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ИРРИГАЦИЯ ВА МЕЛИОРАЦИЯ

ГИДРОТЕХНИКА ИНШООТЛАРИ ВА НАСОС СТАНЦИЯЛАР

ИРРИГАЦИЯ ВА МЕЛИОРАЦИЯ ИШЛАРИНИ МЕХАНИЗАЦИЯЛАШ

СУВ ХЎЖАЛИГИ ИҚТИСОДИ ВА ЕР РЕСУРСЛАРИДАН ФОЙДАЛАНИШ

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CLIMATE CHANGE ANALYSIS AND EVAPOTRANSPIRATION CALCULATION FOR IRRIGATION SCHEDULING ON THE EXAMPLE OF KARSHI STEPPE

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Аннотация

Ушбу мақолада иқлим ўзгариши шароитида тадқиқотларни глобал иқлим моделларининг (ГИМ) иқлим ўзгариши маълумотлар базаси, метеостанция ҳамда масофали зондлаш (МЗ) маълумотларини илғор технология ва услублар ёрдамида аналитик усулларини таҳлил қилиш келтирилган. Сув мухим ресурс ҳисобланиб, уни қишлоқ хўжалигида тўғри тақсимлаш ва бошқариш иқлим ўзгариши шароитида етарлича қийин вазифа ҳисобланади. Мақоладаги ёритиладиган усул бугунги кундаги замонавий усуллардан бири ҳисобланиб, унда иқлим ва унинг динамик ўзгариши хамда МЗга ёндашган ҳолда кичик ва катта масштабли ҳудудларда сув ресурсларини режалаштириш ва уни бошқаришнинг ҳисоблаш усули ёритилган. Ушбу тадқиқотдан асосий мақсад – иқлимнинг ўзгариши ва буғланишни ГИМ ва МЗ маълумотлари ёрдамида сув ресурсларини бошқаришнинг таҳлилий усулларини замонавий услубда хисоблаш келтирилган. Буғланиш – сув баланси ва сув ресурслари хамда суғориши режимини ташкиллаштиришда асосий элемент ҳисобланиб, ушбу изланишдаги эришилган натижалари сув ресурсларини янада самарали бошқаришда асосли маълумот сифатида фойдаланиш мумкин.

Abstract

The current research analyses the climate change datasets from the Global Circular Models (GCM), data from official meteostations and Remote Sensing information as advanced technology and methods, aimed at improving research analyses in the context of climate change. Water is very important resource and its proper distribution and management in the agricultural areas is a challenge in conditions of the climate change. The method introduced in this paper represents an advanced methodology to compute climatic variables and their dynamic changes as well as remote sensing-based approaches for future equitable water distribution and its balance in small or large scale areas. Therefore, this research will give an overview of how to analyze the climate change and evapotranspiration (ET) rates using Global Circular Model (GCM) and Remote Sensing information for water management purposes. As evapotranspiration is part of water balance and is a key element for water management and irrigation scheduling, the achievements of this study can be used as a base data for more efficient water management in the region.

Аннотация

В данном научном исследовании проводится анализ баз данных глобальных циркулярных моделей (ГЦМ) по изменению климата, государственных метеостанций, а также информации дистанционного зондирования (ДЗ) в качестве передовых технологий и методов, направленных на улучшение аналитических методов исследований. Вода является очень важным ресурсом и ее надлежащее распределение и управление в сельскохозяйственных районах является ответственной задачей в условиях изменения климата. Рассматриваемый в данной работе метод является передовым для расчета климатических переменных и их динамических изменений, а также подходов на основе дистанционного зондирования для равномерного распределения и балансаводы как для небольших площадей, так и крупных массивов. Цель данного исследования – проведение обзораметодов и способов анализа изменения климата и эвапотранспирации (ЕТ) с использованием ГЦМ и данных ДЗ для управления водой. Поскольку ЕТ является частью водного баланса и ключевым элементом в области рационального использования водных ресурсов и режима орошения, результаты этого исследования могут быть использованы какоснова для более эффективного управления водными ресурсами в регионе.

