).

[1] Modified from LEWS – https://cnrit.tamu.edu/lews/bullitins/LEWS1.pdf

2.2.2 Water resources Monitoring Module

An operational water resource monitoring tool has been developed using NASA satellite data such as TRMM rainfall data, SRTM elevation data, ASTER, and TOPEX/Jason-1 water level data. The method developed in this project for monitoring small waterholes is unique and simple in that it integrates dynamic coarse resolution datasets (TRMM) with static high resolution datasets such as ASTER and SRTM elevation. Based on the principle of simple water balance, the hydrologic model developed here computes runoff and thereby estimates the change in volume of water over the waterhole. This information is finally converted into daily water level fluctuations data for each waterhole. The model takes in daily satellite data and provides water level fluctuations information in near-real time with a day-lag. This information is highly valuable for the pastoralists, local and regional decision makers who assess the situation and make decision on livestock migration in search of forage and water. Such information would also minimize the chances of conflicts.

2.2.3 Operational Data and Product Processing Module

The forage characterization module and water-resources monitoring module are built in such a way that the daily satellite data are processed and the forage conditions and water-resources data are produced every day with a day lag.

2.2.4 Product Dissemination System

For outreach to pastoral communities, it was outlined in the original proposal that products for the LEWS DSS and new products derived under the NASA ROSES grant would be broadcast for use by pastoral communities and other stakeholders in the region using World Space satellite radio technology. In the past, the LEWS team had partnered with the African Learning Channel to provide content on the Arid Lands Information Network - Eastern Africa (ALIN-EA) bandwidth and containers on the World Space network so that data could be transferred using satellite-based radio Internet (RANET) system in East Africa. During the past two years, ALIN had dropped their RANET coverage for the region. The container and bandwidth costs for the LEWS team to purchase their own RANET coverage is cost prohibitive, therefore RANET is no longer used as a distribution method of LEWS products.

As an alternative distribution strategy, NGO's and government agencies that have email and internet capabilities in the study region were targeted to provide a new means of dissemination to the pastoralist groups. In the case of NGOs, many are already working with pastoral groups in the region and also currently use the LEWS products. Many of these NGO's also serve as Community Information Centers for their target area, so providing LEWS products through this channel provided added services for the NGOs. The LEWS field team worked with the NGO and local governments to develop the product data stream and to gather feedback on format and content as the new products are developed in the coming year.

2.3 Systems Engineering Approach

The NASA LEWS project carried out the tasks of the project following NASA's systems engineering approach. Research activities and accomplishments were documented in three reports in accordance with NASA's guidelines for performance and accountability reporting.

2.3.1 Evaluation Report (E)

This report contains an evaluation of the match between the proposed project requirements of enhancing the LEWS DSS and the available NASA data and modeling tools. Specifically, the report has summarized: the existing LEWS DSS system and the proposed improvements; highlighted the availability and capability of NASA data such as ASTER, SRTM and TRMM and MODIS-VCF; the adequacy of the proposed water balance and stream flow modeling tools; and the use of GPS and RANET technologies to address the needs of the DSS were documented.

2.3.2 Verification and Validation Report (V&V)

The verification and validation report documented the performance of the various NASA data, methods and tools for water resource monitoring and pasture characterization activities of the LEWS DSS, as per the stated objectives of the project. Model sensitivity analysis, field verification, validation techniques and results were included in the report. Transferability of the methods and results to other regions in Africa and other parts of the world with similar needs were investigated. The V&V report also contained a detailed description of any shortcomings in the V&V process.

2.3.3 Benchmarking Report (B)

This report documents impacts and outcomes of the integration of NASA data on the functioning of the LEWS DSS. In this report, we use metrics to quantify improvements in the performance of the LEWS DSS in terms of the DSS goals such as the provision of timely and reliable data on the availability of water resources, to guide livestock migration routes, effective use of pastoral resources, minimization of damage to the environment, and the prevention of conflicts among pastoral communities. In addition, we summarize the transferability of the methods and the results to other regions. The report also contains a detailed description of any shortcomings in the benchmarking process as well as recommendations for continued improvements in the LEWS DSS.

2.4 Purpose of this Benchmarking report

The purpose of this benchmarking report is to document the impacts and outcomes of the integration of NASA Earth Science datasets on the functioning of the LEWS DSS. Several surveys were conducted involving user groups and data was collected to understand the status of the present conditions in the study area. A synthesis of the survey results are provided in this report. Also, a thorough description of the benchmarking activities taken up under this project and also other ongoing activities is given. Data collected as part of user interaction surveys is analyzed and the products of the *Enhanced* LEWS DSS are rated against them.

3. 0 Summary of Systems Engineering Activities

3.1 Summary of DSS evaluation

In the Evaluation report (Senay et al. 2007), the NASA's Earth Science products were evaluated against the enhanced NASA LEWS requirements. ASTER and SRTM were used to characterize water resources and preliminary results presented showed that these data were used for accurately mapping waterholes within the study area. The report also includes discussion and evaluation results of MODIS NDVI and VCF to map forage baseline. The accuracy of the SRTM 90 meter elevation data used in this study was evaluated and found to be adequate for mapping topographic features and suitable for hydrologic modeling. The evaluation report also highlighted the use of TRMM rainfall data merged product (with Infrared imagery from geostationary weather satellite constellation) as it would capture short duration and fast moving storms and the data would be used for near-real time processing and applications. It was observed that, although the positional accuracy of GPS technology is good enough to track seasonal migration patterns of the pastoralists, there could be many logistical challenges to implement this approach. Finally, it was concluded that all NASA's Earth Science inputs selected in this study meet the requirements to build the enhanced LEWS DSS. These datasets were also identified to play a critical role in the execution and continuous operation of the LEWS DSS.

3.2 Design and Implementation

3.2.1 Description of process for integrating NASA input with DSS environment

A detailed explanation of how each NASA earth science data products are used for the proposed enhanced LEWS DSS is given here. This section can be broadly divided into four categories:

3.2.2 Characterizing water resources with ASTER Data

The first step towards building LEWS DSS is the construction of a geo-database of waterholes, within the study area. This information forms the basis for other processes in the DSS. This task was accomplished by applying a classification procedure on ASTER imagery. Schematic representation of the process to build a waterhole database using ASTER imagery is shown in Figure 2. Spectral analysis of Visible and NIR bands yielded waterholes larger than 30 meters in diameter. Red and Infrared bands in ASTER were particularly useful for identifying water bodies. In addition, ground surveys were carried out to validate the satellite based classifications and to acquire further ancillary data. This geo-database consists of a complete list of water resources that are currently being used by pastoral communities. Furthermore, the waterhole database was used to rate waterholes based on important attributes such as volumetric capacity, accessibility, effectiveness, and flood hazards based on the ancillary data gathered during the field surveys.. This database is easy-to-use and is available online so that policy makers and the public from all sectors can use it for decision making.

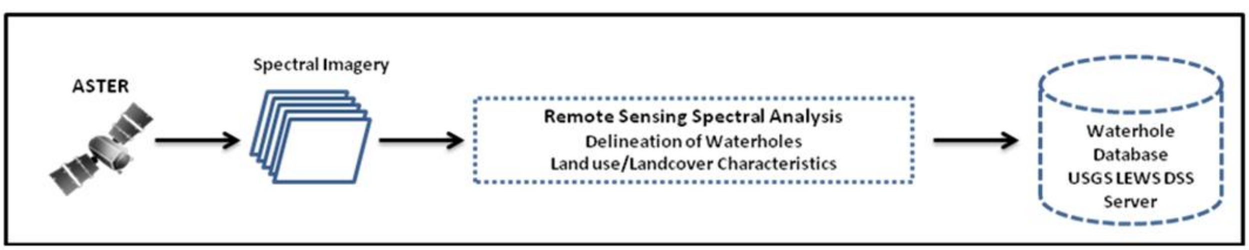

Figure 2. Generation of waterhole database using ASTER imagery

3.2.3 Mapping forage baseline using MODIS VCF

In setting up the forage monitoring model for LEWS DSS, baseline forage cover is determined by a ground sampling approach in which selected sites were visited by LEWS teams to characterize forage classes at the sites. The model is then set up at the sampling sites and modeling results are interpolated to other sites using NDVI data.

The products for this exercise included an up-to-date inventory and description of the pastures adjacent to water resources in the study areas. The geo-database resulting from this one time characterization will enable the condition of both water and forage resources to be evaluated in tandem with the products developed in this study are transitioned for operational guidance of migration activities.

3.2.4 Mapping seasonal migration patterns with GPS technology

A combination of field survey (community interview) and GPS-tracking technology was planned to record movement patterns of pastoralists and their herds in response to changing forage and water supply. However, due to several reasons, GPS technology was not used in understanding the migration patterns. Instead, surveys were conducted with key informants to gather required information. The data would be used to compare patterns of mobility of various communities' and grazing management behaviors vis-à-vis the prevailing forage and water resource conditions. This would provide insights that will allow improvement in the LEWS information flow in the target region. The outcome of this objective would be to develop practical recommendations that pastoral communities and land managers can use to optimally exploit the forage and water resources and improve the productivity in these arid and semi-arid rangelands.

This activity of surveying migration routes yielded a spatially and temporally explicit database of community livestock seasonal mobility patterns. This up-to-date formal delineation of seasonal movement patterns is accurately spatially referenced in a GIS, providing a means to track down how pastoralists utilize the landscape resources at all times. All digital material is accompanied by appropriate metadata. The database and maps would show herd aggregation regions across seasons and ultimately, assist in refining advisories emerging from the LEWS monitoring system with the newly integrated ASTER and TRMM-based water supply monitoring systems. Maps of livestock herd movements were printed out and incorporated into reports that will be handed out to national policy makers and international relief agencies to guide development and relief intervention efforts to pastoralists in these arid lands. This is the first authoritative source and formally documented source of information regarding international cross-border livestock mobility in this region. This database would offer a significantly improved and comprehensive livestock early warning system by yielding data to characterize not only the location and condition of both the forage and water resources used by pastoral communities, but also the relative rates of utilization of these resources.

