DEVELOPMENT OF DECISION-MAKING TOOLS FOR DROUGHT MONITORING AND EARLY WARNING IN KYRGYZSTAN

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ABSTRACT: Drought has negative spillover effects in society, economy and environment in Kyrgyzstan. The water scarcity can lead to less crop production and it makes hard to guarantee food security. The management of drought monitoring is necessary for the country because it trigger the vicious circle between drought and socio-economic conditions. This study will assess the risk of drought based on the risk framework developed by the Intergovernmental Panel on Climate Change (IPCC), including climate hazards, environmental exposure and social vulnerability. Thus, the study aims to provide a decision-making tool by predicting each drought dynamics in air, soil and crop, integrating different aspects of climate hazards. On the basis of the concept, the dynamics can be assessed with three steps to achieve the research goal. The study first will define three types of drought which frequently are examined in the Kyrgyzstan. Second, a suitability analysis will be conducted in water, crop and pasture in order to figure out water resources system such as canal and topographical conditions. Following the analyses, this study will finally assess the drought risk of air, soil and crop respectively, applying the proper drought index. As a results, the study will forecast the different scales of climate hazards, and the degree of risk in air, soil and crop drought in Kyrgyzstan. This study will contribute to achieve the Sustainable Development Goals (SDGs) in water management and food security. This research is enable Kyrgyzstan to engage in the global research consortium, Food, Agriculture, Biodiversity, Land use and Energy (FABLE).

1. INTRODUCTION AND BACKGROUND

Drought has negative spillover effects in society, economy and environment in Kyrgyzstan. The hydrological drought can lead to agricultural drought and it makes hard to ensure food security. The management of drought monitoring is necessary for the Kyrgyz Republic because the drought occurred in Kyrgyzstan can trigger the vicious circle between drought and socio-economic conditions. The crop cultivation had directly suffered drought damage in the period of 1991 to 2014. It emerges as the necessity of forecasting drought monitoring, resulting from economic and social impacts by the unexpected drought (Omurzakova, 2019). This necessity of drought monitoring has been confirmed in the international meeting throughout experts and government officials, highlighting the importance of the geospatial information which can serve as decision making tool in drought monitoring and water management. Corresponding to the issue mentioned above, the objective of this study is to develop a high-quality user-tailored decision supporting tool and its applications to monitor drought patterns and issue for early-warning using geographic information system (GIS) and remote sensing (RS) techniques based on the risk framework developed by Intergovernmental Panel on Climate Change (IPCC). For doing this, this study will carry out three followings: (1) suitability analysis for water, crop and pasture; (2) drought risk assessment; (3) earth observation based drought monitoring. Since the country have not been carried out drought forecasting so far, we expected that the earth observation can serve as an important tool for monitoring current drought, and the drought index driven from meteorological data are able to forecast future drought.

2. METHOD AND STUDY AREA

We focus on developing a framework of drought monitoring and early warning system, especially based on risk concept to advance the conceptual framework we adopted in our previous research in Kazakhstan. The framework focuses on the risk assessment using hazard, exposure, and vulnerability based on Assessment Report (AR 5). According to AR5, the risk is defined as “probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur and its results from the interaction of vulnerability, exposure, and hazard.” It focuses on assessing the risk of climate-related impacts that may harm a system and vulnerability is only one component to control potential consequences of a hazard (IPCC, 2014). In our framework, we developed an algorithm for drought risk assessment using geospatial and statistical data. We used basic equation for drought risk assessment (Figure 1).

