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GIS based analysis of agricultural production (Wheat), water estimation and effects of climate change on Gujranwala, Pakistan from 2008 to 2018

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Abstract

This study examines the temporal analysis change in agricultural activities of Gujranwala, Pakistan. Global warming is expected to have an intense effect on earth's environment and vegetation overwhelm the distribution and abundance of food. Past researches explains the ability of different crops to cope up according to the magnitude of temperature change and their phenology. Pakistan is located in tropical region majorly, wheat crop is extensively produced and generates a lot of income for farmers. This research evaluates the increase of wheat crop in Gujranwala from 2008 to 2018 for the month of November. For this purpose vegetation cover or agricultural activities were monitored for said period by using Remote Sensing (RS) and Geographic Information Systems (GIS). LANDSAT 8 (30m per pixel) for both years were taken for analysis and to thematically map results. This research considers three parameters which includes Land Use and Land Cover (LULC) of Gujranwala in relation with Normalized difference Vegetation Index (NDVI). In addition, assimilation of surface soil moisture was another focus part of this study in order to create water demand estimation for agriculture.

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Introduction

Climate change impacts agricultural activities and it is highly activated by day to day growth in greenhouse gases which comprises of carbon dioxide, nitrous oxide and methane gases (Lambin *et al.,* 2003). This climatic change encompasses as a result of shift in rainfall pattern, temperature increase, evapotranspiration, floods, droughts and degradation of water and land resources. Globally, land use and land cover changes (LULC) are well familiar. Many past researches and analysis manifest that human activities such as population growth, over urbanization and intensive agriculture with prompt economic development has reform Earth's surface, which causes environmental changes (Samie *et al.,* 2017). Therefore, human intrusion is the key factor that affects climate, which act different at different regions of the earth.

Majorly, the economy of Pakistan depends upon the agriculture sector as it generates 25% (one fourth) of total gross domestic product (GDP). Almost 66% of the total Pakistan's population is settled in rural areas and their main source of work is farming (Kurosaki, 1995). In Pakistan, agricultural is categorized into two cropping seasons: kharif (monsoon) and rabi (non-monsoon). Kharif season has bajra, jowar, maize, millet, rice, sugarcane, cotton and soybean whereas rabi crops consists of wheat and mustard (Zuberi, 1989). These crops are producing economy of Pakistan but in recent years due to improper irrigation facilities, raised evapotranspiration and increased temperature soil has lost its moisture.

Gujranwala is a fast growing industrial city and located about 70 kilometers north of Lahore, the capital of Punjab province in Pakistan (Altaf and Deshzao, 1996). Its geographical coordinates are 32.160N, 74.180 E and is 226 meter (744 feet) above sea level (Altaf and Deshazo, 1996). Gujranwala is the fifth largest city of Pakistan and it lies on Grand Trunk (GT) road which was built by Emperor Sher Shah Suri in 16th Century. This city consists of several commercial and industrial centers for the manufacturing of ceramics, metals, tools, leather, utensils, fans, textiles and agricultural market. Climate of city is mainly impact by its inland position. Dry and hot climate with extreme high temperature are experienced in summers, similarly winters are cold. Annual temperatures of city are 30.90C in summers while 18.80C in winters are recorded (Mahmood *et al.,* 2011).

Wheat is the major cash crop and plays an important role in the economy of Gujranwala as the climatic conditions of city is favorable for its production. According to Space and Upper Atmosphere Research Commission Pakistan (SUPARCO), the conductive factors for wheat production includes prolonged sunlight hours and high photosynthetic process. Statistics shows that temperature is increasing every year therefore the yield of wheat is also raising which ultimately multiplies the GDP. On the other side, heavy rainfall, enriched soil moisture, flood condition is not suitable for wheat growth (hafizabad, 2015). Wheat crop is grown in winter season of every year. Sowing of wheat takes place in October particularly in rain fed areas, almost 70% has been completed by the end of November. While, the harvesting is done during the months of February and May (Batool and Javaid, 2018).

This research study investigates the contrast of vegetation covered, soil moisture along with the water demand estimation for agriculture over the span of 8 years for Gujranwala, Pakistan. For analysis LANDSAT satellite images were taken and NDVI, LULC was applied through techniques of GIS and RS.

Materials and methods

Study area

Land Use Land Cover Classification

Land use and land cover shares distinct relationship on both regional and global scales. Land use categorize or classify human settlement, urbanization and agriculture which includes various forms of cultivation, livestock grazing. Whereas, land cover comprises of the biodiversity, environment, climate and natural cover of land (Turner *et al.,* 1994). These LULC changes have sequel upon climatic variabilities on local, regional and global environment. Resultantly, the extreme use of land changes the land cover (e.g., from grassland to degraded grassland by over grazing) (Desalegn *et al.,* 2014).

