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RESEARCH ARTICLE

LAND USE LAND COVER CLASSIFICATION AND WHEAT YIELD PREDICTION IN THE LOWER CHENAB CANAL SYSTEM USING REMOTE SENSING AND GIS

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ABSTRACT

Reliable and timely information regarding area under wheat and its yield prediction can help in better management of the commodity. The remotely sensed data especially in combination with Geographic Information System (GIS) can provide an important and powerful tool for both, land use land cover (LULC) classification and crop yield prediction. The study objectives include LULC classification and wheat yield prediction. The study was conducted for Rabi Season from Nov. 2011 to April 2012, in the command area of three distributaries i.e. Khurrian Wala, Killian Wala and Mungi of Lower Chennai Canal (LCC) system. The Landsat-7 imagery data with spatial resolution of 30 m was used for this study. Physical features were monitored and assessed using Normalized Difference Vegetative Index (NDVI). LULC classification was done for wheat and non-wheat area which shows wheat proportion and area 87.22% and 28867.95 Ha in Khurrian wala, 71.07% and 22423.20 Ha in Killian Wala and 79.18% and 17974.34 Ha in Mungi distributary, respectively. The correlation values between maximum NDVI value and yield data were 0.45, 0.36 and 0.39 for Khurrian Wala, Killian Wala and Mungi distributary, respectively. On the basis of this correlation, average wheat yield was estimated as 3.48 T/Ha, 3.83 T/Ha and 3.80 T/Ha for Khurrian Wala, Killian Wala and Mungi distributary, respectively.

KEYWORDS

LULC, LandSat-7, NDVI, remote sensing and GIS, wheat yield prediction.

1. INTRODUCTION

Agriculture is the backbone of economy of most of the countries in the world by providing livelihood to 60% of the world's population. From the gross acreage cultivated and annually grain production point of view, wheat is an important world's staple food. Due to easy transportation, storage and usage, wheat is the dominant grain of world commerce (Gooding and Davies 1997). Regional scale yield data helps to identify areas with high or low yield which further allows management policies and analysis of temporal and spatial patterns for yields for enhanced understanding of control for crop production. These estimates are basis for management of agricultural lands, fixing prices of food and trade policies. Land use is the utilization of the land by humans for economic activities like agriculture, forests, construction, and farming (Waqas et al. 2019). Agriculture land areas are adapted and managed intensively through a variety of human activities, which can have a wide effect on hydrologic cycles, ecosystem functioning, patterns of land use and changes in environmental system. Therefore, timely and accurate crop yield prediction can play an important role for the future marketing and import/export policy of the country. With a population of 220 million, Pakistan is an agriculture country with fertile land and four seasons to grow crops round the year and wheat is being grown at 65% of total cultivable area. Resultantly, it is necessary to explain enhanced and advanced LULC classes which offer improved information to scientists and policy makers.

Various methods like agro-climate models, remote sensing techniques, statistical method and field sampling are being used for LULC and crop yield modelling(M J M Cheema and Bastiaanssen 2010; Fahad et al. 2019; Waqas et al. 2019). These methods, however, have many limitations like field data collection is resources intensive and personal biases often subjective to chance of errors. Remote sensing methods are the best among all due to their accuracy, less time consumption and better synoptic coverage for mapping the agriculture and water balance components (Awan et al. 2011; Awan, Tischbein, and Martius 2013; M J M Cheema and Bastiaanssen 2010; M J M Cheema, Immerzeel, and Bastiaanssen 2014; Muhammad Jehanzeb Masud Cheema et al. 2016; Karimi et al. 2013; Usman et al. 2015; Waqas et al. 2019; Waqas et al 2020). Satellite data also offers the direct calculation of Normalized Difference Vegetation Index (NDVI) values that monitor the biomass development and represents variation due to the changes in meteorological parameters (M J M Cheema and Bastiaanssen 2010; Waqas et al. 2019). NDVI values approaching to -1 refers to any water body, approaching to zero generally refers to barren land or snow and high values up to 1 refers to dense vegetation like tropical rainforests. A wide range of sensors with specific time series and spectral resolution, makes remote sensing more reliable and precise for LULC classification and yield modelling (M J M Cheema and Bastiaanssen 2010; Usman et al. 2015).