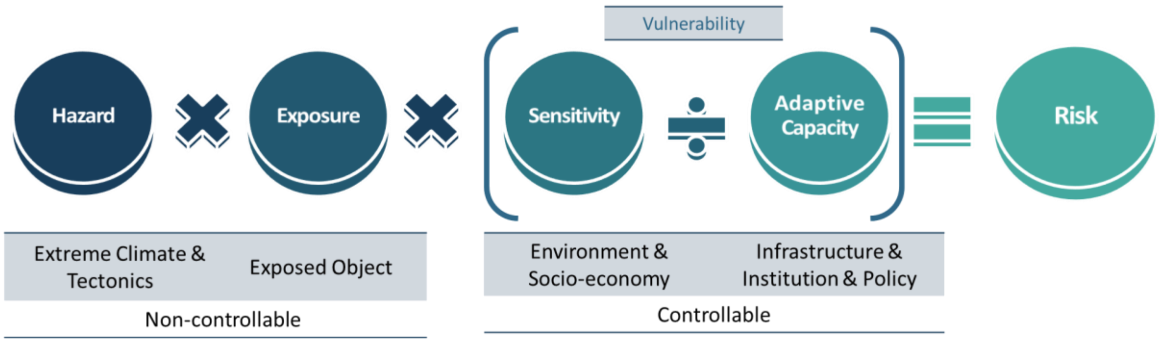

Figure 1 Equation for drought risk assessment

2.3 Study area

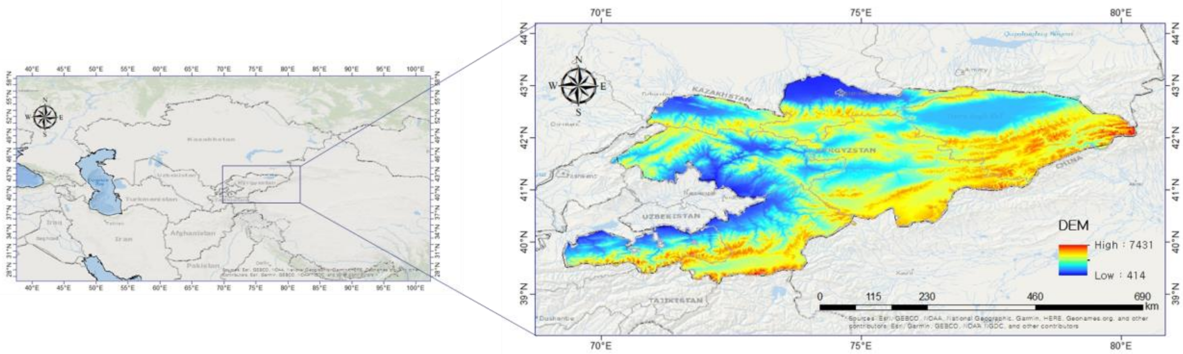

Figure 2 Study area

The study area is the entire Kyrgyzstan where located at longitude 74° 34' and latitude 42° 52’ (Figure 1). The climate conditions are greatly variables depending on the latitude, ranging from sub-polar climate in the highlands of Tien Shan and subtropical climate in the Fergana valley to warm temperate in the northern foothills. The precipitation shows large variability inter-annually, but the country possesses huge reserves of water resources accumulated in seasonal snow and glaciers. The melted snow can be main water sources in drought summers.

3. A CONCEPTUAL FRAMEWORK

3.1 Literature review

We reviewed the existing monitoring framework to develop our conceptual framework. One is the web services based drought monitoring, the other is earth observation based drought monitoring. The web services based drought monitoring systems are widely used across the countries, emerging as an urgent need to enable near real-time monitoring and analysis of drought at spatial and temporal resolution (Deng, M et al.,2013). First, we reviewed the web-based drought monitoring system on a national, regional and global scale to figure out how the system can be customized to Kyrgyzstan. Second, we examined the various earth observation data (EOD). Of EOD, satellite images produced by using multi-spectral sensor (MSS) are effective tool for estimating drought by monitoring vegetation and soil condition. Since each substance has its own spectral reflection characteristics, land cover and its condition could be monitored with the combination of several bands in MSS. For example, bands in near-infrared range, which is known to be sensitive for chlorophyll, is widely used to calculate vegetation indices. The use of satellite image has a strength on acquiring actual vegetation stress and soil wetness caused by the accumulated drought effect.

3.2 Developing Framework for drought monitoring and early warning system

The framework aims for identifying current drought condition and forecasting future drought, developing two parts like past to present and future (Figure 3). First, the drought monitoring model can be provided by identifying the vulnerable area and the hazardous climate impacts (past to present). It is primary step to identify the vulnerable areas through suitability analysis, figuring out whether the areas were sensitive to drought or not. In parallel with this, the drought trends between meteorological data and the vegetation greenness index should be understood by using past and current stationary data and the satellite-observed data. The calibration is necessary process to identify the drought condition by comparing our model output and the vegetation greenness, since it considers as the validation process. Once drought model is validated, we will forecast the future drought monitoring by using the predicted meteorological data. Input data is the vulnerable area, the predicted precipitation and temperature. Finally, agricultural drought and vegetation greenness were predicted.

