EVALUATING IRRIGATION COOLING EFFECT ON SURFACE TEMPERATURE USING MODIS AND LAND SURFACE MODEL IN THE ARAL SEA BASIN

Tohoku University, Student Member ○Jacqueline Muthoni Mbugua
Tohoku University, Regular Member Yoshiya Touge
Tohoku University, Regular Member So Kazama
Tohoku University, Regular Member Temur Khujanazarov

1. INTRODUCTION

The scale of irrigation in the Aral Sea basin is massive mainly because of the expansion of irrigated areas during the Soviet era. In turn, the region was plunged into a deep environmental crisis signifying one of the greatest environmental tragedies of the 20th century (Glantz, 1999; Micklin, 2000). Problems include excessive water loss through low irrigation efficiency and increased soil salinization. Low irrigation efficiency exacerbates the effects of drought as water is not made available to downstream areas. Some studies estimate that the overall irrigation efficiency in this basin is between 30 to 50 percent (Nazirov, 2005; Ryan et al., 2004). Toderich et al., (2008) found that the land affected by salinization, especially through human-induced factors increased from 87 to 95 percent within 5 years in the Syrdarya province.

Irrigation water is important in considering heat and water balance in the basin. In this basin, the irrigated area changes dynamically due to the effect of drought and soil salinization. However, the extent of this irrigated area is unknown since it is difficult to collect data in a wide area, especially in developing countries. Available global datasets such as the Global Land Cover Characterization (GLCC) are static and the irrigated areas are not isolated. Additionally, vegetation based indices are unsuitable for application in this region due to the high groundwater level which flourishes the native plants making it difficult to separate the irrigated areas.

This study aims to assess the potential of using Land Surface Temperature (LST) from MODIS and a Land Surface Model (LSM) to detect the annual changes in the cooling effect of the irrigated area.

2. METHODOLOGY

Soil with high soil moisture responds slowly to temperature changes due to the difference in heat capacity between water and soil. Additionally, evapotranspiration is higher in irrigated areas than in areas with natural vegetation. This further lowers the LST during the day. The LSM provides LST for ideal conditions while MODIS provides the LST observed by the satellite. The mesh was assumed to be fully irrigated or non-irrigated when simulating irrigation conditions. The LSM was utilized to remove the effect of geology and climate since it considers the climatic variability such as rainfall and geological variability such as altitude which may affect the LST.

MOD11A1 of 1km resolution and 12hour resolution was used for the satellite data. Simple Biosphere including Urban Canopy (SiBUC) LSM (Tanaka, 2005) was used to simulate the land surface processes since it considers artificial water operation in the irrigated areas. Japanese 55-year Reanalysis (JRA-55) was used for forcing data and Global Satellite Mapping of Precipitation (GSMaP) version 6 data was used for precipitation data in order to isolate irrigation effect on soil moisture. Hourly data was linearly interpolated while spatial data was interpolated using Inverse distance weighting (IDW). GLCC and ECOCLIMAP(http://www.cnrm.meteo.fr/gmme/PROJETS/ECOCLIMAP/page_ecoclimap.htm) conditions, and leaf area index conditions, and leaf area index. LST by the LSM was simulated using SiBUC LSM with a spatial resolution of 5km for every hour.

3. RESULTS AND DISCUSSION

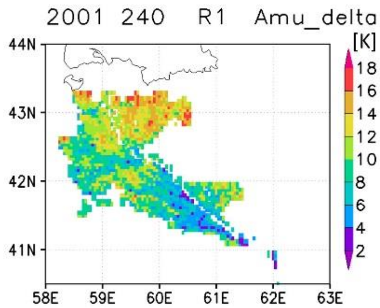
LST Indices were developed for the purpose of detecting the cooling effect of irrigation on the LST and applied in a downstream delta of the basin.

$$R_1 = \Delta ST_{SAT} - \Delta ST_{LSM\_NI} \quad (1)$$

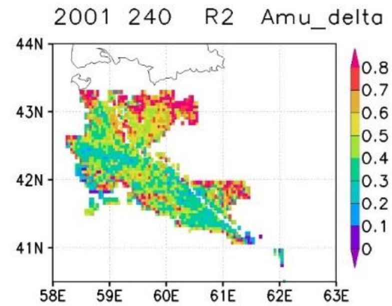
$$R_2 = \frac{ST_{SAT}^{day} - ST_{LSM\_NI}^{day}}{ST_{LSM\_IR}^{day} - ST_{LSM\_NI}^{day}} \quad (2)$$

where, R is the rrigation index, ST is surface temperature, ΔST is surface temperature difference between day and night, $AveST$ is long term average of surface temperature. And suffix of SAT means observed by satellite, LSM_IR and LSM_NI means simulated with fully irrigation and without irrigation, respectively, and day means daytime

