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ASSESSMENT OF THE LAND RECLAMATION CONDITION USING GIS TECHNIQUES AND ENVIRONMENTAL VARIABLES: CASE STUDY IN KULAVAT CANAL IRRIGATION SYSTEM, KHOREZM

ABSTRACT

The aim of this study is quantitatively assessment and map land reclamation condition in irrigated croplands of Kulavat canal irrigation system. Environmental variables, such as soil texture, salinity and bonitet, groundwater table and salinity, distance to irrigation systems and density of drainage networks, are the main datasets required for assessing land reclamation condition. These data were extracted and manipulated in geographic information system (GIS) as thematic layers. Spatial analyst function in GIS software was used to detect spatial distribution of variablesand assessing the land reclamation condition, of which the map of environmentally sensitive areas of study area is produced. The results obtained reveals that the study area comprises of three sensitivity classes such as good, medium and low condition, on basis of the stratification map. It is seen that the low areas for land reclamation condition in study area are found in the north-western and south-eastern parts, these areas represent 7 % of the total irrigated lands in study area (26,700 ha). The areas of mediumcondition represent 47 % of the total area. The areas of good condition comprise 33 % of the total area. The other parts (13 %) of the study area belong tonon-assessed class. By noticing the evaluation of environmental factors, the soil (texture), land condition (groundwater table) and water availability (distance to the irrigation systems) have the intensive effect on land reclamation condition throughout the study region. A GIS tool hasa potential to generate such as mapsthat can be used in specific land management improvement programs.

KEYWORDS: land reclamation condition, remote sensing, GIS, Khorezm

INTRODUCTION

Population growth and climate variability necessitate using available land and water resources effectively to maintain sustainable agricultural production in the Central Asian countries, especially in lowlands of the Amudarya and Syrdarya rivers. Whereas mismanagement of land and especially water resources caused land degradation and yield loss. As generally, applied in land reclamation condition assessment by ameliorative expedition in Uzbekistan, conventional methodology is based on qualitative analysis of information derived from network of piezometer wells

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(e.g., groundwater table and salinity) and sampling sites (e.g. soil salinity). This method has certain disadvantages in terms of the time and cost required for objective assessment and interpretation of land reclamation condition. Meantime resulted information in terms of map should provide quantification within and between field variability and thus has to be representative for the given region. It is clear that, land reclamation condition is affected not only with three datasets, but by variable environmental conditions and management factors such as soil texture, fertility, water availability, drainage density and so on, among others. These environmental variables can be distinguished and mapped by using certain key indicators [*Kairis et al.,* 2014] for assessing the land capability to withstand further degradation, or the land suitability for supporting specific types of land use. In addition, it is often advantageous to aggregate several indicators into an index allowing different factors to be taken into account simultaneously in order to monitor the state of the environment or compare different sub-systems [*Basso et al.,* 2000]. However, combined assessment of available variables is still lucking in Uzbekistan in particular and in Central Asia in whole. How can the available data from different organizations be integrated? What are the relationships amongst the factors? These are major issues which are not easily resolved. It is, however, only through an integrated, multi-level, approach that both the land and water management and the existing interactions amongst the individual components of the landscape can be evaluated. In response to these problems, main goal of this study is to quantitatively assess and map land reclamation condition in irrigated croplands of Kulavat canal irrigation system with application of relatively new methodology — “overlaying” or so called “stratification” that allows to find out environmentally sensitive areas, on which further land improvement measures can be taken. Created method in a GIS environment simplifies data handling, provides ease of access to the information acquired and its timely updating, and enhances interpretation by facilitating cross data analysis procedures and the application of sophisticated classifications. It is also possible to retrieve and analyze transformation phenomena quickly, as they progress, in order to identify and instigate the necessary intervention.

MATERIALS AND METHODS OF RESEARCHES

Study area

The study site is located in left bank plain of the Amudarya River within “Kulavat” irrigation command area (ICA) of Khorezm, Uzbekistan (fig.1a, b). The site covering an area of approximately 42,000 ha lies within the northern climatic zone. According to Köppen-Geiger climate classification map, the site is classified as arid and cold desert climate (BWk) [*Kottek et al.,* 2006].