3.2.5 Monitoring of water resources using TRMM and hydrologic modeling

A new tool that could help monitor the availability and conditions of water resources is vital for decision making by the pastoralists, local and regional decision makers. This is one of the main enhancements proposed to the existing LEWS project. In this module, products that monitor daily water availability were developed for individual waterholes, and daily water level hydrographs for waterholes were monitored. The detailed description of all the processes involved in building a water resources monitoring tool are given in Figure 3. This information on water availability were integrated with the existence of forage conditions product i.e., spatial patterns of forage availability and water resources availability will be provided. Such information will not only be imperative for rapid response to pastoralists needs in times of stress but would also encourage equitable use of resources. These products would therefore lead to a more complete and timely understanding of different dimensions of human conflict arising from competition for limited resources.

3.2.6 Implementation of the project

The project is designed to be implemented in near-real time. The goal of the project is to produce information on forage; water level conditions and other drought forecast information daily (with a day lag) and disseminate the information to the users through the web and e-mail.

To achieve this, several computer programming routines were written. These routines would automatically download all the required data from the internet, pre-process the data and post process the outputs (text files and graphics). Model output is regularly uploaded onto a sever, where internet scripting language would read and display graphs and tables for each waterhole on the NASA LEWS DSS webpage, launched in 2009. [http://watermon.tamu.edu/]

Collaboration with local institutions

Collaboration with several local institutions was made during the NASA LEWS DSS project execution. Of all the collaborations, two institutions played major role. Contributions made by the International Livestock Research Institute (ILRI) in Kenya, and, Oromia Agricultural Research Institute (OARI) in Ethiopia are worth mentioning. Specific contributions made by these institutions are given below.

1. Carrying out baseline survey
2. Collecting information on ground situation within the pastoral areas of the study site
3. Verification and validation of waterholes identified from ASTER imagery
4. Carrying out informant interviews for migration route survey
5. Coordinating user interaction workshop activities
6. Collection of ground truth waterhole water levels data for model validation on weekly basis and,
7. Dissemination of information and mobilizing people from pastoral communities to actively use the NASA LEWS DSS Datasets

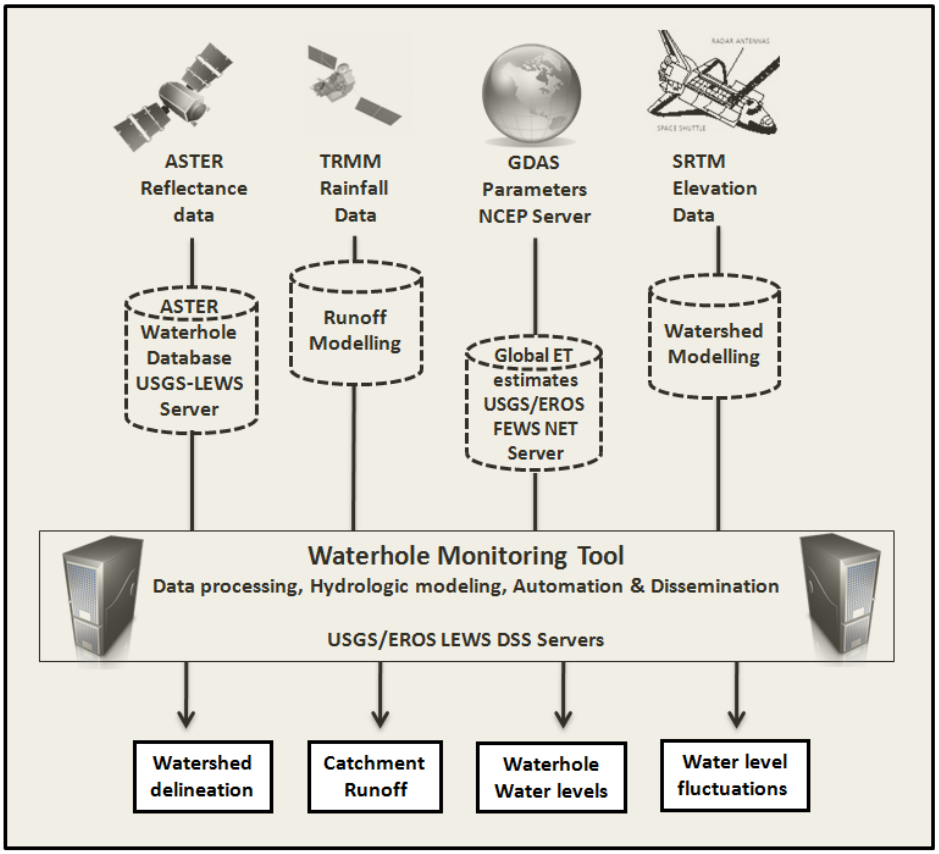

Figure 3. Processes involved in Water Resource monitoring module.

3.3 DSS Verification and Validation

The performance characteristics of the various NASA data, methods and tools for water resource monitoring and pasture characterization were verified and validated against the stated objectives of the project. Model sensitivity analysis, field verification, validation techniques and results were included in the V&V report. The V&V process helped us to not only test the NASA inputs but also served as a tool to increase credibility of the product among the stakeholders. The entire V&V process was explained in Senay et al (2008).

4.0 Benchmarking

4.1 Overview of existing conditions prior to NASA LEWS

A baseline review of LEWS DSS was conducted in 2008 covering selected LEWS monitoring and some areas targeted for development of water monitoring resources through the NASA/LEWS project initiated in 2006. The purpose of the review was to provide a benchmark against which to measure future improvements in the scope and effectiveness of the LEWS decision support system when water resources monitoring and herd migration tools are added to the existing forage monitoring products and assess the usefulness and usability of the products to mitigate the effects of drought in the Greater Horn of Africa region. The information was to help the LINKS (Livestock Information Network and Knowledge System) project to offer better support to the national and regional implementations of the NASA LEWS. The survey findings were used to document service improvements/changes to the LEWS decision support system.

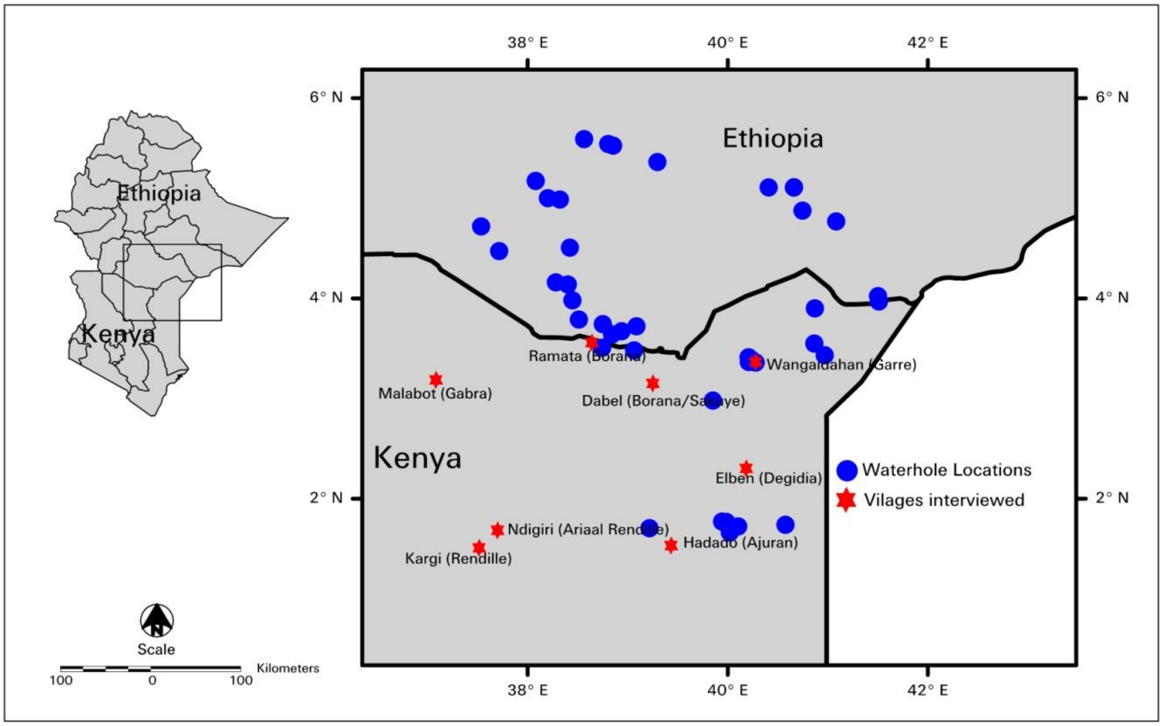

Figure 4. Spatial distribution of villages interviewed (red stars) and waterholes monitored (blue circles). Names of each ethnic tribe in each village are shown in brackets. Two sites (Bubisa and Olla) are not shown in figure as their coordinate information was unknown.

The review was based on a group approach where group interviews were conducted with a total of 10 (Dabel, Wangaidahan, Ramata, Ndigiri, Kargi, Malabot, Bubisa, Hadado, Elben and Olla) sites covered in 6 districts (Marsabit, Moyale, Wajir Central, Wajir East, Mandera Central, and Mandera West) within 2 (Eastern and Northeastern) provinces of Kenya involving eight different ethnic groups and clans with the latter being found among the larger Somali ethnic community. On average 14-15 people were present in each community while the information was collected. In three sites (Dabel, North Horr and Olla) had female representation with 3 women in Dabel, one each in North Horr and Olla.