In Remote Sensing (RS) and Geographic Information System (GIS) applications, changes are appraise as surface element to find contrast temporally. LULC change information is significant because of its practical uses for different purposes with special emphasis on agriculture land identification, monitoring and management. In this research study, LULC has been mapped to analyze the land changes experienced in Gujranwala from year 2008 to 2018.

Normalized Difference Vegetation Index (NDVI)

Anthropogenic activities are highly affecting ecosystems and great stress is on vegetation, globally. Distributing vegetation cover is not only about land cover pattern but it also comes with the shortage of food and agricultural facilities of the country. Monitoring of vegetation cover, for the maintenance and sustainability of the healthy life should be supreme. Vegetation cover and open green spaces plays chief role in maintaining ecosystem, environment and climate of the earth. Remote sensing has made things easier for the detection and monitoring of vegetation even on larger scale. With the passage of time land covers are changing some of them are naturally while mostly are due to human intrusions. NDVI is one of the important key factor to calculate the presence of vegetation in a particular area of interest. NDVI has many applications and is most used indices for vegetation monitoring, moisture detection in crops and also crop stress (Owe *et al.,* 2001). Values of NDVI ranges from -1 to +1, that ranges for different scales and levels of vegetation and their classes.

$$NDVI= (NIR-R) / (NIR+R) \qquad \text{(Eq. 1)}$$

In the above equation (Eq. 1) the calculative measure of vegetation index by NDVI is mentioned. Near Infra-Red (NIR) is subtracted with Red (R) wavelength than divided by NIR is added with R wavelength.

Surface Soil Moisture

Soil moisture is the volatile environmental component that composite the effect of climate, soil and vegetation or greenery on the vigorously water restricted ecosystems. Many researches communicate that enriched soil moisture is found in agricultural landscapes rather in bare soil, therefore, green spaces are always recommend to grow however the amount of precipitation also varies (Ali *et al.,* 2017).

According to the National Aeronautics and Space Administration (NASA), (Owe *et al.,* 2001) globally, the natural environmental circulation takes places between land surface and the atmosphere. Surface moisture is a link that is directly involve in exchanging heat and moisture betwixt land and atmosphere. The soil moisture content is a variable element because it keeps on changing due to less or high rainfall, evapotranspiration and irrigation or agricultural activities. Surface soil moisture is important in estimating water demand as it keep the balance. However, the moisture is often somewhat difficult to calculate on larger scale but in Remote Sensing (RS) it is easier to measure.

Results and discussion

Supervised Classification Gujranwala, 2008

Land cover change assessment is one of the main application of remotely sensed data. A number of pixel based classification algorithms have been developed over the past years for different analysis in RS and GIS. The most notable is maximum likelihood supervised classification (D'Odorico *et al.,* 2007). For this study, LANDSAT 8 satellite images of years (2008 and 2018) were acquired for vegetation cover assessment. After the pre-processing steps, on screen visual interpretation was carried out for both years and changes were elucidated. Visual interpretation and supervised classification were employed to represent the map of LULC.

For the estimation of LULC year 2008 LANDSAT (November, 28th) six classes were classified as low vegetation, high vegetation, reserved forest, open land, urban area and water bodies. According to the examination of year 2008 as shown in Fig.1, high vegetation was classified as 286.42 sq km pixel value, low vegetation counts 1528.62 sq km, reserved forest 24.645 sq km, open land 1348.57 sq km, urban 361.174 sq km and for water bodies 49.958 sq km respectively.

Supervised Classification Gujranwala, 2018

For the contrast examination of both years (2008 and 2018) satellite image of Gujranwala 2018 (November, 8th) was obtained from LANDSAT 8. Similar, six classes were set as low vegetation, high vegetation, reserved forest, open land, urban area and water bodies for the execution of analysis. The temporal analysis of year 2008 with 2018 were quite different and changed. As elaborated from Table 2 and shown from Graph 2, high vegetation has increased its area from 286.42 sq km to 970.584 sq km or in other words 8% to 27% vegetation cover has been expand in these 10 years. Correspondingly, urban area has grew larger from 361.17 to 696.82 sq km almost 9% of urban growth has been monitored. On the other side, open land has reduced its percentage from 37% to 15% in past period. Overall, vegetation has shown inflation in terms of water bodies and reserved forest but low vegetation cover has lessen the percentage from 43% to 33% as shown in Fig. 2.