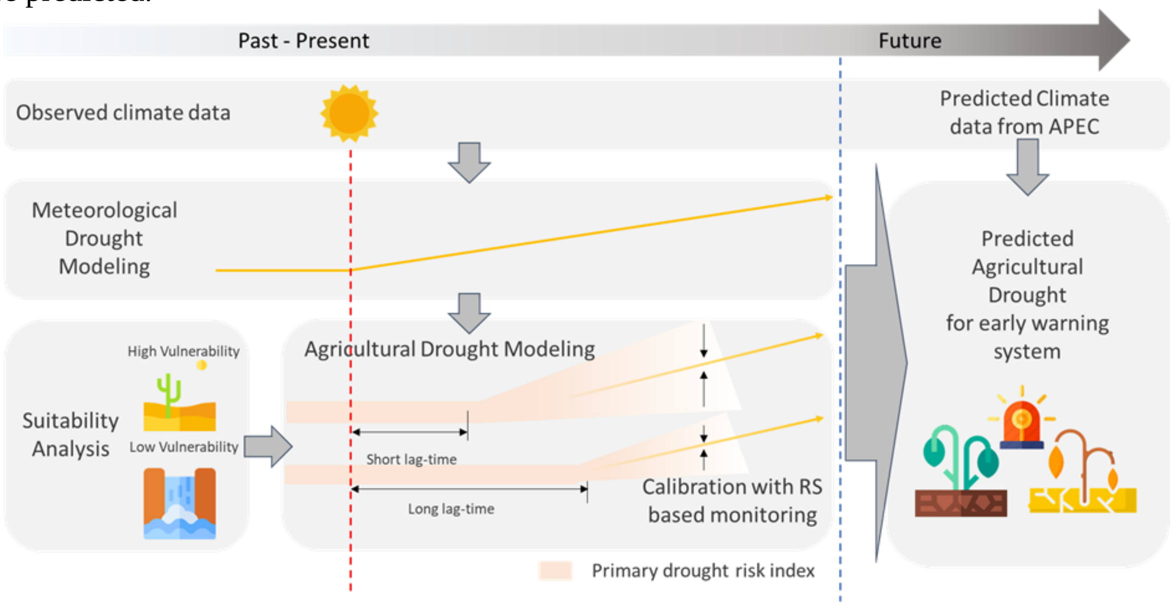

Figure 3 Conceptual Framework for drought monitoring and early warning system

3.3 RESEARCH PROGRESS

3.3.1 Suitability Analysis for water, crop, and pasture

The suitability analysis can be the process of vulnerability in the Step 2. To assess the current drought monitoring and forecast the future drought monitoring, it is essential to identify the vulnerable areas, figuring out whether the areas were sensitive to drought or not. Facing the drought, some regions where surrounded by water sources will not be risky, while other region will be risky if there have no water sources around here. Thus, it seems to be reasonable to suggest that the irrigation system should be established where far away from water resource, if irrigation system is not equipped. With the basis of the concept, two theme of research should be carried out in parallel. The flow accumulation, slope, Terrain Ruggedness Index (TRI), precipitation, soil type, distance from agricultural activities, distance to settlements, land cover and geological layer can be analyzed for dam suitability (Figure 4).