With scars and uneven distribution of mean annual precipitation of 94 mm year^{-1} and high evaporation rate of 1400−1600 mm year^{-1}, water from the Amudarya River is main source in practicing irrigated agriculture. Soils in the study site are formed under the influence of water from the meandering Amudarya River [*Kats,* 1976]. Total length of irrigation and collector-drainage network in the study area are 1614 and 1025 km, respectively (fig. 1c) where specific length of in-farm irrigation (63 m ha^{-1}) and drainage (32 m ha^{-1}) network are denser compared to average values (51 and 25 m ha^{-1}, respectively) in the Khorezm province.

The thematic layers

The three main criteria were considered when selecting the information layers for the study:

- the extent of the data coverage;
- the ease of updating the data quickly and economically;
- the fact that the structure of the system will allow the information layers to be refined, developed, or removed as appropriate in the light of experience.

The sources and mapping scale of the data used to create thematic layers in GIS are given in table 1.

Soil texture, soil salinity and soil bonitet maps of the study area at 1: 25 000 scale was acquired from Scientific Research Institute of Soil Science and Agrochemistry (SRISSA) and State Committee of Land resources, geodesy, cartography and cadaster (Goscomzem). The maps containing texture information up to 2−3 m, bonity scores within 30−80 balls and salinity level up to 5 classes were scanned, digitized and geo-referenced in Khorezm Rural Advisory Support Service (KRASS) using georeferencing extension in ArcMap™ 9.2. In this study soil texture at 0−2 m was average weighted in order to create one-layer soil texture map. The Normalized Differential Vegetation Index (NDVI) was calculated using the following equation [*Rouse et al.*, 1973]:

$$NDVI = \frac{(R_{NIR} - R_{red})}{(R_{NIR} + R_{red})}.$$

Where R_{NIR} and R_{red} spectral bands of Landsat-8 OLI data in near infrared (0.851–0.879 μm) and red (0.636–0.673 μm) spectrum, respectively. The eleven scenes of Landsat-8 data during 2013−2015 was used in order to calculate NDVI values. In this study mean NDVI value during the period was used.

Irrigation and drainage network map at the scale 1: 25 000 was acquired from Samarkand Aero geodetic Enterprise of the Administrative Board of geodesy and cartography; scanned, digitized and geo-referenced in KRASS. These maps then used to create irrigation and drainage density classesusing spatial analyst function in GIS.