Remote sensing and GIS have diverse application in the crop production management components. Remote sensing data-based study for irrigated

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agriculture shows that freshwater have becomes an increasingly scarce resource, so there is need of serious concern about the water management (M J M Cheema, Immerzeel, and Bastiaanssen 2014; Waqas et al. 2019). (Awan et al. 2016) analyzed the equity of the water distribution in the irrigated area of the Indus basin using remote sensing. (Awan et al. 2017) presented the novel approach of the irrigation response using the satellite remote sensing. (Liaqat, Choi, and Awan 2015) assessed the actual evapotranspiration using the satellite derived energy balance. (Fahad et al. 2019) predicted the wheat yield based on the integration of satellite derived soil moisture into the crop models.

The present study was conducted for assessment of area under wheat and its yield prediction in command area of three distributaries of Lower Chenab canal system (LCC) i.e. Khurrian Wala, Killian Wala and Mungi distributary. The study was conducted for Rabi season 2011-2012.

2. DATA AND METHODS

2.1 Study Area

This study was conducted in the command areas of three distributaries of Lower Chenab Canal (LCC) system i.e. Khurrian Wala, Killian Wala and Mungi distributary, lies in Rechna Doab (area between Chenab River and Ravi River). The area lies from 30º34′ to 31º47′N and 72º10′ to 73º40′E, at an average elevation of 184 m above sea level (Fig. 1). The area comprises of three different agro-climatic zones (Table 1), i.e. the cotton-wheat zone, rice-wheat zone and a mix sugarcane-cotton-wheat zone (Waqas et al. 2019). The LCC takes off water from Khanki head works located on Chenab River. There LCC (East) Circle contains total four branch canals including Lower Gugera branch, Mian Ali branch, Upper Gugera branch and Burala branch. The quality of groundwater of the study area is sweet and fresh in some regions but in many regions its quality is poor. The area is fertile and rich in agriculture and the crust of this area is formed of alluvial soils, coming and settling through various floods. The area host very intensive and modern agriculture and land management practices. This area is arid in Rabi and semi-arid in Kharif with average rainfall of about 300mm/year which is highly seasonal. About 50% of total rain falls in moon season i.e. July and August and remaining 50% falls in remaining year.

Table 1: Area with cropping zone of all three distributaries

Sr. No	Distributary	Area (ha)	Cropping zone
1	Khurrian wala	33096.69	Rice-Wheat
2	Killian wala	31549.23	sugarcane-cotton-wheat
3	Mungi	22700.52	Cotton-Wheat Zone

2.2 Data

The study was conducted for Rabi season 2011-12, which starts from November and ends in April. The collected data for this study consists of remotely sensed data (satellite images of LandSat-7), command area data, agriculture census data, crop calendar and cropping pattern data. Detail description is given in Table 2:

Table 2: Summary of data collected

Data type	Data products/ components	Data source	Data specifications
Satellite data	LandSat-7	https://www.glovis.usgs.gov	30 m spatial resolution
Metrological data	Precipitation, temperature, wind speed, humidity & sun shine hours	Department of Crop Physiology, University of Agriculture, Faisalabad (Pak)	Daily basis for years 2011-12
Agriculture data	Agricultural census data, crop patterns, crop calendar,	Concerned agricultural departments and organizations	Rabi Season 2011-12