Table 1. LULC Supervised Classification Gujranwala, 2008.

LULC Gujranwala (Year 2008)		
Class	Area (sq km)	Percentage
Urban	361.1742	10%
Water	49.95843	1%
Reserved forest	24.64503	1%
Low vegetation	1528.622	43%
High vegetation	286.4255	8%
Open land	1348.575	37%

Table 2. LULC Supervised Classification Gujranwala, 2018.

LULC Gujranwala (Year 2018)		
Class	Area (sq km)	Percentage
Urban	696.8272	19%
Water	60.75774	2%
Reserved forest	130.7504	4%
Low vegetation	1204.408	33%
High vegetation	970.5845	27%
Open land	553.694	15%

Graph 1. LULC Supervised Classification Gujranwala, 2008.

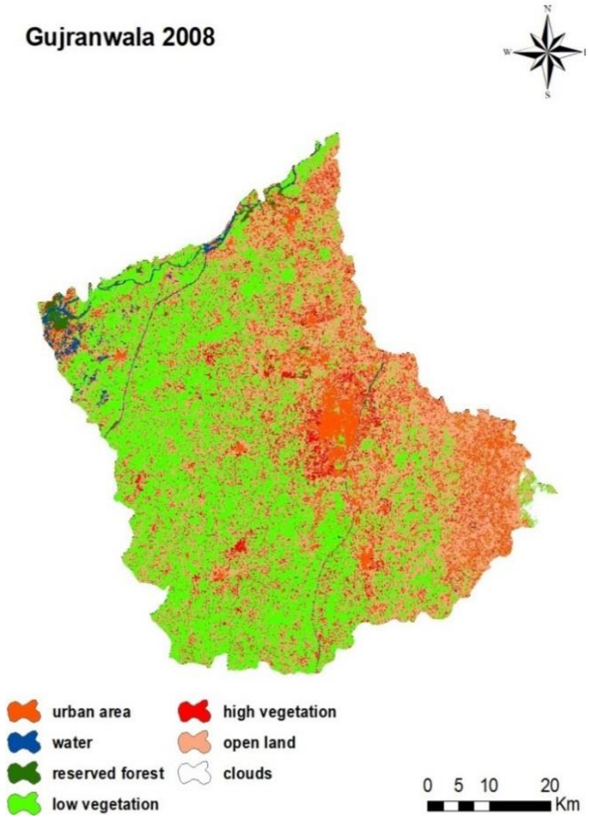

Fig. 1. LULC Supervised Classification Gujranwala, 2008.

Graph 2. LULC Supervised Classification Gujranwala, 2018.

Normalized Difference Vegetation Index (NDVI) 2008 and 2018

In Fig. 3 (a) and (b) Maps show the values of NDVI calculated for vegetated and non- vegetated class of Gujranwala. In year 2008, as conveyed in Fig. 3 (a) the vegetated class ranges value between 0.103 - 0.654. Whereas, in year 2018 vegetation has been increased by 0.103 to 0.934 as depicted in Fig. 3 (b) both maps also communicate that the use of non-vegetated land has been lower down over the span of 10 years.

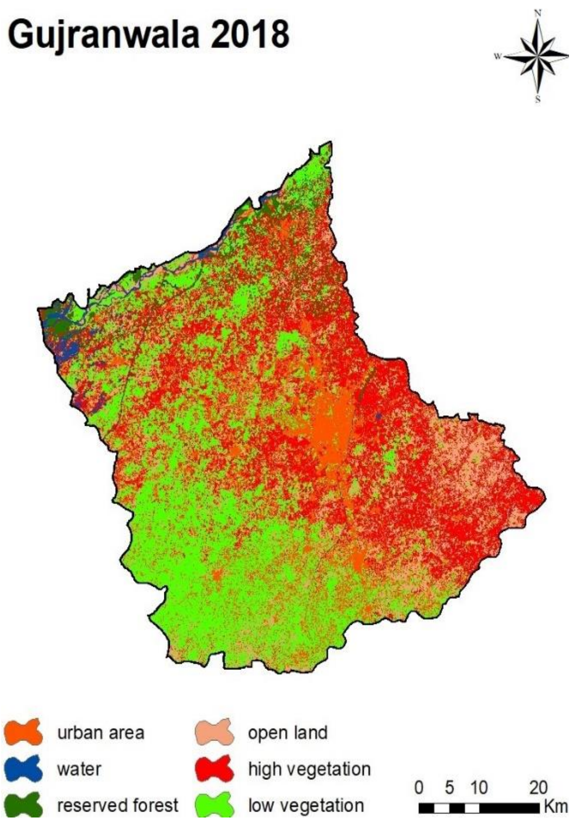

Fig. 2. LULC Supervised Classification Gujranwala, 2018.

