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Research Article

Development of an Online System for Optimal Placement of Agricultural Crops in Desert Regions

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Abstract

Enhancing the efficiency of optimal placement of agricultural crops in desert regions requires modern technologies. Digital geographic information systems and cloud computing technologies play a significant role in this field, enabling data-driven decision-making. This article presents the concept of developing an online system for the optimal placement of agricultural crops using the capabilities of Google Earth Engine (GEE) and ArcGIS Online Dashboard.

Keywords: *Google Earth Engine (GEE), ArcGIS Online, NDVI, EVI, GIS, JavaScript, Python, QGIS, ArcGIS.*

INTRODUCTION

Agriculture in desert regions presents unique challenges due to extreme climatic conditions, limited water availability, fragile soils, and the growing impacts of climate change. Despite these challenges, desert areas hold significant potential for agricultural production if resources are managed efficiently and modern technologies are applied. The optimal placement of crops in such regions is not only a matter of productivity but also a critical aspect of sustainable resource management, ensuring that scarce water and land are used in the most efficient way [1], [2]. The integration of digital platforms, geospatial technologies, and decision-support systems has opened new opportunities for addressing this challenge. Developing an online system for optimal crop placement in desert regions represents a forward-looking approach that combines scientific knowledge, technological innovation, and practical solutions for farmers and policymakers. Desert ecosystems are highly sensitive, with agricultural expansion often leading to land degradation, soil salinization, and depletion of water resources if not carefully managed [3], [4], [5]. Traditional methods of crop planning, which rely heavily on experience or historical patterns, are increasingly insufficient in the face of new pressures such as population growth, urbanization, and climate variability. As water becomes scarcer and temperatures rise, the need for data-driven decision-making becomes urgent. An online system can serve as a centralized platform to provide real-time information, spatial analysis, and predictive modeling for determining the most suitable crop types and their optimal locations in desert landscapes. The use of Geographic Information Systems (GIS), Remote Sensing (RS), and Artificial Intelligence (AI) forms the technological backbone of such a system. By integrating satellite imagery, climate data, soil characteristics, and hydrological information, the platform can identify zones where specific crops have the highest likelihood of thriving under desert conditions [6]. For example, indices derived from remote sensing, such as the Normalized Difference Vegetation Index (NDVI) or Land Surface Temperature (LST), can reveal patterns of vegetation health and soil moisture. Coupled with soil salinity data and water availability maps, these datasets allow the system to provide recommendations tailored to the unique ecological conditions of each desert area.

Another critical component is the incorporation of optimization algorithms. These algorithms can evaluate multiple variables simultaneously such as crop water requirements, expected yield, economic value, and resilience to heat stress to propose the most efficient crop allocation strategies. The system can also include scenario analysis, enabling users to model how future changes in temperature, precipitation, or irrigation capacity might affect crop productivity. This predictive capability is vital for long-term planning and adaptation to climate change[7], [8], [9].

From a practical perspective, an online crop placement system offers significant benefits to both farmers and policymakers. Farmers gain access to a user-friendly interface where they can input their field characteristics and receive recommendations on suitable crops, irrigation methods, and planting schedules. This empowers them to make informed decisions that enhance yield while conserving water and soil resources. Policymakers, on the other hand, can use the system to design regional strategies for food security, assess the environmental impacts of agricultural expansion, and ensure that investments in desert agriculture align with sustainability goals.

The development of such a system also contributes to broader global objectives, including the United Nations Sustainable Development Goals (SDGs), particularly those related to zero hunger, clean water, climate action, and life on land. By optimizing agricultural practices in arid and semi-arid environments, the platform not only supports food security but also mitigates risks of desertification, biodiversity loss, and resource conflicts. The creation of an online system for optimal crop placement in desert regions represents a convergence of digital innovation and sustainable agricultural development. It acknowledges the urgent need to balance productivity with resource conservation in some of the world's most challenging environments. Through the integration of geospatial data, climate modeling, and decision-support algorithms, such a system can guide the efficient use of scarce land and water resources, improve farmer livelihoods, and strengthen resilience to climate change[8], [10]. As deserts increasingly become focal points for agricultural expansion, the role of intelligent, online, data-driven solutions will be indispensable in shaping the future of food production in these fragile ecosystems.