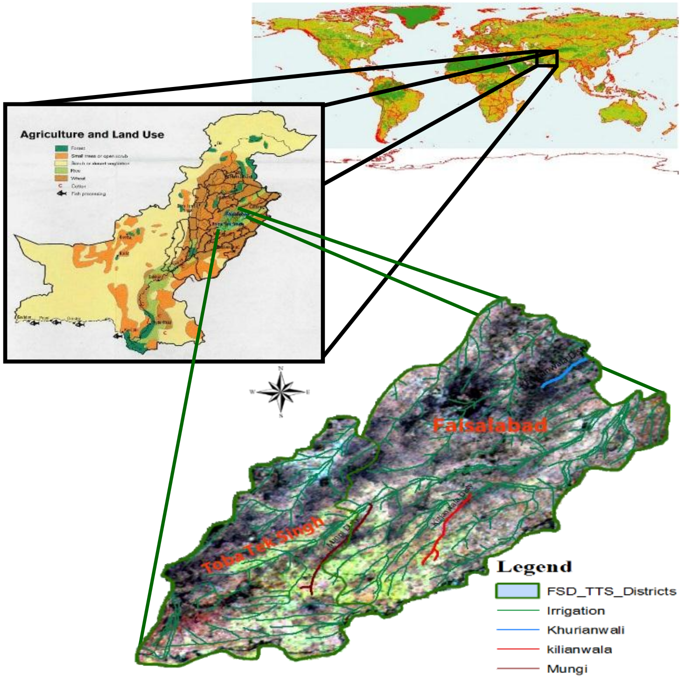


Figure 1: Geographical description of study area

2.2.1 Satellite Data

The Sun-synchronous LandSat-7 with 30 m spatial and 16 days temporal resolution was selected for current study. Landsat-7 is the most reliable and accurate for calibration of Earth-observing satellite; its measurements are extremely precise when compared with the same measurements taken on the ground. This data was obtained for Rabi season 2011-12 from the website of LandSat satellite: https://www.glovis.usgs.gov. The data download facility is freely available in the form of preprocessed data of Level 1. After geo referencing, study area shown to lies in three different tiles i.e. 150-39, 150-38 and 149-38. The total available images for Rabi season 2011-12 for study area were eleven. Five images were selected for each tile on the basis of image quality, cloud coverage and download availability. The metrological data was obtained from Metrological station, Crop Physiology Department, University of Agriculture, Faisalabad (Pakistan), for the years 2011 and 2012. Agriculture data was collected from different concerned agricultural departments and organizations like Punjab Agriculture department, Faisalabad and Food Agriculture Organization (FAO).

2.2.2 Field Data for Ground Truthing

Field data required for this research consists of two phases. First phase was to collect the data for LULC classification and to determine the area under wheat. Data for land use land cover classification was collected in peak Rabi season i.e. in end of the March from command area of all three distributaries. In second phase, data for yield estimation was collected near harvesting season from 28 to 31 April, 2012. Total 36 samples were taken in both visits along with other information including geographical coordinates, major land cover, crop phase and cropping pattern. For later visit, wheat samples with 1m^2 area were harvested and collected from each sampling point. The yield data was further processed and results were concluded for total sample weight, grains weight, biomass weight, grains average and biomass average. As the distance from intake matters a lot for cropping pattern and cropping intensity. Field data was collected from head middle and tail and from the both right and left side of the canal command area to get uniform and accurate results.

Table 3: Landsat images data for study area

Tile (path-row)	Image Date	Cloud Coverage (%)	Image Quality	Study Site Quality	Product ID
149-38	13.11.2011	0	Good	ETM+L1T	LE71490382011317PFS00
	31.12.2011	1	Good	ETM+L1G	LE71490382011365PFS00
	01.02.2012	22	Medium	ETM+L1T	LE71490382012032PFS00
	05.04.2012	0	Good	ETM+L1T	LE71490382012096PFS00

	21.04.2012	5	Good	ETM+L1T	LE71490382012112PFS00
150-38	20.11.2011	0	Good	ETM+L1T	LE71500382011324PFS00
	22.12.2011	0	Good	ETM+L1T	LE71500382011356PFS00
	08.02.2012	0	Good	ETM+L1T	LE71500382012039PFS00
	24.02.2012	0	Good	ETM+L1T	LE71500382012055PFS00
	28.04.2012	3	N/A	ETM+L1T	LE71500382012119PFS00
150-39	20.11.2011	0	Good	ETM+L1T	LE71500392011324PFS00
	22.12.2011	1	medium	ETM+L1T	LE71500392011356PFS00
	08.02.2012	0	Good	ETM+L1T	LE71500392012039PFS00
	24.02.2012	0	Good	ETM+L1T	LE71500392012055PFS00
	12.04.2012	0	Good	ETM+L1T	LE71500392012103PFS00

2.3 Methods

Satellite data was processed in ERDAS Imagine 9.2 and Arc GIS. The data downloaded from website was in tiff format so it was converted into image format to make it copmaitbale with sftware. This image consist of total seven nine bands including two thermal bandsthe data were processed for all bands except thermal bands as the thermal properties are not included. All images from November 2011 to April 2012 were stacked in a single composite file of 7 layers by layer stacking technique. This was required to analyze temporal changes in vegetation cover and identify crop growth stages with the help of crop phenology. To get the combine images of study area that includes three tiles, mosaicking was performed to join all the tiles with the reference of geographical coordinates.