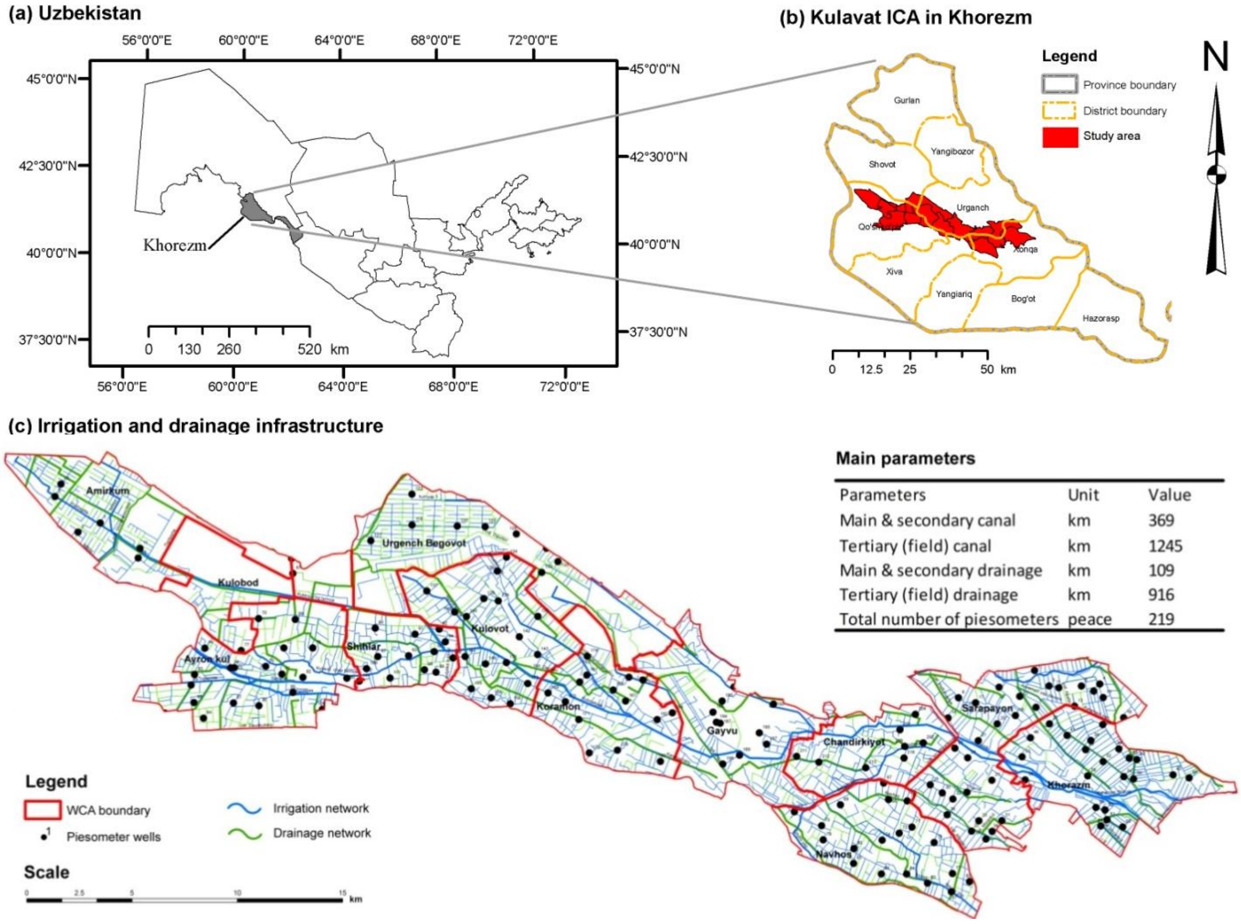

Fig. 1. Location of Khorezm region, Uzbekistan (a), study area (b) and main land reclamation infrastructures in study area (c)

Table 1. Source and scale of agro-ecological parameters used in GIS

No	Parameters	Scale	Year	Source of data	Remarks
1	Soil texture map with explications	1: 25 000	2005	SRISSA	Scientific Research Institute of Soil Science and Agrochemistry (SRISSA), Uzbekistan
2	Soil bonitet map	1: 25 000	1999	Goskomzem − SRISSA	State Committee of Land resources, geodesy, cartography and cadaster (Goscomzem) − SRISSA
3	Soil salinity map	1: 25 000	2001−2003	ME	Melioration Expedition (ME), Khorezm branch
4	NDVI map	30 m	2013−15	Landsat 8 OLI	cloud-free Landsat-8 OLI archive data were acquired through EarthExplorer at http://earthexplorer.usgs.gov
5	Irrigation network	1: 25 000	2001−10	SamAeroGeod	Samarkand Aero geodetic Enterprise of the Admin. Board of geodesy and cartography, 2001 (recorrection was done 2010)
6	Drainage network	1: 25 000	2001−10	SamAeroGeod	Samarkand Aero geodetic Enterprise of the Admin. Board of geodesy and cartography, 2001 (recorrection was done 2010)
7	Groundwater table map	GPS base coordinates	1990−2004	ME	Melioration Expedition (ME), Khorezm branch
8	Groundwater salinity map	GPS base coordinates	1990−2004	ME	Melioration Expedition (ME), Khorezm branch

Long-term observations (1990−2004) at a 10-daily basis on groundwater table (GWT) and seasonal (April, July, October) basis on GW salinity were obtained from the Khorezm Melioration Expedition (ME) of the Ministry of Agriculture and Water Resources Management (MAWR). Spatial distribution of average long-term vegetation period (April-September) GWT and GW salinity were mapped through inverse distance weighting (IDW) method in ArcMapTM environment [*Kenjabaev, Sultonov,* 2016]. The quantification of different environmentally sensitive areas at the canal system scale was carried out by evaluating the overall influence that single information layers have on the phenomena under study. The first tasks were to establish a data bank and develop suitable techniques to manage the information layers whilst accommodating their different types and levels of detail. Intermediate and final maps were produced after the various elementary layers were rasterized, registered, and referenced to an elementary pixel size of 30x30 m which is the ground resolution of the most detailed layer in the data base of Landsat-8 OLI.

RESULTS OF RESEARCHES AND THEIR DISCUSSION

Agro-ecological layers

The current working set of thematic layers to construct the categories for assessing land reclamation condition in the study area is given in fig. 2. Soils in the site according to USDA soil texture classification are dominated by medium loams (41 %) which together with light loams and sands constitute 89 % of all soils in the study area (fig. 2A). These soils are also dominated in irrigated lands of Khorezm province (86 %) [*Kenjabaev, Sultonov,* 2016]. The medium and high salinity of soils in the study area comprise 67 % of total lands (fig. 2B). The yielding capacity of the agricultural crops in irrigated lands is determined by ‘bonitet ball’ which describes the soil fertility and capability measured on a 100-point scale. From total assessed land area of 34,864 ha in Kulavat, 34 % is below average (e.g., < 50 ball, fig. 2C). The NDVI values (fig. 2D) increases from 0.30 to 0.90 from the direction of north-west to south-east owing sandy soil in the north and high soil fertility in the south (fig. 2C).