Introduction

Water resources in Central Asia are very much important for many sectors and the economy of the Central Asian countries. In this region, majority of population is living in rural areas and the economy of the region is highly dependent on agriculture (S. Peyrouse 2009). Amu Darya and Syr Darya rivers are the main sources for irrigation of the agricultural areas. Therefore, water management in Central Asia is a key issue and energy demanding, as for study area proper water management and energy saving is a challenge where water and energy in big demand while lifting water from Amu-Darya to the steppe. During Soviet Union time the steppe was cultivated mostly with cotton crop, but time to time irrigated crop types was changed differently in the study area. One example could be extensions of wheat plantations and reduction of cotton planted areas for the purpose of meeting local food needs (Abdullaev et. al).Since different crop has different water requirements, proper water management systems is interlinked to the measurement of different types of crops and their water requirement in the context of changing climate. Study area is is the one of the case where regional climate and water related issues exist and this area is being vulnerable to the increasing temperature which would lead to the increase of crop water consumptive demand in the region (White et. al.).

Study area

Karshi steppe is located in southern part of Uzbekistan and the climate is continental and dry, precipitation is mainly occurring during winter period and therefore irrigated and industrial areas highly depend on water resources in the

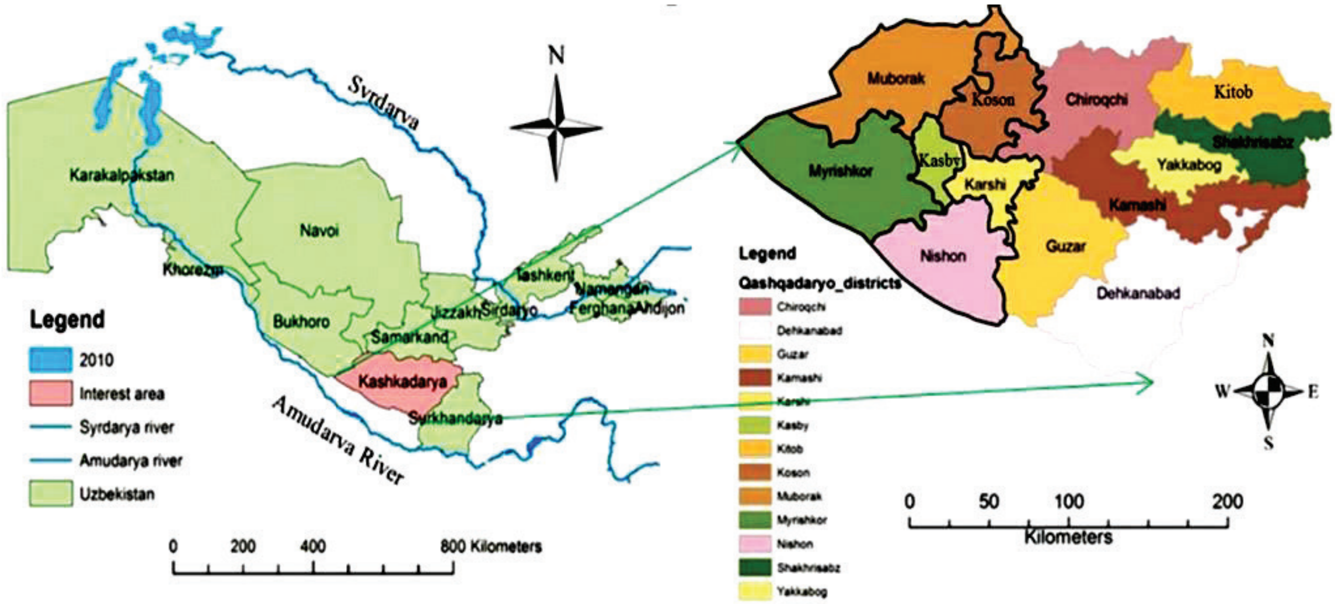


Image 1:Geographical location of study area

region. Study area consists of six regions which are located in western part of Qashqadaryo province. The source of irrigation is AmudaryaRiver where the water resources are pumped to the steppe (Image 1).

Objective

The main objective of this study is to conduct climate change analysis and future projections for the study area and calculate crop coefficients and evapotranspiration rates using remote sensing information. Evapotranspiration assessment is interconnected with climate change and therefore it is necessary to study climate parameters and its assessments for further analysis of crop water requirement. Following below is the workflow steps of this study.