STUDY AREA

The study area is Karshi District in Kashkadaryo Region, southern Uzbekistan, located at the edge of the Kashkadarya oasis and bordering the arid Karshi Steppe. The district lies between 270–500 meters above sea level, with flat to gently undulating terrain shaped by ancient alluvial deposits and irrigated farmlands. This transitional landscape reflects both fertile cropland and desert margins, making it a representative site for research on crop placement in desert regions. Climate and water resources[11]. Karshi District has an arid continental climate, with hot summers exceeding 35–40 °C and cold winters near 0 °C. Annual precipitation is very low, concentrated in late autumn and spring, while potential evapotranspiration is extremely high. Agricultural production depends almost entirely on irrigation water supplied through the Karshi Main Canal, which transfers Amu Darya water, as well as local inflows from the Kashkadarya River. Dependence on pumping systems and canal networks makes water management a critical factor for crop sustainability. Soils and land quality. The area is characterized by light sierozem soils, alluvial deposits, and saline soils in low-lying areas. Secondary salinization caused by shallow groundwater and irrigation return flows is a significant issue, reducing productivity. Soil fertility is generally low, requiring careful management and crop selection. Cropping systems. Major crops include wheat, cotton, alfalfa, maize, vegetables, and sunflower. Irrigation is mostly by furrows, although drip and sprinkler systems are being introduced in some farms. Crop yields are highly dependent on water availability, soil salinity, and heat stress—conditions that demand precision planning. Karshi District provides an ideal case study for developing an online system for optimal crop placement. Its combination of water scarcity, salinity, diverse cropping patterns, and available remote sensing data makes it a suitable model for sustainable agriculture in desert regions.

DATA COLLECTION AND METHODS

Data Collection. This study employed multi-temporal satellite imagery from Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). Landsat 8 provides multispectral data at 30 m spatial resolution and thermal data at 100 m (resampled to 30 m), which are suitable for regional-scale agricultural analysis. Scenes covering Karshi District and its agricultural lands were selected for the main vegetation periods to capture crop growth dynamics. Cloud-free images (less than 10% cloud cover) were prioritized.

The imagery was accessed and processed through Google Earth Engine (GEE), which provides a cloud-based platform for large-scale geospatial analysis. Pre-processing steps such as radiometric calibration, atmospheric correction, mosaicking, and clipping to the district boundary were performed automatically within GEE, ensuring consistency and efficiency.

Vegetation and environmental indices were calculated from Landsat 8 imagery, including:
Normalized Difference Vegetation Index (NDVI) – crop vigor and biomass;
Soil Adjusted Vegetation Index (SAVI) – vegetation under sparse cover;
Normalized Difference Water Index (NDWI) – soil and crop moisture conditions;
Land Surface Temperature (LST) – thermal stress monitoring.

These indicators were supplemented with ancillary datasets (soil maps, irrigation networks, and crop type statistics) obtained from local agricultural agencies for validation.

METHODS

The analysis was carried out entirely on Google Earth Engine (GEE), which enables automated processing of time-series satellite data. Landsat 8 imagery was filtered by date and location, followed by computation of vegetation indices and LST for each growing season. Temporal composites (seasonal averages and maxima) were generated to reduce cloud contamination and highlight crop growth stages.

Using the derived indicators, suitability maps were developed to identify zones favorable for specific crops based on vegetation vigor, soil moisture, salinity stress, and thermal conditions. The workflow in GEE allowed rapid visualization, spatial comparisons, and scalable mapping of crop placement scenarios.