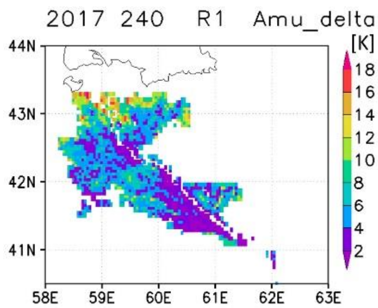
Key words: Aral Sea Basin, Irrigation, MODIS, NDWI, Remote sensing,
Contact address: Tohoku University, 6-6-06, Aza-Aoba, Aramaki, Aoba-ku, Sendai 980-8579, Japan, Tel:+81227957455



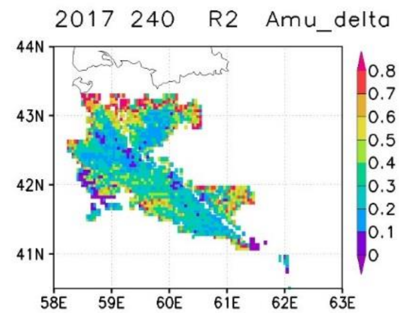
(a) R_1 index 2001



(b) R_2 index 2001



(c) R_1 index 2017



(d) R_2 index 2017

Figure 1 Effect of drought on LST in the irrigated area

R_1 removes the climatic and geological effects on ΔLST in order to identify the irrigation effect. R_2, on the other hand, observes the rate of the irrigation effect on the mesh, that is, the irrigation fraction.

Figure 1 (a-d) above shows the effect of drought on the irrigated area as observed by the indices R_1 and R_2. Both indices have a higher value in the month of August 2001 especially in the northern parts of the delta. A severe drought in 2000 and 2001 heavily affected the irrigated areas in this delta. Areas in the most northern part of the delta could not be irrigated due to a lack of water. The effect of this drought can be clearly observed by the proposed indices. R_1 shows changes to the irrigated area due to the irrigation effect which in this case, relates to the reduction of the irrigated area due to drought. R_2 seems to be directly related to the irrigation fraction and therefore has a much clear result on the impact of drought than R1. This index compares an ideal natural simulated effect of irrigation and the actual irrigation conditions.

4. CONCLUSION

The difference in heat capacity between water and soil, denotes that soil with high moisture content such as irrigated soil will not respond immediately to temperature changes. The LST indices developed to detect the cooling effect of the irrigated area show some potential for the purpose. The indices were able to detect the irrigated area and the effect of drought effect on this area. Irrigation fraction during a drought year was observed to be lower in a drought year as compared to that of a normal year especially further away from the water source due to water scarcity.

5. ACKNOWLEDGEMENT

This research was partially supported by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Scientific Research (B), 2017-2022 (17H04585, Yoshiya Touge) and the collaborative research program (29G-11) of the Disaster Prevention Research Institute of Kyoto University.

6. REFERENCE

Glantz, M. H. (1999). *Creeping environmental problems and sustainable development in the Aral Sea basin* (M. H. Glantz (ed.)). Cambridge University Press. http://books.google.com/books?hl=en&lr=&id=2YXnBxZg7c4C&pgis=1

Micklin, P. (2000). *Managing Water in Central Asia*. Royal Institute of International Affairs.

Nazirov, A. A. (2005). *Central Asia: Water for Food* (No. 31).

Ryan, J., Vlek, P., & Paroda, R. (2004). *Agriculture in Central Asia: Research for development*. ICARDA.

Tanaka, K. (2005). Development of the new land surface scheme SiBUC commonly applicable to basin water management and numerical weather prediction model. In *PhD thesis*. Kyoto University.

Toderich, K., Ismail, S., Massino, I., Wilhelm, M., Yusupov, S., & Kuliev, T. (2008). Extent of salt-affected land in Central Asia: Biosaline agriculture and utilization of the salt-affected resources. In *Advances in assessment and monitoring of salinization and status of biosaline agriculture. Reports of expert consultation, Dubai, UAE. World Soil Resources Reports No. 104.* (Issue 648).