Irrigation density is higher (3.5−7.1) in the south-east (fig. 2E) being intensive installation of irrigation network starting from head of Kulavat canal. Whereas drainage density is higher in the north to north-west (fig. 2F) due to densely installation, in order to capture and diverge excess groundwater from the territory. About 50 % of lands in the study area were covered by shallow GWT depth (0−1.5 m) during the vegetation period (fig. 2G) which is higher than the critical threshold of 1.5 m defined for the Khorezm Region. About 98.7 % of total land area in study site has GW salinity ≤ 3 g/l during the vegetation period (fig. 2H).

Environmentally sensitive areas

Figure 3 shows environmentally sensitive classes of study area. The results obtained reveals that the study area comprises of three sensitivity classes such as good, medium and low. It is seen that the low areas for land reclamation condition in study area are found in the north-western and south-eastern parts, these areas represent 7 % of the total irrigated lands in study area (26 700 ha). The areas of medium condition represent 47 % of the total area. The areas of good condition comprise 33 % of the total area. The other parts (13 %) of the study area belong to non-assessed class. By noticing the evaluation of environmental factors, the soil (texture), land condition (groundwater table) and water availability (distance to the irrigation systems) have the intensive effect on environmental sensitivity throughout the study region.

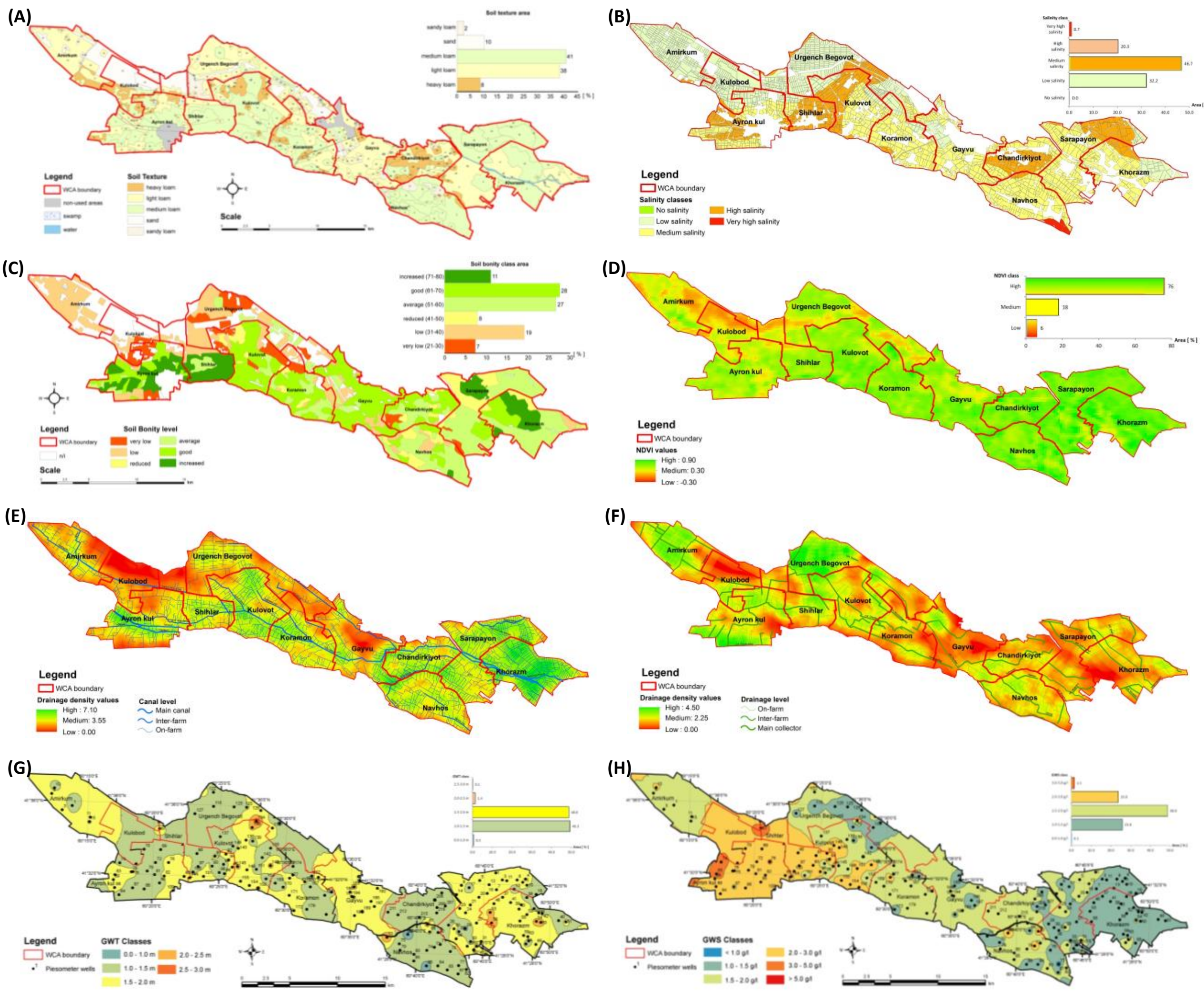