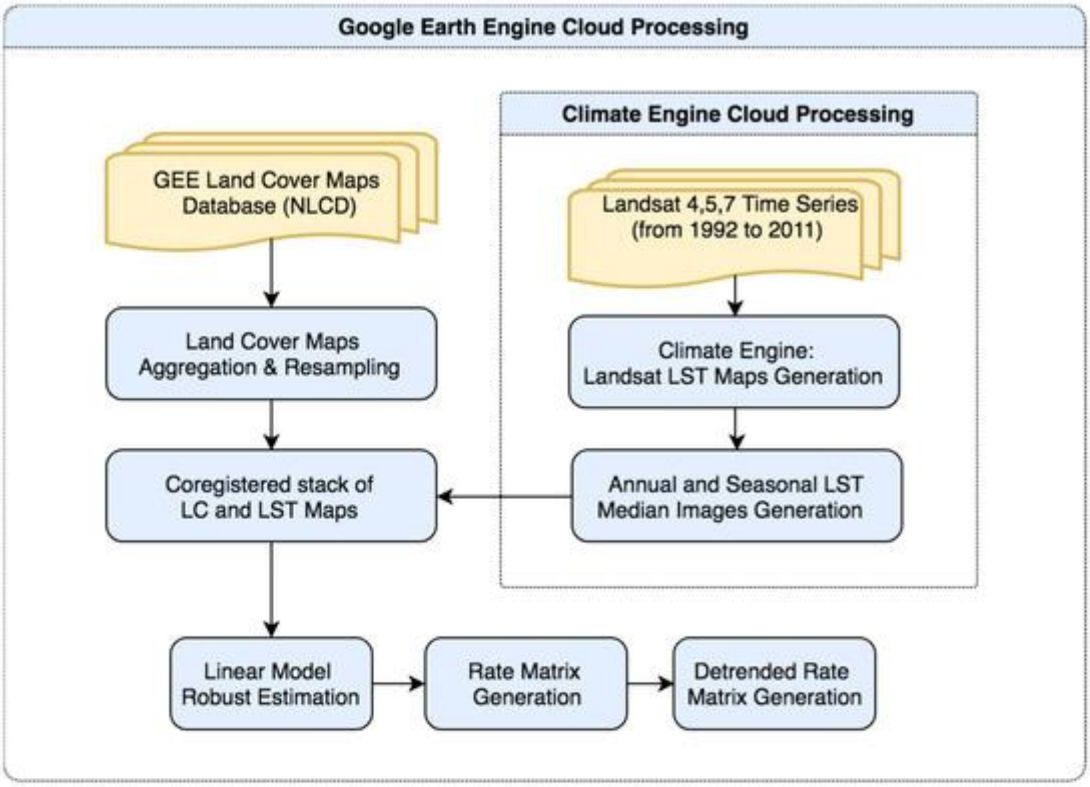

Figure 1: Model of an Online System for Crop Placement Using GEE

This integration of Landsat 8 data with Google Earth Engine provides a robust framework for creating an online decision-support system that supports optimal crop placement in desert agricultural regions like Karshi District.
The GEE module includes the following main stages:

a) Data uploading and preprocessing

```
var region = ee.Geometry. Rectangle([65, 40, 67, 42]); // O‘rganilayotgan hudud
var image = ee.ImageCollection("COPERNICUS/S2")
  .filterBounds(region)
  .filterDate("2024-01-01", "2024-12-31")
  .median();
```

b) NDVI calculation and allocation of suitable areas for crops

```
var ndvi = image.normalizedDifference(["B8", "B4"]).rename("NDVI");
var ndviThreshold = ndvi.gt(0.4); // Yaxshi vegetatsiyali hududlar
```

c) Assessment of soil moisture and terrain

```
var dem = ee.Image("USGS/SRTMGL1_003"); // SRTM relef ma’lumotlari
var slope = ee.Terrain.slope(dem);
var aspect = ee.Terrain.aspect(dem);
```

d) Mapping and visualization

```
Map.centerObject(region, 8);
Map.addLayer(ndvi, {min: 0, max: 1, palette: ["yellow", "green"]}, "NDVI");
Map.addLayer(slope, {min: 0, max: 30, palette: ["white", "black"]}, "Nishablik");
```

Integration and Connection to the Online Platform

GEE Web Platform: Operates directly in the Google Earth Engine code editor.
Usage via Web-App or API: Results are sent to a web service or GIS system through the GEE Export function.
If you want to develop this module further, integration with the GEE Python API and GIS platforms (QGIS, ArcGIS) is also possible. The module can be further enhanced based on your research scope and objectives.

The online system for optimal crop placement is primarily designed to ensure the efficient distribution and management of agricultural lands.

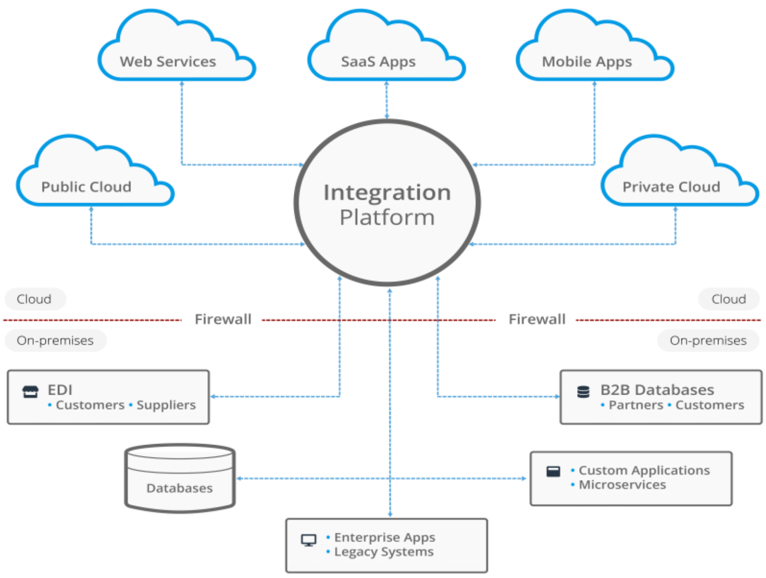

Figure 2: Operational Module of ArcGIS Online Dashboard for Crop Placement

In this system, the ArcGIS Online Dashboard operational module plays a crucial role due to its convenience and visualization capabilities.