4.1.1 Findings from Group interviews:

The findings during the baseline survey were documented to understand the ground situation prevailing in the NASA LEWS study areas. Several problems were documented during the one-to-one community based surveys. The review was focused on a range of questions including questions on the availability and non-availability of water, pasture, incidence of disease, livestock marketing, insecurity, conflict and land tenure problems; livestock movement, factors influencing decisions to migrate, sources of information on suitability of grazing areas, indicators used to aid decision making, knowledge on livestock early warning system, and dissemination of information. Hotspots for each problem were identified. Out of all the problems identified, the most serious and common problems were:

Shortage of Forage:
Shortage of Forage was the most serious problems identified in this region. Shortage of forage was ranked as very serious in eight sites (Dabel, Ramata, Ndigiri, Kargi, Malabot, Bubisa, Elben and Olla) and serious in 2 sites (Wangaidahan and Hadado).

Shortage of water for livestock and pastoral communities:
Besides forage, water is the second most important input for pastoralists' livelihood. Because livestock have clear limits on their ability to exist without drinking and pastoralists are mobile, they react to changing water supplies as well as forage conditions. Therefore, adequacy of water supply to meet water needs of livestock and the people determines how far livestock can forage from a watering point and hence the total area that can be used, even if forage conditions just outside that area are sufficient to sustain the animals. If water sources are drying up over large areas, pastoralists have a problem and their livelihood will become more vulnerable. Shortage of water was reported to be very serious in all sites except Malabot where people said that there were many shallow wells at the edges of the Chalbi desert which provided reliable source of water.

Other major issues:
Among the several other issues, social insecurity due to resource-based conflicts and to a lesser extent storm floods concerns were raised in several regions with in the study site.

NASA LEWS DSS project is one of the first organized initiatives with the plan to address the concerns of the pastoralists using a remote monitoring system. The dissemination of forage availability using NASA technologies would help pastoral communities to reduce the problem of identifying locations of forage availability. The dissemination of water availability information would help the pastoral communities to make better decisions based on the water available in each waterhole.

4.1.2 Existing method of monitoring forage and water:

There are no existing methods in place that monitor water and forage within the pastoral areas of East Africa. Pastoral communities in this region live in extremely fragile environments where natural disasters and crisis are common phenomena. Pastoral communities have traditionally relied on historical memory, cloud behavior at given times of the year, atmospheric effects on star brightness, and behavior of plants and animals to develop coping strategies for such crisis situations. Most of the time, when such situations arise, these communities migrate from one place to another in search of forage and water. Recently, as different communities compete for the same resources, insecurity has become a major problem with loss of property and life becoming common due to conflicts over limited resources.

More recently apart from the traditional approaches, most of the pastoral communities have been using scouts to locate forage and water. Specially trained people are employed who venture out to new lands in search of forage and water. However, these scouts are always at risk as they venture into unknown lands in search of forage and water.

Due to lack of resources and funding, the NGOs and local government agencies working in the pastoral areas rely on the historic knowledge and information gathered from the regional surveys for planning and decision making. Often, these agencies have difficulty in surveying these pastoral areas due to intensified conflicts between different pastoral communities.

Traditional methods of gathering information are sometimes inaccurate, time consuming and costly. There is also a great deal of risk in gathering such information. Furthermore, information gathered from the scouts representing competing pastoral groups is not reliable.

4.2 Overview of operational environment

Operational component of the LEWS DSS has two main components.

- Dissemination of Water availability in waterholes through watermon webpage (http://watermon.tamu.edu/)
- Dissemination of Forage availability through CNRIT webpage (http://cnrit.tamu.edu/).

Water monitoring (Watermon) Website:
The major output from this project is the water monitoring website (http://watermon.tamu.edu/). This webpage offers users the ability to monitor waterholes in near real time. The site provides the current status of water levels for each waterhole (daily depth variation information) which would enable pastoral communities/NGOs/decision makers to make appropriate decisions.

The water monitoring website was launched in the summer of 2009. Initially, sixteen representative waterholes in the region (Figure. 5) were operationally monitored (8 in Kenya and 8 in Ethiopia) for variations in waterhole depths. After thorough validation of the modeled water levels, since May 2010, the total number of waterholes monitored was increased to 41. Since then waterhole water level fluctuations data is being made available for 41 waterholes (16 in Kenya and 25 in Ethiopia are being monitored. Users can also download historic waterhole depth information from the year 1998. Depending on the internet connection speed, two online versions of the waterhole monitoring project are available for site visitors. The low bandwidth version of the site offers the data for optimal browsing where the data and water levels are displayed using basic graphing options. A high bandwidth site offers better graphics and graphing options for the users who have high speed internet connection.

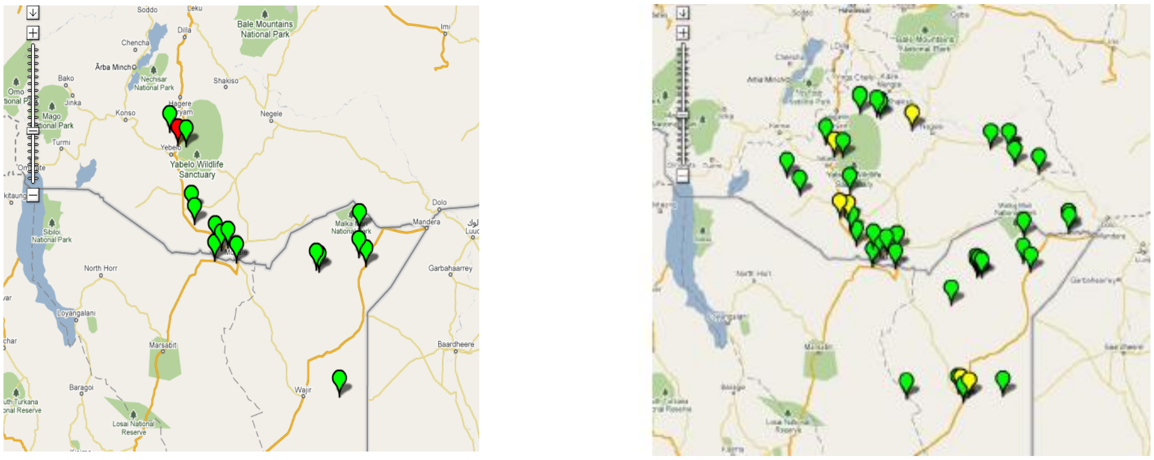

Figure 5. Map of waterholes monitored under the LEWS DSS project (a, left) Phase-I (Jan 2008 - April 2010): 16 waterholes – 8 in Kenya and 8 in Ethiopia (b, right) Phase-II (May 2010 – Present): 41 waterholes 16 in Kenya and 25 in Ethiopia. The color denotes the condition of the waterhole. **Red** means Alert; **Yellow** means Watch and **Green** mean Good condition.

Waterhole water level information: For each waterhole monitored, users can click on the balloon shown in the Figure 5 to access water level information. Daily variations in data on three variables (a) waterhole water levels (b) rainfall distribution (c) evapotranspiration are made available for each waterhole. Figure 6 below shows the plot of data provided for a waterhole in the study area.

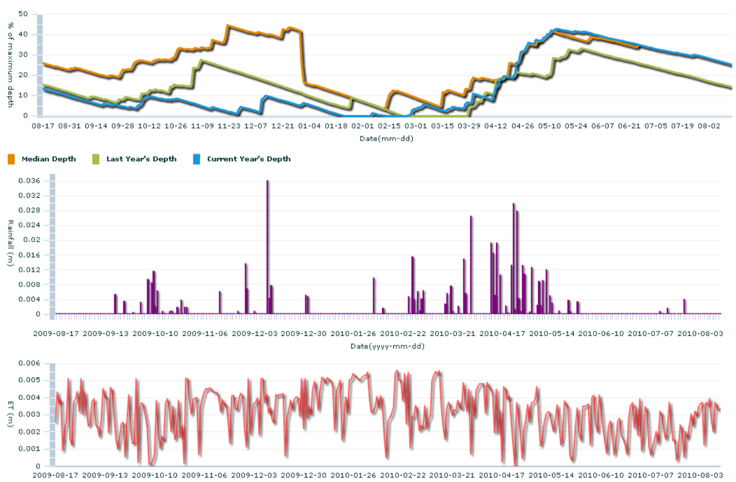

Figure 6 Date available for waterhole ETH-34. Top: Waterhole water level variations Middle: Rainfall distribution; Bottom: Evaporation (ET)

4.3 Benchmarking Activities

4.2.1 Planning & Design

Prior to LEWS DSS, there was no organized existing method on the availability of forage and water resources to the pastoral communities of Ethiopia/Kenya. During dry seasons, nomadic communities migrate in search of forage and water. Such migrations are often based on the historic knowledge of locations where forage and water would be available. However, due to presence of limited number of such locations, often several communities from different locations reach same location leading to conflicts and ultimately loss of property and life. LEWS DSS was aimed at improving this situation. Now, the information on the availability of forage and water provided by the NGOs/decision makers to the pastoral groups, help them to make proper migratory decisions. Such decisions, based on the data made available from LEWS DSS are aimed at minimizing conflicts to save lives and property.

4.2.2 Description of methods and metrics used

As virtually nothing existed prior to the development of the LEWS DSS products, it was challenging to find a gauge to benchmark them.

The main benchmark metrics used were:

1. NASA LEWS DSS workshops
2. Feedback from NGOs, local/regional point of contacts.
3. Watermon webpage statistics.

4.4 Benchmarking Activities: NASA LEWS DSS Workshops

Two workshops were conducted in Nairobi, Kenya and Addis Ababa, Ethiopia during March, 2010. Kenyan workshop was held on March 24-25, 2010 in Nairobi whereas, Ethiopian workshop was held on March 29-30, 2010. The purposes of these workshops were: (a) to showcase the NASA LEWS DSS products to the stakeholders in the region (b) to gather feedback from the user communities (c) conduct benchmark survey. Several participants attended these workshops comprising stakeholders from the Governmental organizations, NGOs and international institutions working with the pastoralists groups (Figure 7). NASA LEWS DSS products were introduced to the stakeholders and the participants had a chance to play with the waterhole monitoring website and products during the hands-on-session in the workshop.