Fig. 2. Produced agro-ecological layers in GIS comprising: Soil texture (A), Soil salinity (B), Soil bonitet (C), Mean Normalized Vegetation Index, NDVI (D), Irrigation network density (E), Drainage network density (F), Mena groundwater table (G), Mean groundwater salinity (H)

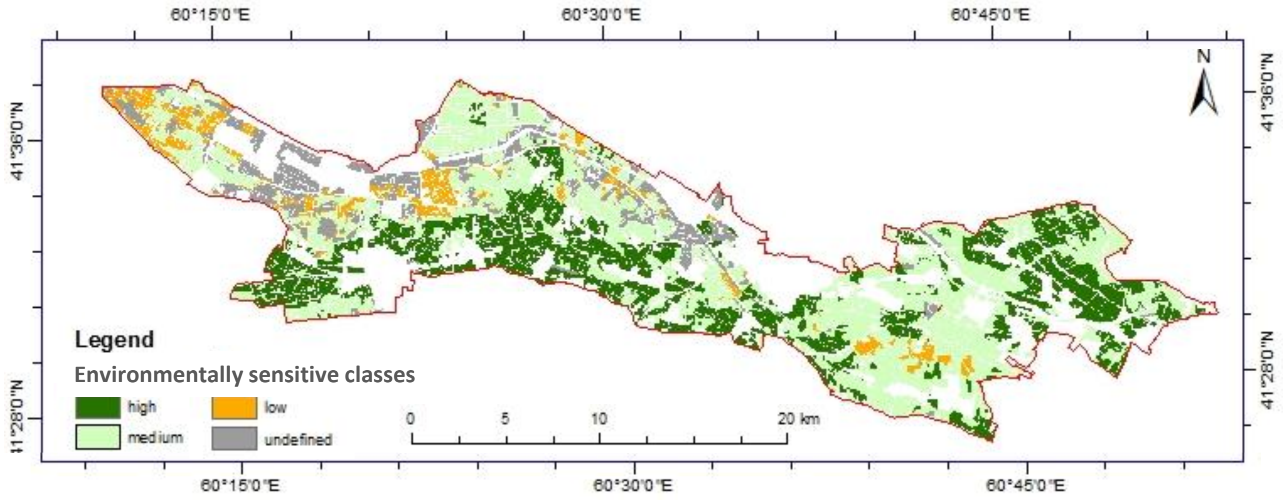

Fig. 3 Environmentally sensitive areas of the study area

CONCLUSIONS

The GIS software, with available soil, vegetation, hydrological and infrastructure data was successfully employed to create thematic layers and to assess environmentally sensitive areas in Kulavat canal irrigation system. The proposed approach allowsidentifying and understanding the factors thatcombine and accelerate land degradation in order to adequately manage the land and itsresources. Establishing systems for analysis of land reclamation condition using environmental information which is difficult or expensive to collect, update, or upgrade, even if valid scientifically, will have limited utility when used for large, complex environments or when used for continuous monitoring. With the proposed approach of stratification, the layers can be added or removed as necessary: some layers might be incorporated because it was desirable to investigate some particular aspect of a defined environment in detail, others might be added simply as a first approximation owing to the difficulty of obtaining data or from inadequate knowledge. Meanwhile, the approach can be used for bigger areas such as district (administrative irrigation system, AIS), province (basin administrative irrigation systems, BAIS), national (sub-basin) and regional (Amudarya and Syrdarya river basins).

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