RESULTS

As supplementary data for the research, the bonitet (soil quality) map of the study area for 2023 was adopted and utilized during the data processing stage. Soil fertility was assessed by working plots (technological fields), and their level of agricultural use was classified into five categories. Based on the distribution of these categories within wheat fields, analytical assessments were carried out. The increase in bonitet indicators, reflecting improvements in soil fertility, was visualized using color codes: 30 – dark orange, 50 – yellow, 60 – light green, and 70 – dark green.

The main characteristics of soil and natural conditions such as genetic soil types, mechanical composition, erosion, salinization, flooding, gypsum content, thermal resources, and other environmental factors were taken into account for their influence on vegetation processes. The growth and developmental stages of plants, as well as the ripening periods of crops, were identified. In the process of visualizing and evaluating the research outcomes, the Normalized Difference Salinity Index (NDSI) was adopted as a key parameter, and its correlation with the bonitet level was analyzed.

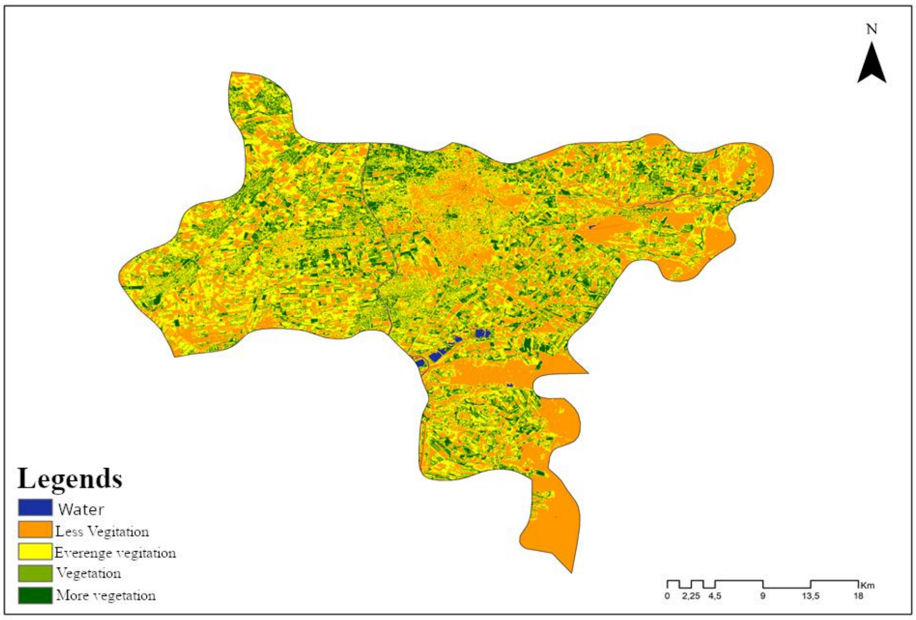

Figure 3: NDVI analysis values of greenness in Karshi district

Statistical analysis was performed in the R studio program, with 34 randomly selected pixels for each bonnet class. In the presented graph, the increase in the main status with the increase in the bonnet class was clearly traced. For example, the medians are, respectively, 0.32; 0.39; 0.42; 0.49 from the bonnet from 40 to 70 years. The asymmetry results in a Botine of 50 Botine equal to 5.