2.3.1 Supervised Classification

Field survey data was used for supervised classification on the Landsat TM 4 layer composite pseudo color image from November 2011 to April 2012. Supervised classification indicates that the analyst influences the results by using the signature file as a sample of known identity (i.e., pixels already assigned to classes) to classify pixels of the unknown identity (i.e., to assign unclassified pixels to one of the several known classes). Though there are many supervised classifiers, the maximum likelihood classifier (MLC) was used. This was so because MLC is a well-known parametric approach based on the assumption that the data may be modeled by a set of multivariate normal distributions. Furthermore, MLC does not consider only cluster, but also its shape, size and orientation. Therefore, a pixel is assigned to the class or cluster with highest probability. The resulting maps have the same number of classes as the number of classes detected in field during field survey which makes it easier for class detection in unsupervised map.

2.3.2 Derivation of NDVI Values

Cropping intensity, crop types and different cropping patterns were assessed and observed using Normalized Difference Vegetation Index (NDVI), a special algorithm. The NDVI is a normalized difference measure was obtained by comparing the near infrared and visible red bands expressed by the following formula.

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

Where: NIR: reflectance in near-infrared band, and red: reflectance in red band

2.4 Validation and Accuracy

To estimate the accuracy and consistency of satellite driven information, accuracy assessment studies were performed. First approach is the error matrix method, which uses unsupervised classification and geo-referenced data to have an accurate knowledge of the ground condition (Usman et al. 2015). A survey for ground trothing was conducted during March to capture peak Rabi cropping season and in April to take the samples of crop yield as April is harvesting time for mostly wheat crops. Because the study was regional based for detailed crop mapping, ground trothing was performed for the entire region. The Garmin GPS 60 was used for taking sample readings. If a class was detected 70% dominant of certain land use, the area was named as that class.

3. RESULTS AND DISCUSSION

3.1 Land Use Land Cover Classification

The total pixels containing wheat and Non-wheat area was calculated by attribute table. In Landsat 7 images Scan Line Corrector (SLC) failed after May 31, 2003. These products have data gaps, but are still useful and maintain the same radiometric and geometric corrections as data collected prior to the SLC failure. In this research, weighted average was used to convert area under patches into wheat and non-wheat area. The spatial resolution of Landsat-7 is 30 meters so one pixel contains an area of 30*30=900 m^2. Area except wheat was emerged into one class named as non-wheat area. LULC for wheat and non-wheat area in hectare and % of wheat area in study area is presented in Table 4:

Table 4: LULC for wheat area in hectare and % of wheat area in study area

Distributary	Wheat Area (Ha)	% Area of total area
Khurrian Wala	28867.95	87.22
Killian Wala	22423.20	71.07
Mungi	17974.34	79.18

3.2 Correlation between NDVI value and Yield

Total five satellite images from command area of each distributary were collected and processed for study area during whole Rabi season. NDVI value for each image was extracted and February images has maximum NDVI value due to the peak season of crop growth. To develop a relationship between NDVI values and crop yield, a correlation between max NDVI value and crop yield was drawn for each distributary. A correlation and trend line between crop yield and maximum NDVI value is drawn for all three distributaries as shown in Fig. 3 and 4. The coefficient of determination between yield and maximum NDVI value has been found 0.45 for Khurrian Wala distributary, 0.36 for Killian Wala distributary and 0.39 for Mungi distributary. Although there has been found less significant correlation between NDVI and yield but the trend line is found positive in all three distributaries. On the basis of correlation between NDVI and wheat yield, the total yield for each distributary was estimated (Table 5).