The first workshop, held in Nairobi Kenya at the Jacaranda Hotel, had 19 participants in attendance. The second workshop was held in Addis Ababa, Ethiopia on the International Livestock Research Institute campus where 31 individuals participated. These participants represented a range of institutions (attendee lists for both workshops are attached). Topics of discussion included an introduction to NASA technologies available to identify waterholes (surface water resources) in semi-arid east Africa using remotely sensed data and imagery, and an introduction and demonstration of a simulation model designed for processing this

Figure 7. Participants at the NASA LEWS DSS Workshops. Top - workshop @ Nairobi, Kenya (March 24-25th, 2010); Bottom - workshop @ Addis Ababa (March 29-30th, 2010).

information into a user friendly format. The hands-on demonstration of the Water Monitoring website online demonstration was enthusiastically received by all participants in both workshops and generated many discussions about how it could be adapted to fill specific needs for various projects. The consensus was that this was a very good product with many applications ranging from livestock movement and livelihood improvement to conflict zone mitigation efforts.

Feedback from participants included their observations of major strengths and weaknesses of the proposed Livestock Vulnerability Index (LVI) systems and suggestions for improving the concept. These major points were:

Strengths:

- The LVI would provide a "one-stop" shopping portal for early warning information related to livestock and livelihoods that rely on livestock
- Combined several key data sources to provide better and integrated early warning information
- Near-real time information for decision makers
- Presentation of waterhole water level information is simple and easy to use/understand
- Ability to model trends in waterholes and range vegetation through time
- Provides a tool to monitor effects of with climate change, land use and degradation
- Relevancy for the pastoralists- final users
- Important to involve users in consultations and collective decision-making potential to inform trans-boundary issues on trade and animal health

Weakness:

- The need to include borehole and well monitoring
- Need to increase coverage area to include more waterholes; expansion to other pastoral areas
- Concern that small waterholes are not captured
- Need to assess or account for water volume at waterholes
- Need to improve the vegetative cover to maintain livestock and link to status of the water points
- Need to work on dissemination so as to maximize the utility of the DSS
- The need develop capacity to forecast water conditions at least one month into future
- Literacy among pastoralists and lack of access will reduce its use
- Need to get input of private sector or other stakeholders

4.5 Benchmarking Activities: NASA LEWS DSS Benchmark Survey results

Benchmarking is intended to measure changes in effectiveness of the DSS in response to adoption of NASA enhancements. Benchmarking is a tool to evaluate the 'Use' and 'Usability' of the DSS, before and after implementation. More simply stated, benchmarking provides a measure of the changes between a baseline and current performance to gauge the impact of the NASA enhancements with the resulting impacts and outcomes documented in a benchmark Report. Benchmarking was performed separately on the (a) forage monitoring system and (b) water monitoring system.

4.5.1 Benchmarking for the Forage Monitoring System

Benchmark surveys were established to addresses the utility of LEWS-DSS as an information tool for monitoring resource conditions and mitigating for drought. The purpose of the surveys were to evaluate the usefulness or value of the information provided by the LEWS-DSS for decision making with regard to livestock grazing management and mitigating for drought, and suggested improvements. Unfortunately, several extant factors affected the operation of the system during 2009 and early 2010 which affected the delivery of the early warning products in a timely manner. These factors include the ending of funding for the Global Livestock Collaborative Research and Support Programs in June 2009 and the subsequent changeover in personnel and institutionalization of the system. In 2010, the problem with the scan motor on the NOAA-17 satellite, suspension of AVHRR-NDVI image production, and the long delay in resuming production of AVHRR NDVI from NOAA-18 has limited the ability to produce regional forage maps which also hindered system operations. Therefore it was expected that stakeholder might be limited.

The first survey was administered on-line in April 2008 with the follow-up survey being available in July 2010. For each survey, stakeholders in Kenya and Ethiopia were notified via email that the survey was being conducted and instructions were provided on how to access the system. Stakeholders were reminded again after the initial email. Twenty-seven stakeholders took part in the initial survey, whereas only 10 participants were recorded for the follow-up survey. Unfortunately, many survey questions were either only partially answered or skipped all together during the process of completing both surveys, and more so for the second effort. Therefore, statistical analysis of the survey data was not practical. However, generalizations about the data received are made and summarized below.

Usefulness or Value of the LEWS Forage Products:
Respondents in 2008 indicated universally (100%) that the LEWS-forage monitoring products were valuable to their decision-making process; this was also supported by a 100 percent positive response rate by respondents in 2010. When asked to rate whether the forage conditions products (i.e., current and historic forage conditions, and forage forecasts, etc.) that are provided by the LEWS-DSS were valuable for decision making regarding where to graze animals or to sell livestock when shortage of forage is predicted, respondents indicated that this information was valuable or somewhat valuable for all products provided (Figure 1). This finding was supported by results of the follow-up survey administered in 2010 (Figure 9).

Regarding increased confidence in decision making due to the information provided by LEWS, 50 percent of respondents' indicated that this data increased their confidence in the decisions they make "greatly" and the remaining 50 percent indicated that their confidence was increased "moderately". Findings of the 2010 follow-up survey indicated a slight increase in confidence (60 percent "greatly" and 40 percent "moderately", respectively) due to information provided by LEWS.

Likewise, when ranking the value of data related to water resources, respondents ranked this information as valuable to very valuable to their decision-making. The one exception to this trend was regarding runoff amounts and flood hazard data, where informants ranked these data as only moderately valuable. Furthermore, when asked if the addition of data/information related to water resources monitoring would improve the LEWS product the majority of respondents indicated that this information would either "greatly" or "moderately" improve the forage condition data provided. Current surface water availability, historic water availability, rainfall data, and historic evapotranspiration data were all indicated to be a valuable asset to them. Respondents to the 2010 follow-up survey provided support for this by indicating that the addition of information pertaining to surface water availability and water related information was very useful to somewhat useful to their decision making, strategy development, and planning.

As a herd migration management tool, 50 percent or more of respondents indicated that the additional water related data helps to reduce overgrazing and land degradation, to reduce potential for conflicts over resources, and improves their confidence in making resource management decisions (Figure 10). The findings of the 2010 follow-up survey corroborate this finding.

Generally, respondents indicated that they would like to continue receiving the LEWS forage condition data at the prescribed time intervals (i.e., monthly reports for the current condition reports, every 3 months for forecast data, etc.) currently in effect. The preferred format for receiving this data is via radio broadcasts, written materials (monthly reports, flyers, briefs etc.) and to a lesser degree, oral communication to the individual or through the Chiefs of the communities.

Improvements:
Survey respondent provided suggestions on ways to improve the system that included:

- Linking the LEWS-DSS web-site to other providers of early warning systems information (i.e., FEWSNET, Arid Lands Resource Management Project, etc.)
- Make the information more readily available/accessible to pastoralist communities at the village level
- Make maps a selectable download item so that those with limited computing or internet capacity can choose which ones they want/need to speed up download processing times
- Encourage openness among the livestock sector actors to promote use of the product
- Provide training or "short courses on data collection, analysis and also monitoring and evaluation."
- Include discussions or evaluations of the contributions of trees/shrub to the forage base. Specifically, on the invasion of *Prosopis juliflora* and how this species contributes or not to the forage base especially during periods of drought.

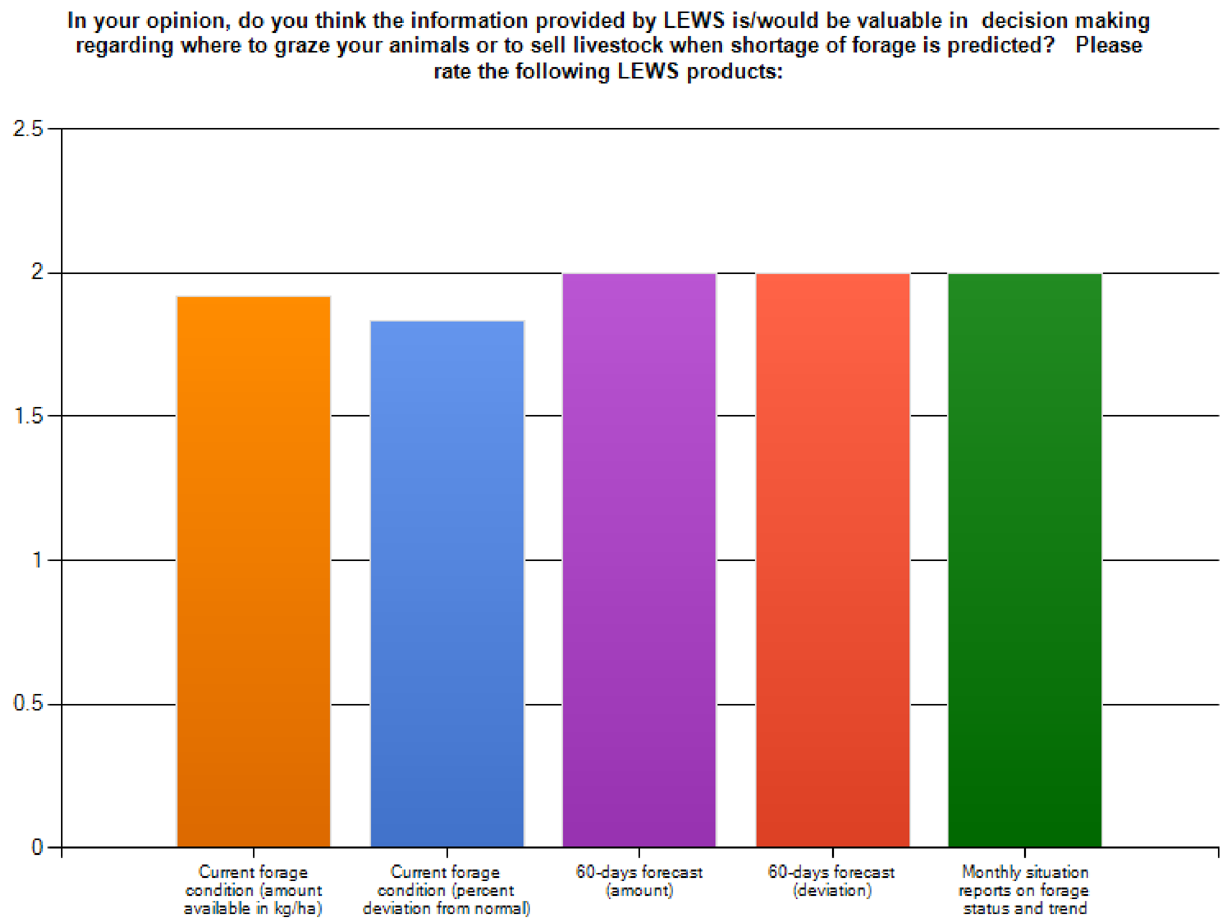

Figure 8. Summary Chart indicating Rank of Value of Each Product Indicated to Respondents Decision Making. The Rank Values are as follows: 2 = “Valuable”, 1 = “Somewhat Valuable” and 0 = “Not Applicable”. Derived from the Initial on-line Survey Administered (http://www.surveymonkey.com/) in 2008.