1. Climate change analysis
2. Calculate Reference ET
3. Calculate crop coefficient
4. Calculate Actual ET

Reference ET is calculated using Climate and GCM datasets, crop coefficient is derived from remote sensing information and actual ET is calculated using reference ET and crop coefficient

Data and materials

Climate data

Intergovernmental Panel on Climate Change (IPCC) together with several research institutes developed a projections for future climate. Thus, climate model CMIP5 "Coupled Model Intercomparison Project" phase five promotes a standard set of model simulations. This Climate change data was derived through the new portal, the Earth System Grid - Center for Enabling Technologies. "Coordinated Regional Climate Downscaling Experiment (CORDEX) is providing global coordination of regional climate downscaling for improved regional climate change adaptation and impact assessment" (http://wcrp-cordex.ipsl.jussieu.fr/). Downscaled data CMIP5 was obtained for CORDEX area of South Asia denoted as WAS44 region. This dataset was performed to do a bias corrections based on existing climate data for the region and apply bias indexes to the future for future climate projections. Thereafter, corrected climate dataset was used to estimate reference evapotranspiration for Karshi steppe. South Asia (WAS44) dataset includes partly Central Asian states, therefore it was sufficient to use this datasets for the region of interest.

Downscaled climate dataCMIP5

New scenarios has been defined by scientific community for the Fifth Assessment Report of IPCC denoted as Representative Concentration Pathways (RCPs). This scenarios for new CMIP5 framework of the World Climate Research Program. RCPs, represented below estimates higher atmospheric CO2 concentrations in 2100 relative to present day as a result of a further increase of cumulative emissions of CO2 to the atmosphere during the 21st century (Assessment Report5)

- 2.6 W m-2 for RCP2.6,
- 4.5 W m-2 for RCP4.5,
- 6.0 W m-2 for RCP6.0 and
- 8.5 W m-2 for RCP8.5.

These four RCPs includes different scenarios,

- one mitigation scenario leading to a very low forcing level (RCP2.6),
- two stabilization scenarios (RCP4.5 and RCP6), and
- One scenario with very high greenhouse gas emissions (RCP8.5).

Every single RCP provides spatially resolved datasets of land use change based on emissions specifying greenhouse gas concentrations and anthropogenic emissions up to 2100.

Remote Sensing data

The Landsat data was obtained from United States Geological Survey (USGS) webpage. This data product provides data with different band combinations where this data is used to monitor water resources, glacier, sea ice movement, invasive species encroachment, coral reef health, land use change, deforestation rates and population growth (Landsat sciences). Number of bands represent different portion of the electromagnetic spectrum.

Methodology

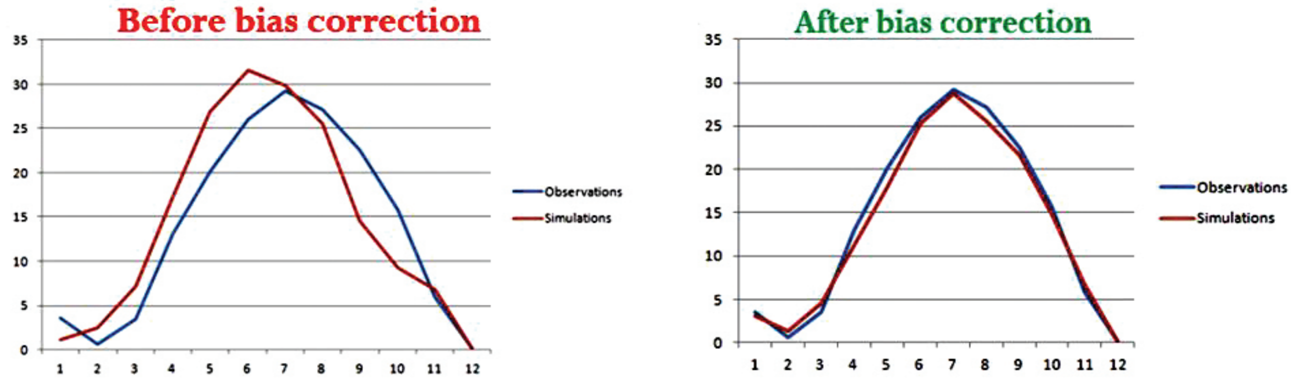
As mentioned earlier, calculation of ET0 requires climate parameters, this parameters are from GCM data after making bias corrections. Widely used bias correction are applied to fine tune the datasets of GCM. Below is the formula for bias correction approach. Bias correction adjusts all parameters of climate for each day. Equation below for bias correction was obtained from the link here http://www.narccap.ucar.edu/.