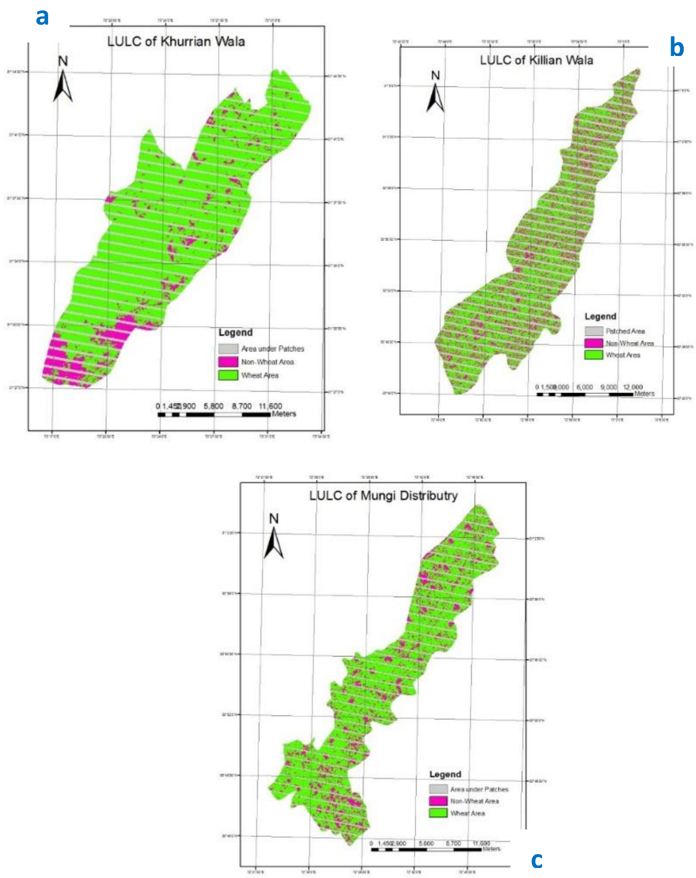


Figure 2: LULC for wheat of (a). Khurrian Wala, (b). Killian Wala, and (c). Mungi distributary

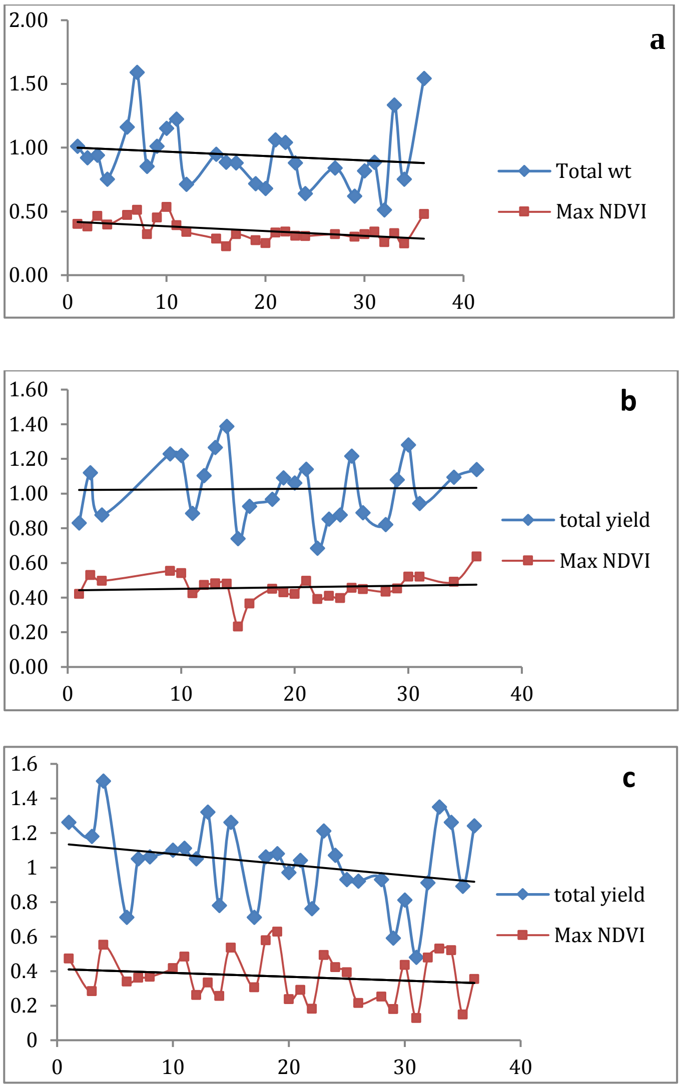
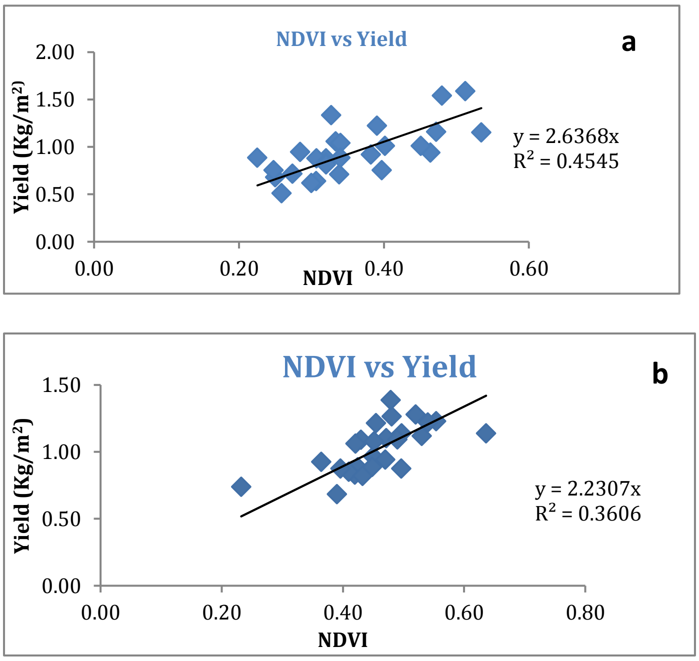