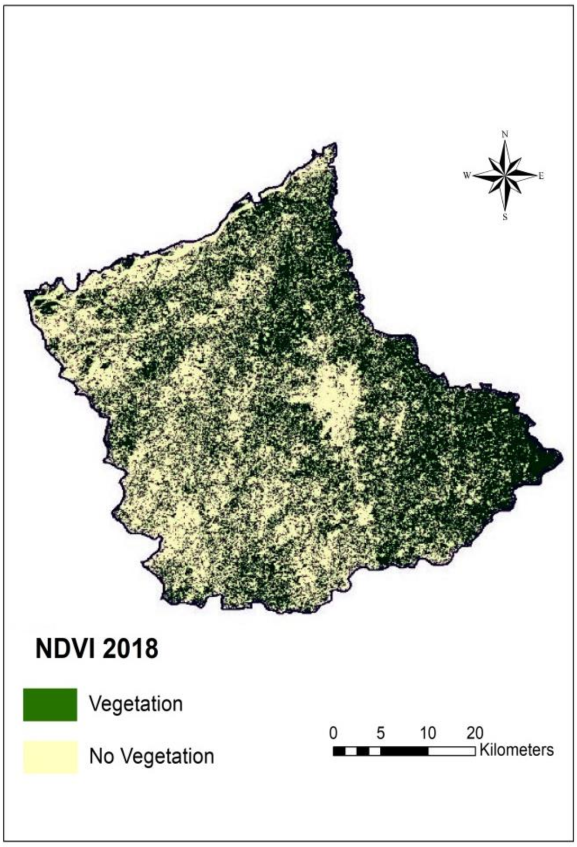

Fig. 3 (b). NDVI Gujranwala, 2018.

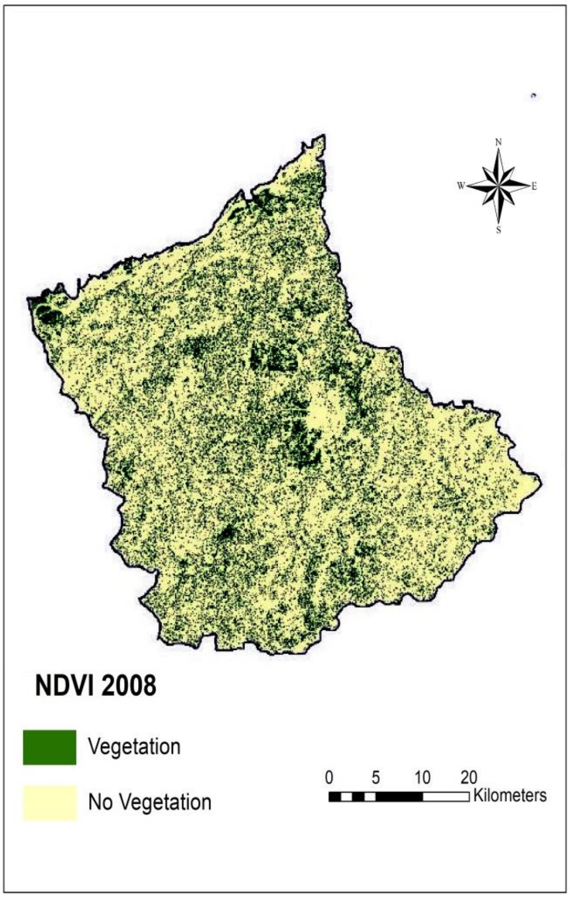

Fig. 3(a). NDVI Gujranwala, 2008.

Surface Soil Moisture

Surface soil moisture is important in estimating water demand as it keep the balance. However, the moisture is often somewhat difficult to calculate on larger scale but in Remote Sensing (RS) it is easier to measure. In this study, the soil moisture of Gujranwala for year 2015 and 2018 has been taken from the website of NASA. The data acquisition of surface soil moisture depicts the presence of water under the earth's surface temporally as shown in both Fig. 4 (a) and (b).

In this research study, it has been figure d out that soil moisture has been turn down in previous three year. The evapotranspiration has raised its influence due to increased intensity of temperature in Gujranwala and resultantly soil moisture has lessened. In year 2015, as portray by Fig. 4 (a) the highest value for soil moisture is 0.19317 (pixel value) is dwindled by 0.151161 by year 2018 as rendered in Fig. 4 (b). Whereas, contrariwise the lower values of soil moisture were recorded as 0.147147 (pixel value) to 0.111201 in past three years.