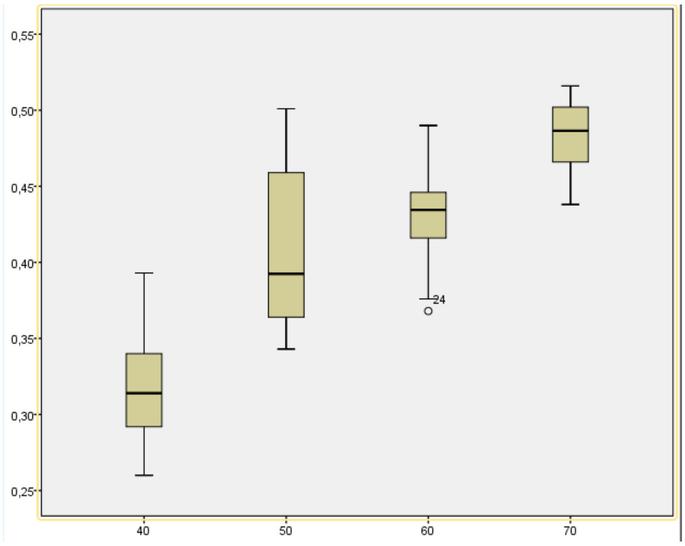

Figure 4: NDVI analysis values are related to soil salinity and vegetation

Thus, it was concluded that the NDVI index is closely related to soil quality, depending on the possibilities of spectral analysis of agricultural land.

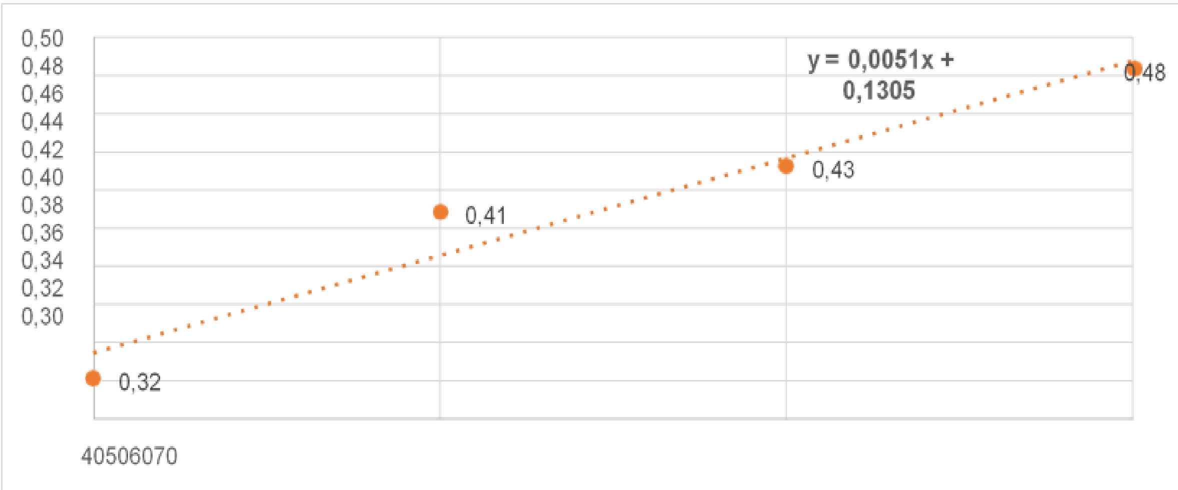

Figure 5: Correlation of NDVI analysis values with soil salinity and vegetation values

The state of land reclamation, in particular, can be expressed in the form of different bonnet classes. The Person correlation coefficient is 0.87, R2 = 0.91 (see Figure 5). The increase in the bonnet class increases in proportion to the average value of the normalized vegetation index, which is characteristic of the state and development of the plant.

CONCLUSION

Traditional methods for crop placement in desert regions are not yielding effective results because natural conditions in such areas are variable and complex. Therefore, it is necessary to develop advanced methods based on geoinformation technologies.

Optimal Area Selection: In desert regions, factors such as soil water permeability, humus content, and climate conditions (e.g., temperature and precipitation levels) are studied for crop placement. Using GIS, this data is combined to identify the most optimal locations.

Developing Efficient Irrigation Systems in Water-Scarce Areas: Water resource scarcity remains a major issue in arid regions. Using remote sensing data and GIS technologies, water resources, land dehydration levels, and potential irrigation systems in the area are analyzed. Based on this, efficient irrigation systems are designed.

Crop Type Selection and Rotation Methods: In desert regions, only suitable crop types should be planted. GIS-based analysis of land and climate conditions can determine appropriate crops and their rotation.

Soil Conservation and Fertility Enhancement: In desert regions, soil fertility can decline rapidly. Geoinformation technologies enable continuous monitoring of soil conditions and the development of optimal crop placement methods. Improved techniques for soil conservation and fertility enhancement are identified.

Monitoring and Evaluation System: Continuous monitoring of the effectiveness of crop placement is essential. GIS systems analyze crop development, productivity, and climate changes, allowing necessary adjustments to be made over time.

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