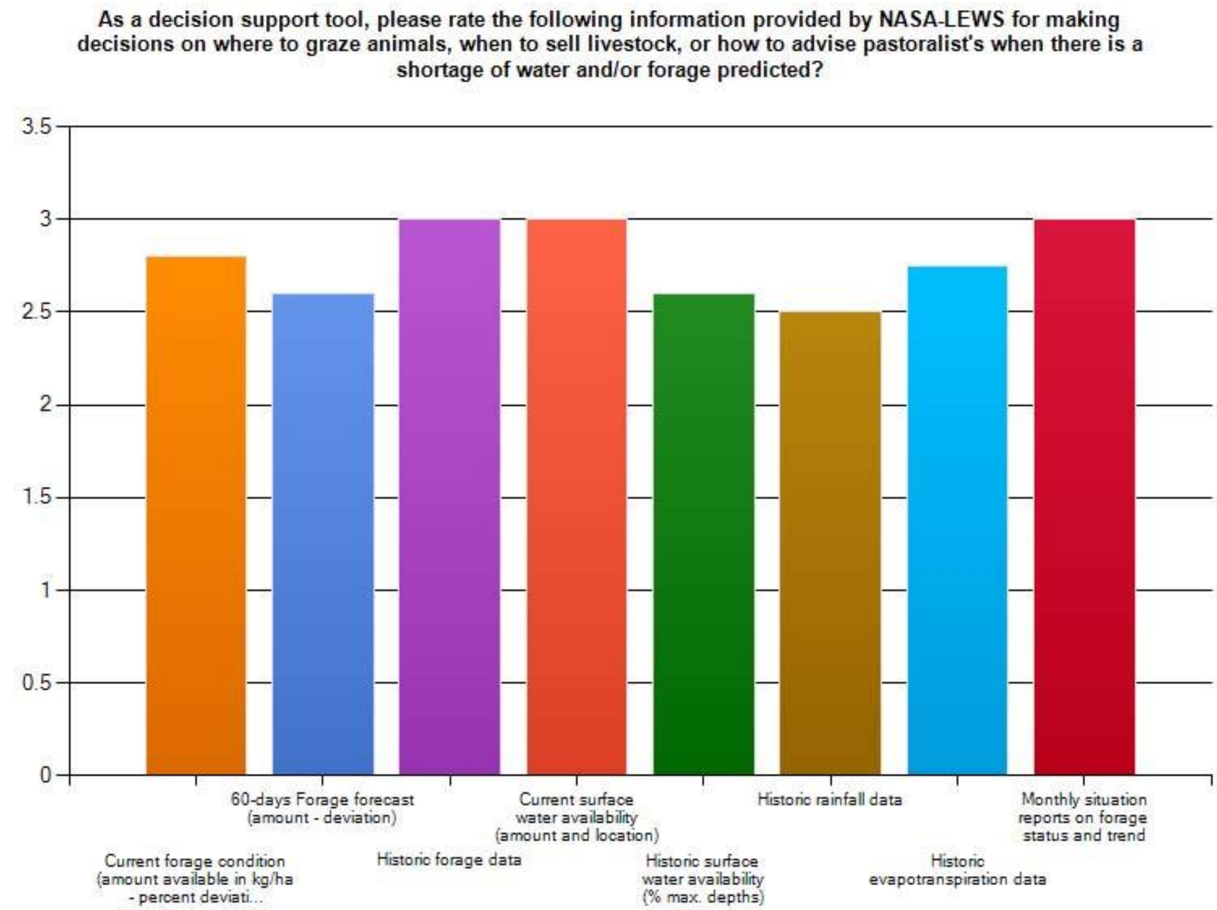

Figure 9. Summary Chart indicating Respondents Ranking of the Value of LEWS Forage Condition Information. Derived from the Follow-up Survey Administered on-line (http://www.surveymonkey.com/) in 2010. Rank Values are as follows: 3 = "Valuable", 2 = "Somewhat Valuable" and 3 = "Not Valuable" to their Decision Making.

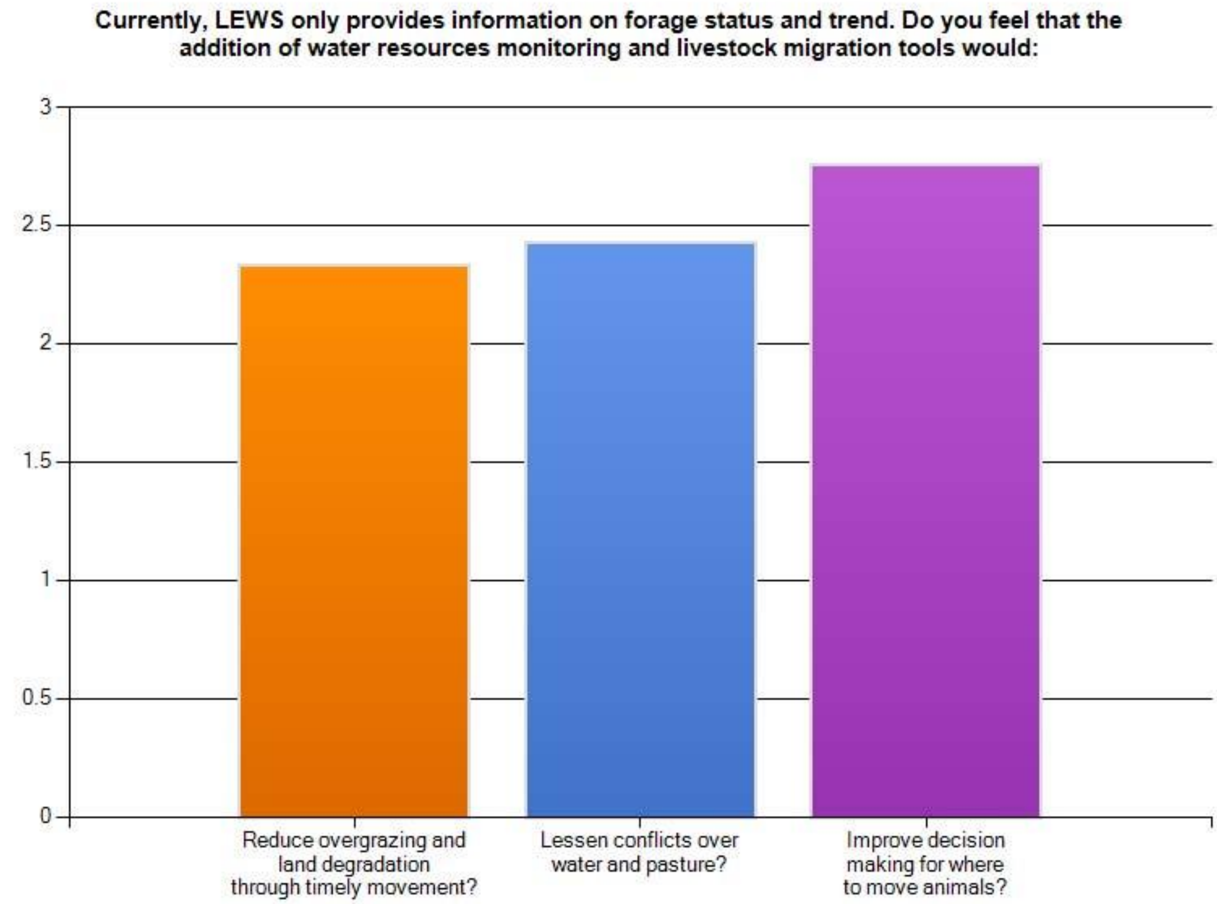

Figure 10. Effect of Adding Information on Water Resources to the LEWS Forage Condition Database provided by LEWS-DSS. Derived from the Initial Survey Administered on-line (http://www.surveymonkey.com/) in 2008. Rank Values are as follows: 3 = "Greatly", 2 = "Moderately", and 3 = "No Effect" on each Factor Indicated.

4.5.2 Benchmarking for the Water Monitoring System

One of the main agenda of the workshop was to conduct benchmark survey. The benchmark survey was conducted using four questionnaires that focused on 1) the usefulness of the Waterhole Monitoring for livestock early warning, 2) the waterhole monitoring product, 3) on the performance of the waterhole monitoring website, and 4) on evaluating the improved-performance of the project compared to existing methods. The questionnaires can be found in Appendix A-D Answers for these questions were graded into different classes from not at all useful to extremely useful by the responders. Composite results for questions under this category for Kenya and Ethiopia are presented here.