Necessary formulation:

Bias Correction Factor (BC) = $MMCV_{obs}$ % or - $MMCV_{his}$ (Where MMCV- Mean monthly climate variable)

Corrected Climate Variable Present ($CV_{c\,(his)}$) = CV_{his} × or + BC

Corrected Climate Variable Future ($CV_{c\,(fu)}$) = CV_{fu} × or + BC



Graph 1: Bias corrected data, left figure before correction and the right one is after correction

Using historical station data, GCM datasets are corrected and calibrated and this way all parameters of GCM datasets are prepared and corrected for further analysis. This datasets are than used for computing reference ET (ET_0). Real ET_0 usually obtained using measurement tools so called Lysimeter (Lysimeter). When ET_0 is unknown or not available from measurement tool than comes to use necessary equations and methods to calculate reference Evapotranspiration. In most cases Penman Monteith equation is recommended to use as a best method for estimating ET_0. Since penman monteith has relatively high data demand for ET_0 calculation, Hargreaves method motivated to apply for this study as an alternative approach where it requires minimum input data.

Climate parameter from GCM data projected up to 2100 based on the scenario with very high greenhouse gas emissions. According to the result illustrated above means that temperature will increase about 4 degrees in 2100.

$$ET_0 = k_{et} \cdot RA \cdot \sqrt{(T_{\max} - T_{\min})} \cdot (T_{mean} + 17.8)$$

$$RA = 0.0023 \cdot \frac{24 \cdot 60}{\pi} \cdot G_{sc} \cdot d_r \cdot [\omega_s \cdot \sin(\varphi)\sin(\delta) + \cos(\delta)\sin(\omega_s)]$$

RA – Extraterrestrial radiation [0.408 mm]

G_{sc} – solar constant

d_r – inverse relative distance Earth-Sun

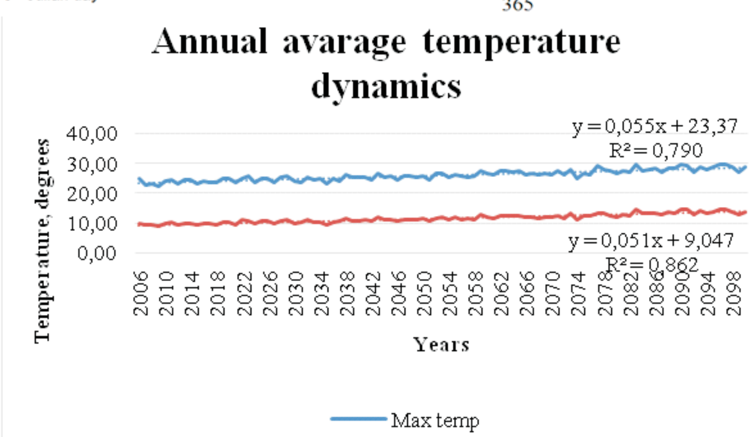
δ - Solar declination

φ – latitude

J - Julian day

$$d_r = 1 + 0.033\cos\left(\frac{2\pi}{365} \cdot J\right)$$

$$\delta = 0.409\sin\left(\frac{2\pi}{365} \cdot J - 1.39\right)$$



Graph 2: Temperature dynamics for Karshi steppe 2006-2100

There is many methods and approaches to calculate Actual ET using remote Sensing information with combination of climate parameters. This section focuses on estimating the crop coefficient (K_c) and crop evapotranspiration (ET_c). Reference evapotranspiration (ET_0) were estimated as mentioned above using Hargreaves Samani method and crop coefficient values were adjusted to real values. Landsat images both geometrically and radio metrically corrected were used to drive the Normalized Difference Vegetation Indices (NDVI) and crop coefficient from NDVI.Mohammed A. El-Shirbenyexplains en equation to derive crop coefficients from Satellite images and validated according to FAO approach. Crop stages in this study derived from FAO-56 suggested K_c values for different crop types in different climate condition. This study carried out actual ET calculation for one wheat crop plot in Karshi steppe. The equation K_c satellite and NDVI is represented below which was established by (El-Shirbeny et al., 2014b) and it is adjusted to the region of interest. Adjusted Equation for Karshi steppe is as follows below

$$KcSatellite = \frac{1.2}{0.6}(NDVI - 0.1)$$

Where: 1.2 is the maximum Kc for wheat under arid and semiarid conditions, 0.6 is the difference between minimum and maximum NDVI value for vegetation and 0.1 is the minimum NDVI value for vegetation.