Figure 3: Trend line of yield and NDVI value of (a) Khurrian Wala (b) Killian Wala (c) Mungi Distributary.



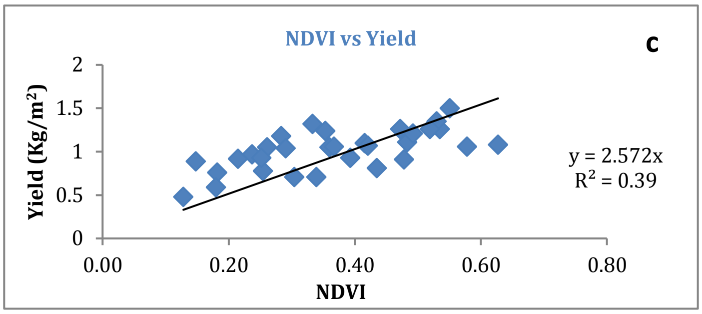


Figure 4: Correlation between NDVI and yield of (a) Khurrian Wala (b) Killian Wala (c) Mungi Distributary

Table 5: Total and average yield of command areas of all distributaries

Distributary	Wheat Area (Ha)	Total Production (Tons)	Average (Tons/Ha)	Average (Monds/Ac)
Khurrian Wala	22447.53	78129.88	3.48	34.80
Killian Wala	19083.51	73025.34	3.83	38.26
Mungi	15092.64	57392.48	3.80	38.02

4. DISCUSSION

The 87.22% of total command area of Khurrian wala distributary under wheat is good proportion of wheat crop due to the fact that only wheat and rice are the major crops in the command area. The result for killian wala is 71.07% of total command area and this relatively low proportion is due to sugarcane and maize are also the major crops along with wheat in command area. The mapping result for Mungi shows 79.18% of total command area is under wheat and this medium proportion for wheat crop is due to command area of Mungi has mix cropping zone with some early cotton, sugarcane, maize and fodder crops.

The average wheat yield in Pakistan is 2.83 Tons/Ha in 2010-11 and 2.71 Tons/Ha in 2011-12 and the total area under wheat was 2833000 Ha in 2010-11 and 2714000 Ha in 2011-12 (Economic Survey of Pakistan, 2011-12). The total availability of canal water to Punjab Province in Rabi season, 2010-11 was 18.73 MAF and in Rabi Season 2011-12 this amount reduced to 17.61 MAF. There was an overall change of -6% of canal water availability in two consecutive years. This is average yield of whole country and includes all area like arid, semi-arid, humid region and hilly areas where there is average yield is very low up to of 1.5tons/ha.

Overall decrease in wheat area and average yield is due to the problems which former is facing and they have begun to grow early BT cotton. As study area is very rich of agriculture, crust of the area is buildup of alluvial soils which come by floods and settled. The irrigation system of the study area comprises of very good network of main canals, link canals, branch canals and many distributaries which are providing water to agriculture land of the area. Very intensive agriculture practices are being carried out in the area, so on average basis, wheat production of 3.48 tons/ha to 3.83 tons/ha can easily be attained.

5. CONCLUSIONS AND RECOMMENDATIONS

Time series of Landsat-7 data with 30m spatial resolution and 16 days temporal resolution showed good results for mapping of LULC classes. The correlation between NDVI and crop yield offers good potential to estimate crop yield not at command area of canal level but at regional and country level. The area under wheat derived from LULC map on the basis of NDVI is good tool for area assessment. So, it is necessary to encourage and promote the applications of Remote Sensing and GIS for land, yield and water management analysis. Policy makers and Government agencies should adopt such techniques and tools for better and timely management of all resources including agriculture, water and forestry. Good results up to accuracy of 85% were obtained by the supervised classification of the NDVI profiles; it is also need to determine the variance within or between groups through statistical analysis. It is also recommended to use land cover product obtained from some high resolution like 10 m and 5m, satellite data.

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