1. **How useful is the NASA LEWS water monitoring system in general?**

In order to get feedback regarding the overall usefulness of the NASA LEWS water monitoring products, a series of questions were asked ranging from the usefulness of NASA LEWS water monitoring system for monitoring in local to national water resources monitoring and planning, in drought contingency planning, conflict resolution, in regional cattle market prices etc.

In Ethiopia, **94%** of the respondents felt that the water monitoring system was "useful to very useful" but **6%** of the respondents felt that the water monitoring system was "sometimes useful". On the other hand in Kenya, **89%** of the respondents felt that the water monitoring system was "useful to very useful" and **11%** of the respondents felt that the water monitoring system was only "sometimes useful". When both were combined, **91%** of the respondents felt that the water monitoring system was "useful to very useful" and **9%** of the respondents felt that the water monitoring system was only "sometimes useful" (see Figure 11)

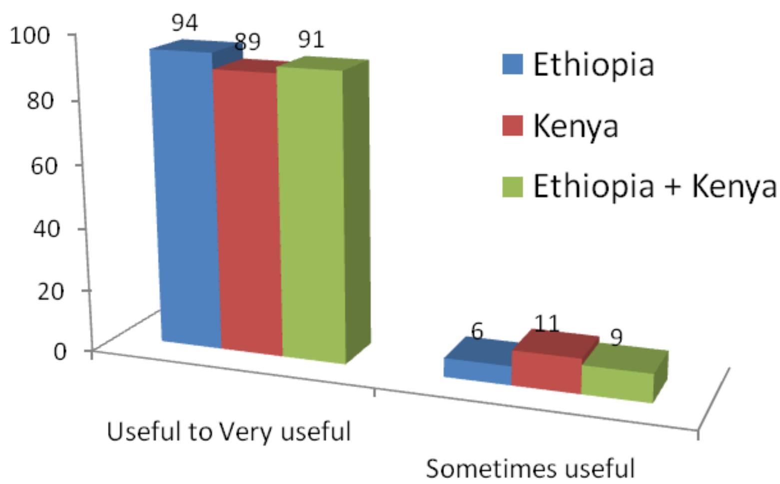

Figure 11. User responses showing the overall usefulness of the NASA LEWS DSS system.

2. **Does the NASA LEWS DSS meet the user requirement and help in decision making process?**

In Ethiopia, **88%** of the respondents felt that the water monitoring system *fully meets the needs of the pastoralists and helps in decision making process* and **12%** felt that the water monitoring system meets the needs of pastoralists and helps in decision making *to little extent only*. Whereas, in Kenya, **87%** of the respondents felt that the water monitoring system *fully meets the needs of the pastoralists and helps in decision making process* and **13%** felt that the water monitoring system meets the needs of pastoralists in decision making process *to little extent only*. Together, **87%** of the respondents felt that the water monitoring system meets the needs of the pastoralists in decision making process and **13%** felt that the water monitoring system is helpful in decision making to little extent only (see Figure 12)

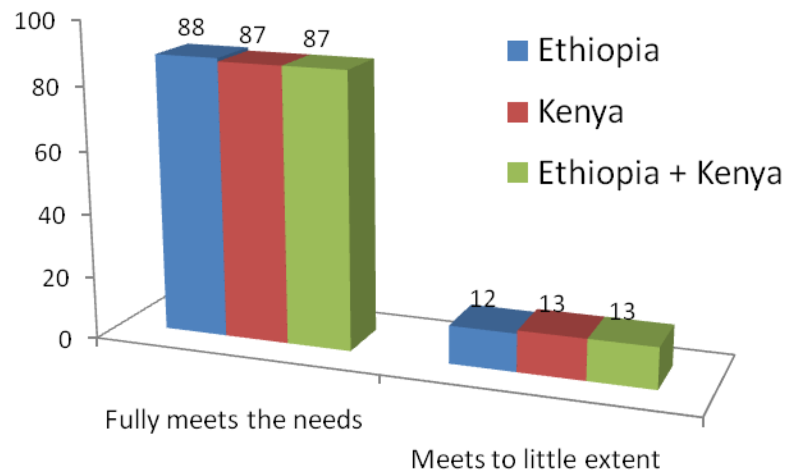

Figure 12. Responses showing the usefulness of the NASA LEWS DSS system in decision making.

3. How is the performance of the water monitoring system website?

With in Ethiopia, **66%** of the participants strongly believed that the watermon website performance was great or had no issues with the website and **18%** of the respondents had issues with loading the website (issues with internet speed). However, 15% of the respondents did not have any comments on the website. In Kenya, **76%** strongly believed that the watermon website performance was great; **14%** had no comments on the website and **10%** of the respondents had issues to load the website (with internet speed). Together, **2%** strongly believed that the watermon website performance was great in Ethiopia and Kenya; **14%** had no comments on the website and **13%** of the respondents had issues to load the website (with internet speed).

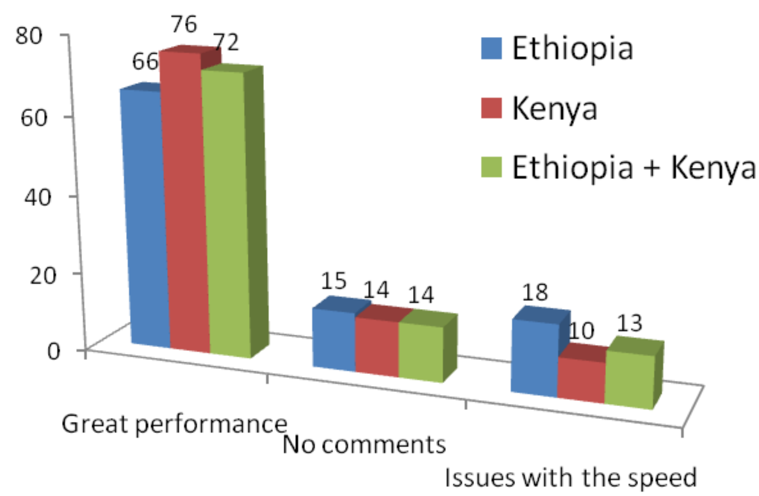

Figure 13. User response showing the performance of the water monitoring website.

4. **How do you compare NASA LEWS water monitoring system over existing methods**?

In Ethiopia, **88%** of the respondents felt that watermon system was more advantageous over the existing methods. **3%** felt it still needs improvement and **9%** did not have any comments. Whereas in Kenya, **91%** of the respondents felt that watermon system was more advantageous over the existing methods. **2%** felt it still needs improvement and **7%** did not have any comments. Together, **90%** of the respondents felt that watermon system was more advantageous over the existing methods; whereas, **2%** felt it still needs improvement and **8%** did not have any comment (see Figure 14).

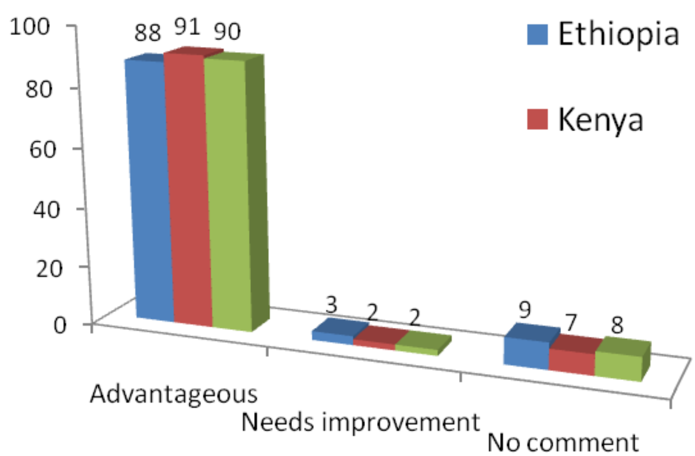

Figure 14. User responses showing the usefulness of NASA LEWS water monitoring system over existing methods.

4.6 Benchmarking Activities: User's/Stakeholder's Feedback

There are numerous examples of NASA LEWS feedback from scientist, researchers, and environmental authorities from NGO and government sectors. Below are the documented examples that demonstrate the utility of NASA LEWS products and its application in the region.

The following letter is from Wondu Fisseha, Operation manger, CARE International, Ethiopia office.

To
Gabriel Senay,
PI, NASA LEWS DSS
USGS EROS, Sioux Falls, SD

Dear Gabriel

.... I was travailing for the last two months to Borana field office and out of country to other GWI-Regional program partner project areas to make technical assessment on reported flood problem occurred in Borana zone and to participate at Global GWI- technical coordination meeting in Tanzania respectively.

One thing which I like to inform you today is we have already started utilizing the product of your Water resource monitoring website data base information to assess reported higher flood occurrences in Borana zone. We were able to get information on the trend of the rainfall amount and increase in water pans depth from information presented on your water resource monitoring website. I has supported us to analysis and describe the intensity of rain fall amount and locations affected by reported water pans and wells damaged due to higher flood occurred in the month April. We have also shared other program units to access your website to get clear understanding on the trend of rainfall amount to justify for reported high flood occurrence in the area so that they were able to plan for appropriate response.

If it is helpful for you to update yourself on the situation of reported higher flood occurrence and damage on water pans, please refer to a report that I send attached herewith that was submitted by Borana Zone Emergency task force.

I am also working on different opportunities on how to make a maximum use of your project product to support our water resource development program in the area. in this regard, I have been compiling GPS coordinate of some water pans and water walls that are I identified to be developed by GWI-program, I have a plan to communicate with you for the possibility of including these water points to be included as additional water points to be monitored through your project. I will send what I intended to do in this regard shortly.

I wish you all the best

Wondu Fisseha, Operation Manager, CARE, Ethiopia

The following is an email received from the food security analyst at the FEWSNET Ethiopia office following the workshop conducted in Addis Ababa, Ethiopia

Dear All,

It has been very interesting workshop that raised the expectation of most of us that work in Early Warning Systems. The combinations of the data that you presented seems to be requiring updates of the existing sites, additional sites for monitoring with refinement and packaging of the products for better accuracy. These will require you to provide more training to potential partners for renewed buy in from former clients that were discontented by LEWS products.