Results

Image below is the NDVI result for a single wheat field calculated using Near Infrared and Red bands of Landsat images and the units are in percentages.

Once NDVI is calculated, it is possible to compute crop coefficient for any crop respectively to their growing stages. Image below is the result of crop coefficient obtained from NDVI using the equation stated above and the unit is the coefficinet of the crop growing stage.

Actual crop water requirement can be calculated using Actual ET equation where reference ET is multiplied for the crop coefficient. Crop coefficient is a spatially distributed data and is performed to calculate on ArcGIS software. It is done using an equation provided below, the equation uses ETO already calculated for the study area and multiply by crop coefficient obtained using above mentioned approach.

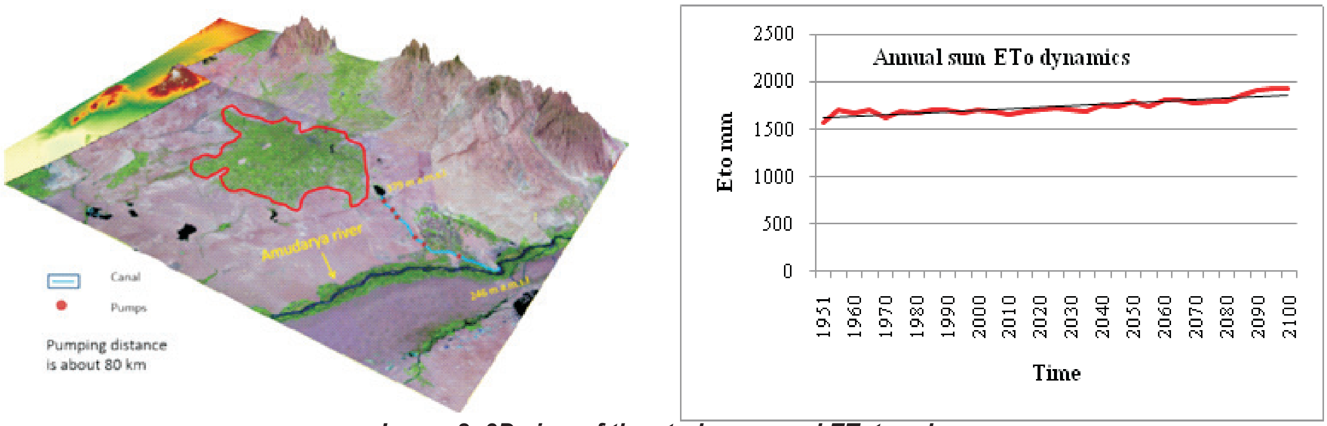


Image 2: 3D view of the study area and ETotrend