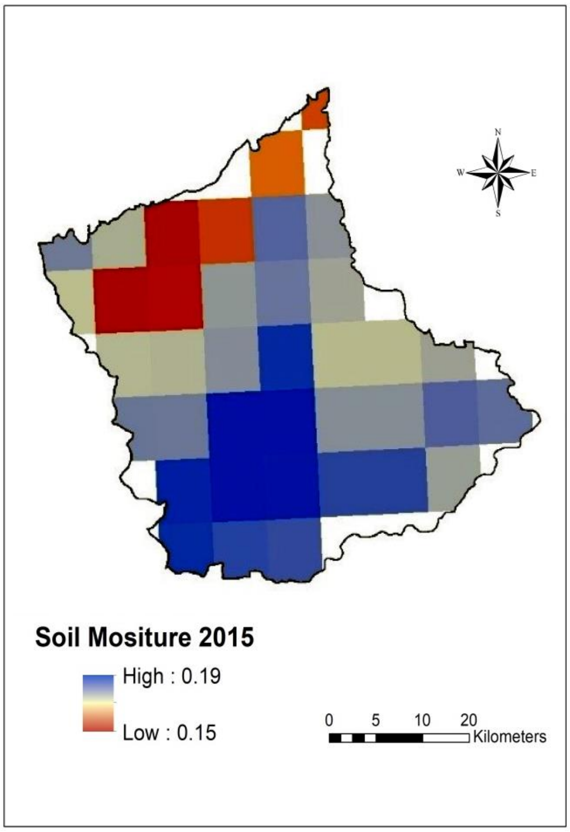

Fig. 4 (a). Surface Soil Moisture Gujranwala, 2015.

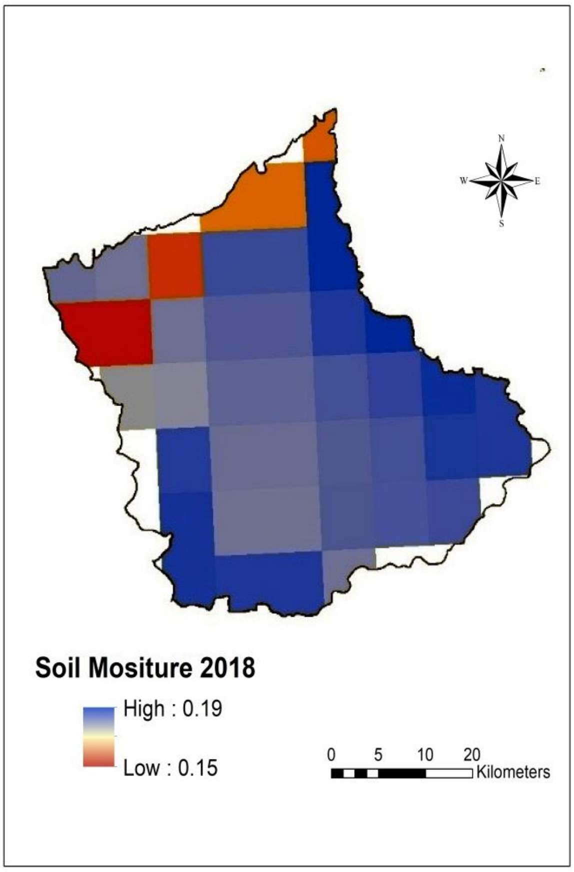

Fig. 4 (b). Surface Soil Moisture Gujranwala, 2018.

Conclusion

Wheat is a paramount staple food crop found in Pakistan hence, economy of Pakistan is majorly dependent on its production. It is equally dominant for agriculture and cattle grazing and feed. Climate of Pakistan is suitable for extensive production of wheat, it is sowed in winters and harvested in summers. Lower temperature is propitious and helps in growth, while intense temperature can hamper seedlings to grow. Correspondingly, rainfall can harm the harvesting of wheat therefore, dry summers are preferable. Long winters and irregular precipitation activities are not worthy for wheat in like manner. According to the food and security of Pakistan [16], it has been scrutinized that both high and lower temperatures showed significant influence on wheat production, while, statistics delineate that sunshine has produced positive effect on its yield. To conclude that, climatic variabilities are directly involved in the yield of wheat which means that changes in temperature can affect the production of wheat in Pakistan.

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