It is a good beginning for you and please keeps us updated on progress and we are looking forward in using your products.

With Regards
Abdirahman Ali Issack
Food Security Analyst,
FEWSNET, Ethiopia

The following is an email received from the food security analyst at the Pastoral Community Development Project (PCDP) Ethiopia office following the workshop conducted in Addis Ababa, Ethiopia.

Dear All

I am one of the NASA/LEWS workshop participants conducted in Addis Ababa.

I Hope what you have done will contribute to the existing early warning system in Ethiopia. I am taring to take it forward with the help of our project (Pastoral Community Development Project) to the extent possible and let you know the progress too.

Keep in touch

Mesfin Arega
Ministry of Federal Affairs
Pastoral Risk Management Senior Officer
Pastoral Community Development Project (PCDP)
Addis Ababa
Ethiopia

4.7 Benchmarking Activities: Watermon Website statistics

Using the Google Analytics - a free web server log file analysis program available online - web statistics for the NASA LEWS DSS sites were acquired for both the NASA LEWS water monitoring site and the NASA LEWS Forage monitoring site. Web statistics were not collected for the NASA LEWS Water monitoring site prior to June 2010, because the data dissemination for this product was principally through direct contacts with NGOs and government agencies.

Figure 15 summarizes the NASA LEWS DSS unique visitors during the period of June 01, 2010 and August 30, 2010. There were 170 unique visitors during this period and there were a total of 516 visits with 797 page views. On average each visitor viewed 1.51 pages per visit with a bounce rate of 72.31 percent. On average the time spent on the website per each visit is 1:52 minutes per visit.

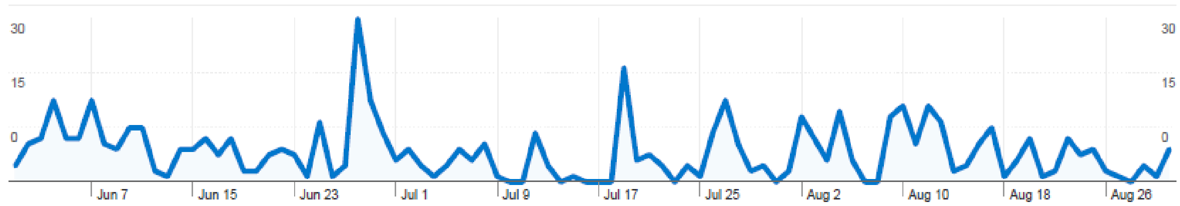

Figure 15. Graph showing unique visitors visiting watermon website between June 1st 2010 and August 30th, 2010.

Since June 1st, 2010 watermon webpage has been visited by several people round the world. Highest number of visitors were seen from the USA. This is quite obvious due to high usage of internet. A total of 24 and 18 people visited watermon website from Kenya and Ethiopia. This is quite low in a period of two and half months' time period. Most of the traffic from Kenya and Ethiopia is from the NGO's and Government agencies that have internet access in the region. However, lack of access to computers and internet to most stakeholders is the main reason for low the traffic from the countries of study region. Further, it is to be noted that the target groups are NGOs and other government agencies working in the rural areas where even access to electricity is a problem.

It is believed that the traffic from Kenya and Ethiopia would improve in future. It can also be seen from the Table 2 that there is some amount of traffic coming from other developing and developed countries.

Table 2. Geographical distribution of the watermon webpage visitors during June 1st, 2010 and Aug 30th, 2010.

Country	Visits	Pages/Visit	Avg. Time/Visit	% new visit
United States	434	1.53	0:01:55	22.98%
Kenya	25	2.05	0:04:19	72.73%
India	19	1.06	0:00:55	83.33%
Ethiopia	18	1.64	0:01:05	73.33%
United Kingdom	9	2.33	0:00:32	77.78%
South Africa	3	1	0:00:40	100.00%
Philippines	2	1	0:00:28	100.00%
Hong Kong	2	1	0:00:48	100.00%
Germany	1	1	0:01:34	100.00%
Mali	1	2	0:01:39	100.00%
Belgium	1	3	0:01:07	100.00%

However, it is important to note that NASA LEWS products are developed for a highly focused user group and web hits would be apparently very low compared to other NASA web pages.

4.8 Findings from the migration survey

One of the objectives of the NASA LEWS DSS project was to perform migratory route survey to study the movement patterns of pastoralists and their livestock herds in response to changing forage and water supply needs in the study area using GPS technology. However, due to difficulties in training pastoralists in the use of GPS technologies and with managing the GPS units (data downloads, batteries, etc.), this approach was abandoned. Instead, information on the migration was gathered through interviews with strategically located key informants who were representative of the major pastoral communities in each of the countries.

Under this activity, we set out to determine the movement patterns of pastoralists and their livestock herds in response to changing forage and water supply. Our findings provide valuable insights to compare various communities' mobility and grazing management behaviors and provided insights into the decision processes of pastoralist (Figure 16). The addition of these insights will improve the quality of information produced by the Water Monitoring and LEWS products and facilitate a more effective early warning system for pastoral communities.

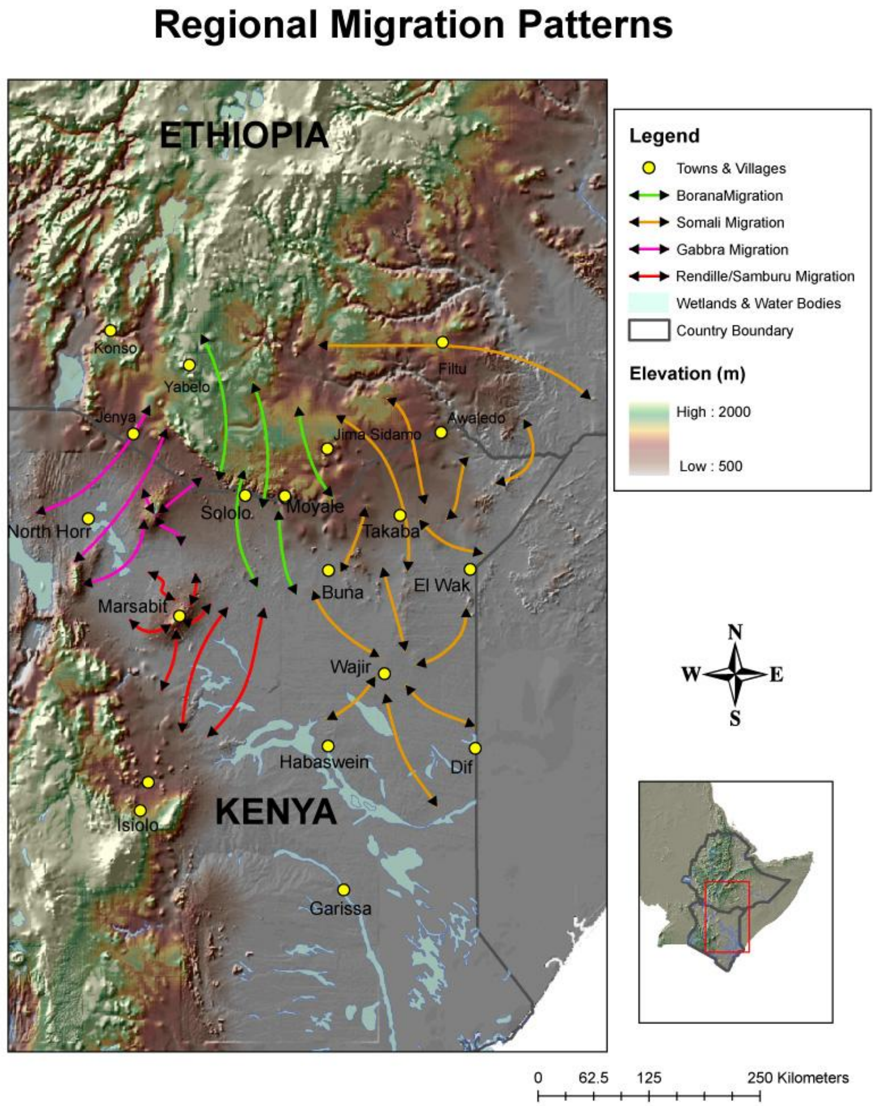

Figure 16. Illustration of Regional Livestock Movements in the Arid and Semi-Arid Rangelands of northern Kenya and southern Ethiopia

Broadly, it was indicated by the people and groups interviewed that weather patterns and biophysical feature are the key drivers of livestock movements throughout the study area. Migration patterns can be generally described as the movement of animals from lower elevations during the rainy seasons to higher elevations during the drier seasons. Lowland range may produce excellent quality and quantity of forage but the reliability of surface water resources is a limiting factor. Conversely, rangelands at higher elevations tend to receive higher rainfall amounts, have a higher probability of adequate surface water resources, and produce forage over longer periods of time. In essence, pastoralists take advantage of elevation differences in rainfall, surface water availability, and forage production and to spread the impact of grazing over larger areas both temporally and spatially, giving them a degree of wealth and food security. Of course there are exceptions to this generalization which may be explained by local conditions and constraints.

In all regions, management of migrating livestock herds are almost universally shaped by the warra/forra herd management system, whereby herds are divided into a home bound warra herd and a migratory forra herd. The timing and distance of the movement of animals is dictated by the availability of water first, and by forage second. Since both water and forage resources are heavily dependent on seasonal weather patterns, which can vary greatly locally and regionally, these resources are typically unevenly available over large areas making the size and direction and distance forra herds are moved difficult to define.

Under the NASA LEWS DSS project, information on the migratory patterns of the pastoralists has been collected that has never been published before. Figure 16 shows the migration patterns of major pastoral communities within the study site. Such comprehensive information on the migratory patterns within the study site has never been made and thus this information will be published in the peer-review journal.