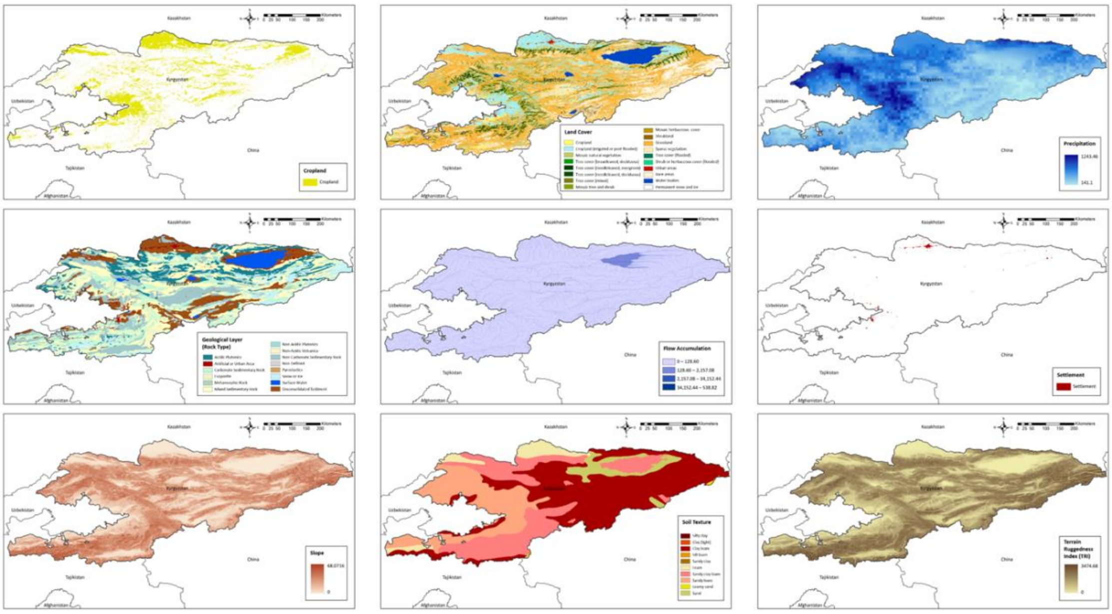

Figure 4 Variables for optimal dam site selection

3.3.2 Drought Risk Assessment

The meteorological drought will be observed by figuring out the data availability. Palmer Drought Severity Index (PDSI) is used to estimate meteorological drought by using the data such as temperature, precipitation and potential evapotranspiration from ground stations. PDSI will be calculated to determine the dryness based on a water balance equation, incorporating both monthly air temperature and precipitation. The self-calibrating PDSI (SC-PDSI) presented by Wells et al. (2004) significantly improved PDSI spatial comparability and made it more reasonable for monitoring extreme wet and dry events. The predicted meteorological data provided by APEC climate Center (APCC) will be used for drought occurrence observation in the future.

3.3.3. Earth Observation (EO) based Drought Monitoring

In Step 3, the remote sensing based modeling can be developed to calibrate the drought risk map from previous research step. For doing this, the drought indices can be mapped such as NDVI, land surface temperature by using the time-series of satellite imageries. The indices related to vegetation and land surface temperature are as follows (Figure 6): Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Red, Blue, Near-InfraRed (NIR), Mid-InfraRed (MIR) bands, Land Surface Temperature (LST), Leaf Area Index (LAI), and the Fraction of Photo-synthetically Active Radiation (FPAR), Vegetation Condition Index (VCI), Temperature Condition Index (TCI), and Vegetation Health Index (VHI). As following step, we will analyze the relationship between meteorological drought from Step 2 and RS based drought indices by using Logical regression model, Support Vector Machine (SVM), and Convolutional Neural Networks (CNNs). Finally, after calibration, we will establish an early warning system through short-time prediction and long-time prediction for Step 4.

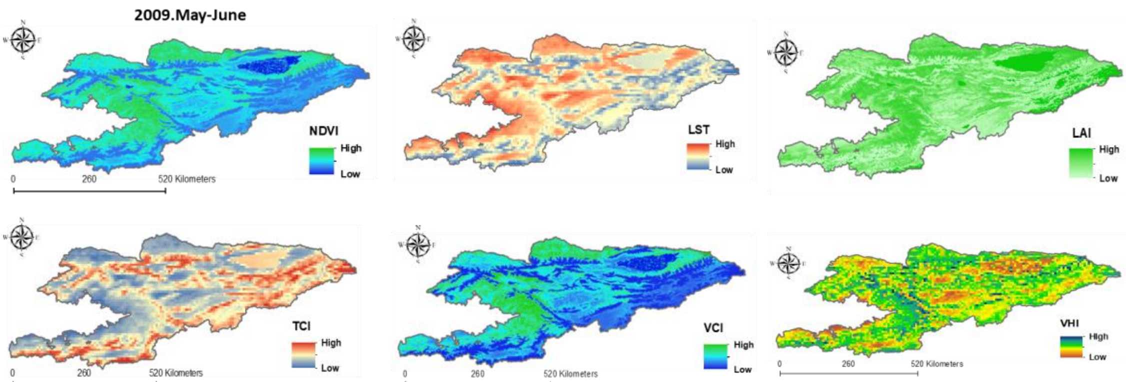

Figure 6 The indices of directly or indirectly affecting drought based on satellite imageries (NDVI, LST, LAI, TCI, VCI, VHI)

4. CONCULSION AND FUTURE RESEACH

The study aims for developing a high-quality user-tailored decision supporting tool and its applications to monitor drought patterns. For explaining an overview of our research, the existing drought monitoring system are reviewed, and then we propose a conceptual framework for drought monitoring and early warming. In the framework, we will validate current drought monitoring with past to present data, and ultimately develop the drought model using the predicted meteorological data. Once developing the drought modelling, we will draw up a manual on GIS applications on our drought modelling. All the process will be transferred to the Kyrgyz people via the channel of capacity building workshop. We expected that the earth observation can serve as an important tool for monitoring drought, since there have not been conducted the drought forecasting in Kyrgyzstan so far.

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