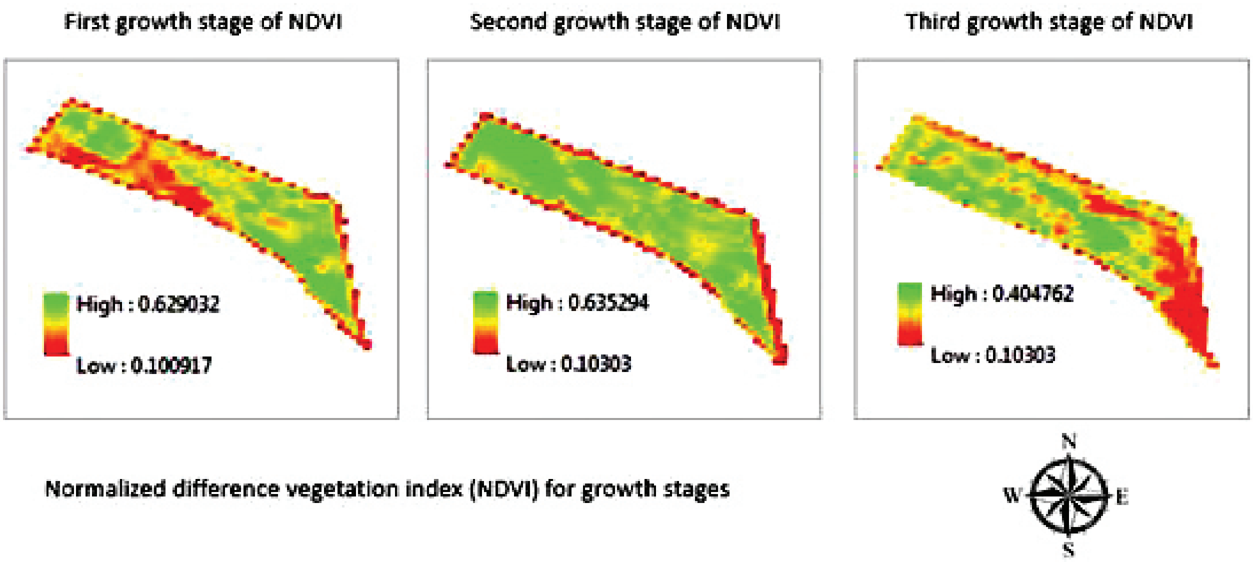


Image 3:NDVI for wheat plot in Karshi steppe for growing stages

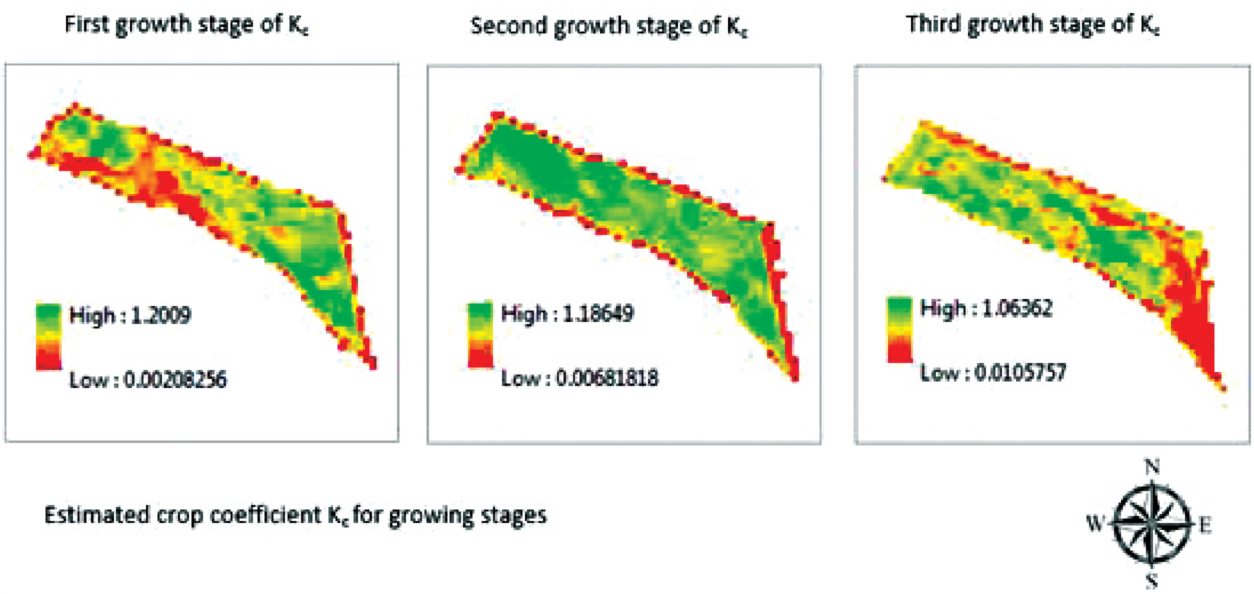


Image 4:Crop coefficient for wheat plot in Karshi steppe for growing stages

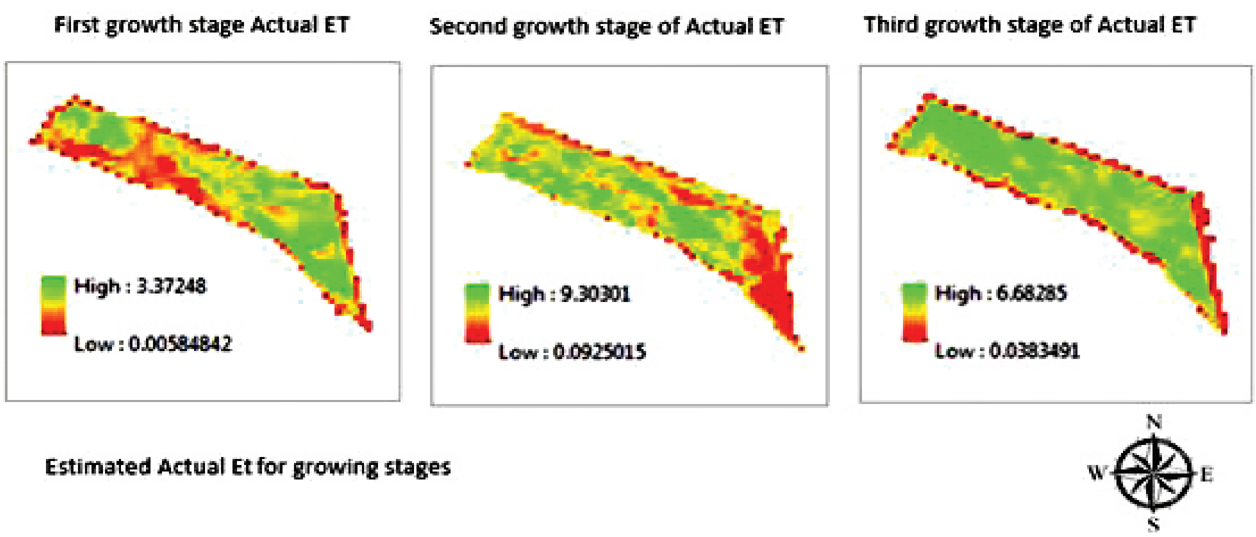


Image 5:Actual Evapotranspiration for wheat plot in Karshi steppe for growing season in mm

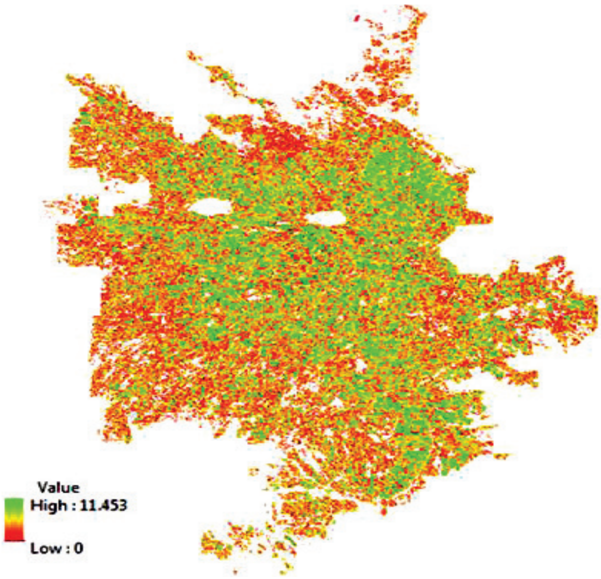


Image 6:One day Actual ET for karshi steppe for July 2011in mm

Below is the equation of Actual ET crop and the result is shown as spatially distributed map and the unit is in mm.

$$ET_c=ET_0 * K_c$$

Author as an example calculated Actual ET for entire Karshi steppe only for one day for the year of 2011, Below image is the spatial distribution of one day actual ET for Karshi steppe.

Conclusion:

The study presents a novel method for assessing crop coefficient to calculate actual evapotranspiration in the irrigation systems using remotely sensed data. We implemented a simple and effective method to calculate crop coefficient for data limited regions utilizing Landsat based NDVI data.Since Evapotranspiration is a part of water balance analysis, it is therefore is very important to introduce advanced technologies and methods for improving the achievements in a short and cost effective way. Moreover, RS data is freely available, it is becoming as a good alternative data for conducting diverse water related research studies. The results of this advanced approach in Karshi steppe can be used as base information for further analysis in other spots of the region to increase the study productivity. Climate change projections for the future can also be used for future planning activities of the water resources in the context of changing climate.

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