4.9 Operational monitoring and continuity into future

The operational model for the waterhole monitoring is setup so it can run without any human intervention. When initiated with a standard computer-scheduler, the script connects to internet, downloads all the required inputs from the web on near-real time (TRMM rainfall, modeled ET) and runs the model to derive waterhole water levels for each day. The same script writes the output to the ftp server, from where it will feed the water monitoring website web server and finally the waterhole water level information is updated on the water monitoring website in near-real time. The web server is hosted in the Texas A&M University at Temple Texas campus on a dedicated server for the NASA LEWS DSS project. Facilities to run the server into future are already been provided by the project and hence the NASA LEWS DSS – water monitoring website will run uninterruptedly into future with minimal human interference that may be needed when input data-stream is interrupted or server is shutdown for maintenance.

However, efforts are still ongoing to identify local host institutions in Kenya who can take over the project execution and data dissemination activities. Ministry of Livestock Development, Kenya and PCDP, Ministry of Federal Affairs, Ethiopia have already expressed interest to take over this project.

5.0 Benchmarking Gaps

The benchmarking process for NASA LEWS DSS products is challenging in the sense that almost nothing existed before the project. Therefore, we have had to rely on metrics such as those described earlier. It is clear from the communication and response from NGOs and disaster managers, that NASA LEWS DSS is becoming popular in the region and is mainstreamed into the decision making process of the NGOs and other organizations in the pastoral regions of East Africa. In addition, we have received several high-level requests from

Ministry of Agriculture, Ethiopia and Ministry of Livestock Development, Kenya to expand the NASA LEWS domain to all the regions within their countries and we are exploring these possibilities.

5.1 Challenges and limitations

For implementation of the project, we have followed an adaptive style of management to overcome/address several challenges that were faced since the beginning of the project. One of the major challenges during the execution of the project was the reliance on the RANET technologies for the dissemination of the information. Basically, RANET project – Radio and Internet for the communication of hydro-meteorological information for rural development, in the east AFRICA region - was funded by a group of international organizations. Due to some unknown reasons, the RANET project stopped and the possibility of our project to utilize their resources for radio broadcasting ceased. Hence, with the absence of radio, we decided to work with the NGOs and Government Institutions who directly work with the pastoral communities in the region. Since, NGOs and Government Institutions would have access to internet; we believed a dedicated website would disseminate information to our stakeholders (NGOs and Government agencies).

There were several challenges that we faced while working with several local institutions. Unlike believed earlier, these institutions had poor access to internet. Further, there were regular turnover of employees which also posed a major challenge for the smooth execution of the project.

One other challenge we faced was with the use of GPS technology for the migration survey. Initially GPS with sufficient battery supplies were given to selected coordinators for carrying out migration survey. Sufficient training on how to use GPS and how to report the results was provided to selected coordinators. However, due to several reasons, the use of GPS for migration survey failed. Finally, information on migration patterns followed by the pastoral communities was gathered through informant interviews.

Lack of access to computers and internet was a main challenge we faced in disseminating the final information to the stakeholders. As an alternative distribution strategy, NGO's and government agencies that have email and internet capabilities in the study region were targeted to provide a new means of dissemination to the pastoralist groups but these sources did not work well due to lack of proper infrastructure and timely availability of internet.

6.0 Summary and Conclusions

Prior to the existence of NASA LEWS DSS, pastoral communities used traditional knowledge to identify areas where forage and water are available. More recently apart from the traditional approaches, most of the pastoral communities have been using scouts to locate forage and water. Even the NGOs and local government agencies working in the pastoral areas rely on the historic knowledge and information gathered from the regional surveys for planning and decision making. Such traditional methods of gathering information are mostly inaccurate, time consuming and costly affair. There is also a great deal of risk in gathering such information. Further, sometimes, information gathered from the scouts representing competing pastoral groups is not reliable.

Now, it is possible to access waterhole water level information in the pastoral regions of northern Kenya and Southern Ethiopia in near-real time - irrespective of geographic location and time. Within this project, the satellite based estimates used in this project are available for free on daily basis over the internet (http://watermon.tamu.edu/). Hence, the operational cost involved in maintenance of the system to generate waterhole water levels is very minimal. Since, the data is generated using satellite based estimated produced by NASA and hydrologic modeling techniques, it is highly reliable and consistent in nature.

One of the major outcomes of this project is the demonstration of the utility of combining NASA technologies and hydrologic modeling techniques to monitor small surface waterholes and forage availability in east Africa region. This project has established that modeled waterhole waterholes are more reliable than other sources of producing similar information. The model with in this project is built in such a way that this method can be applied anywhere in the world very easily. The information provided by the LEWS-DSS gave the users confidence when making decisions on livestock migration and for developing drought contingency and planning strategies. Further, it was found that users would like to see more historic data provided (i.e., data from pre-1998) and to increase the coverage area of the system. In sum, the current Livestock Early Warning System Decision Support System (LEWS-DSS) was viewed favorably in terms of its value to consumers of the data, its usefulness for assisting with decision making, and content of the product.

On the success of NASA LEWS DSS, mapping and monitoring water resources in the pastoral regions of MALI West Africa has been initiated. This project is being funded by USAID through GL-CRSP project. Further, increasing internet speed and improved skill of local researchers in developing countries will make this approach easier to implement in the coming years.

References:

Senay et al., 2007. Evaluation Report on the NASA LEWS project. “Enhanced Livestock Early Warning System (LEWS) – Decision Support System (DSS)” Annual Report Submitted to NASA.

Senay et al., 2008. Verification and Validation (V&V) Report for the “Enhanced Livestock Early Warning System (LEWS) – Decision Support System (DSS)” Annual Report Submitted to NASA.

Appendix – A (Questionnaire – 1)

This questionnaire will focus on the usefulness of the Waterhole monitoring for the livestock early warning. Please provide scores on the scale of 1-5 for each of the following questions; (1- indicates not at all useful and 5 - indicates extremely useful).

1. How useful is current system to monitor local water resources?

   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

2. How useful do you think is the ability of the current system to monitor regional water resources?

   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

3. How useful do you think is the ability of the current system to monitor national water resources?

   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

4. How useful do you think the present system to assess water resources potential in the region?

   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

5. How well do you think that the current system can be used for planning of new pond sites?

   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

6. How well do you think that the waterhole depth information can be used as early warning for the potential herd migration?

   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

7. How well do you think that the waterhole depth information can be used as early warning for potential herd loss due to drought?

   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

8. How well do you think that the waterhole depth information can be used as advisory to local and government workers for making drought contingency planning?

   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

9. How useful do you think that by providing information on waterhole would prevent/resolve conflict among tribes on water resources and herd movement?

   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

10. How useful do you think that the current system can be used to predict or assess regional cattle market prices?

    1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

APPENDIX – B (Questionnaire – 2)

This questionnaire will focus about the product. Please provide scores on the scale of 1-5 for each of the following questions; (1- indicates "doesn't meet the requirement at all" and 5 - indicates "product is perfect and helps in decision making").

1. The information on waterhole water levels is provided on daily basis. Does this timely information meets the requirements of the people in the region?

   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

2. The information on waterhole depth levels are provided at a day lag, i.e. today's website provides yesterday's waterhole depth information. Do you think that this latency of the product meets the requirements of the people in the region?

   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

3. The information on waterhole water levels is updated daily on the watermon website. Does this frequency of update meets the requirements of the people in the region

   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

4. Does the spatial coverage of waterholes monitored under this project meet the user requirement in the region?

   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

5. Currently, daily data of the waterhole depth information is available since the year 1998 do you think that historic information on waterhole depth information meets the user requirements?

   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

6. Do you think that the format in which waterhole depth information is provided through watermon website meets the user requirements?

   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

7. Does the accuracy of the information provided sufficiently meet the user requirements?

   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

APPENDIX – C (Questionnaire – 3)

This questionnaire will focus on the performance of the website. Please provide scores or answers accordingly.

1. Do you have any issues loading the watermon webpage?

Strong No	No	No-Comment	Yes	Strong Yes
☐	☐	☐	☐	☐

2. Do you have any issues loading high bandwidth webpage?

Strong No	No	No-Comment	Yes	Strong Yes
☐	☐	☐	☐	☐

3. Do you have any issues loading the low bandwidth webpage?

Strong No	No	No-Comment	Yes	Strong Yes
☐	☐	☐	☐	☐

4. Is the watermon website easy to understand and user friendly?

Strong No	No	No-Comment	Yes	Strong Yes
☐	☐	☐	☐	☐

5. Does the watermon website provide all the background information you need?

Strong No	No	No-Comment	Yes	Strong Yes
☐	☐	☐	☐	☐

6. What additional information you would like to have on this website? Please elaborate.

APPENDIX – D (Questionnaire – 4)

This questionnaire will focus on evaluating the improved-performance of the project compared to existing methods. Please provide answers accordingly.

1. Compared to existing methods, does the current system provide improved way of monitoring water resources in the region?

Strong No	No	No-Comment	Yes	Strong Yes
☐	☐	☐	☐	☐

2. Does it save time, energy and effort in obtaining waterhole depth information by using the current system when compared to the existing methods?

Strong No	No	No-Comment	Yes	Strong Yes
☐	☐	☐	☐	☐

3. Compared to the existing methods, does the current system offer an advantage in preparing migratory plans in search of water?

Strong No	No	No-Comment	Yes	Strong Yes
☐	☐	☐	☐	☐

4. Compared to the existing methods, does the current system offer any advantage in making contingency plans for drought mitigation?

Strong No	No	No-Comment	Yes	Strong Yes
☐	☐	☐	☐	☐

5. Compared to the existing methods, does the information provided on the watermon website useful in generating reports on the water resources in the region such as monthly water level reports, drought conditions reports for seeking emergency relief etc?

Strong No	No	No-Comment	Yes	Strong Yes
☐	☐	☐	☐	☐