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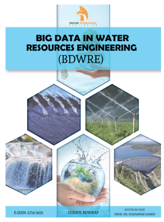

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RESEARCH ARTICLE

CROP AREA MAPPING BY INTELLIGENT PIXEL INFORMATION INFERRED USING 250M MODIS VEGETATION TIMESERIES IN TRANSBOUNDARY INDUS BASIN

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ABSTRACT

Irrigation water could be managed properly by mapping area of various crops. Remote sensing data can provide useful Land Use Land Cover (LULC) for assessment of different crop area and change detection. The present study was carried out with core objective to map crop area within the Indus Basin's transboundary. Four major crops (i.e. wheat, rice, cotton and sugarcane) were identified using Normalize Difference Vegetation Index (NDVI) time series that was picked up from MODIS sensors aboard Terra (EOS AM) and Aqua (EOS PM) satellites with 250m pixel resolution. Crop phonological information was used to train each pixel intelligently for interpretation of unanalyzed NDVI data into crops. Eight days of time series data was used for identification and mapping of various crops on the basis of their phenology for the years 2008, 2010 and 2013. Error matrix was prepared to reveal mapping accurateness and ground truthing was also done in particular canal commands within the Indus basin. Furthermore, the temporal variation in cropped area was determined and for accuracy check, secondary data was matched with prepared maps. LULC maps for year 2008, 2010 and 2013 were defined for Rabi and kharif seasons.

KEYWORDS

LULC, MODIS, Mapping, NDVI, Rabi, kharif, Cropped Area, Error Matrix.

1. INTRODUCTION

Proper management of agricultural land and wise policy making require estimation of cropped area for food security (Abbas et al., 2006). Mapping of Land Use and Land Cover (LULC) takes a significant place in different sectors (i.e. scientific studies, planning and management). While, a strong relationship among environment and the humans can be seen through regional land use patterns (Matsa and Muringaniza, 2011). These both terms (LULC) are not identical, Land use describes the modifications of environment that individuals have made for their selves concerns while land cover defines physical state of surface. Irrigated crops, forestation, water bodies, barren lands, recreational sites, industrial and domestic areas are some examples of land use (Cheema and Bastiaanssen, 2010; Kiptala et al., 2013).

Remote Sensing (RS) imagery that could be taken from aircrafts and satellites is an effective and unique way to map LULC. RS is the investigation and interpretation of information and imageries that can be further used for monitoring of earth resources by the environmental researchers (Landgrebe, 2003). RS satellites revolves in paths above the earth at hundreds of miles and repeatedly imaging the earth surface and transmit back to ground stations for further processing. RS data acquisition approach using onboard sensors are much significant in generating valuable earth data (Schowengerdt, 2007).

World widely, many land cover (LC) datasets have already been developed i.e. LC datasets of International Water Management Institute (IWMI), Global Land-Cover Characteristics data base prepared by the International Geosphere Biosphere Program (IGBP), Global Land Cover (GLC2000 and Glob-Cover) developed by European Space Agency (Loveland et al., 2000; Defourny et al., 2016) while GLC 2000 was developed using Medium Resolution Imaging Spectrometer (MERIS) with 300m resolution (Arino et al., 2008).

In Pakistan, land cover maps of each province were developed by Pakistan Space and Upper Atmosphere Research Commission (SUPARCO) and these datasets are advantageous in mapping and analyzing of common land cover on wider scales. But unfortunately these aren't much helpful in supporting agriculture management, applications and analysis due to lake of adequate information related to LULC. A range of LULC can be seen within the study area (i.e. Indus basin). The clarification of LULC is required for enhanced datasets and information that can further be used in processing and strategy making but it is very critical to describe LULC classes within the Indus basin.

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Intelligent pixel mapping (IPM) technique can only be used for this kind of LULC classification. This approach has more aptitude to draw and explain physical land surface activities from satellite images that are in complex form. IPM generates quantified data from spectral radiances by making smart pixels. The key characteristics of intelligent pixels are multi scale, multi time, and multi data that are reasonable to generate data bases for water, vegetation and climate.

Xiao et al., (2006) described that significant results of crop monitoring can be achieved though Moderate Resolution Imaging Spectroradiometer (MODIS). For LULC analysis, MODIS (Terra and Aqua) offers eight (8) days' time series data while currently this is providing imageries data with resolution of 250m after every sixteen (16) days. Management of agricultural water within the river basin can be efficiently done using spatial resolution of 250m and 8 days of temporal resolution (Zhang et al., 2008).

Previously, Many approaches have already been implemented for extraction of field crops and classification of LC involving supervised classification and maximum likelihood algorithm (i.e. threshold-based technique) (Bolstad and Lillesand, 1991) intelligent and artificial neural networks (Benediktsson et al., 1989). Current study work was performed to detect change in different crops at basin level using remotely sensed data. Spatio-temporal mapping of crops in Transboundary Indus Basin using pixel resolution of 250m were done and data of five years (2007-2010 to 2012-13) was used to detect change in cropping area. The result accuracy assessment was done using available statistical data.

2. MATERIAL AND METHODS

2.1 Study Area

Selected study area lies between latitude ranging from 24°38′ to 37°03′ N and longitude ranging from 66°18′ to 82°28′ E that exists within the Indus Basin. The Indus Basin situated in four countries i.e. China (upstream side), Afghanistan, India and Pakistan (downstream side) with an area of 1.16×10^6 km^2. Pakistan being the largest shareholder of the basin covers 53% of the entire area. While, 33% of the total basin's area falls in the territory of India followed by China and Afghanistan with 8% and 6% respectively.

2.2 Satellite imagery

To map LULC classification (mainly focus crop area), satellite data of multi-temporal resolution was used. For this study, data was downloaded from MODIS, for the year 2007-2010 and 2012-13 were used. Selection of Satellite data was based on its availability and credibility. The MODIS satellite has shown credible results for monitoring of crops (Xiao et al., 2006). However, Zhang and Srinivasan (2008) described that 250m of spatial and 8 days of temporal resolution is sufficient for agricultural water management.

2.3 Normalized Difference Vegetation Index (NDVI)

Rouse et al., (1974) developed NDVI, that is an arithmetical demonstration of electro-magnetic spectrum using different bands (i.e. visible and near infrared). Moreover, NDVI is one of the algorithms that linked individually to vegetation and can be projected directly from remote sensing data (Carbone et al., 2005). NDVI is one of the best and universally used as vegetation indices that directly linked with greenness of plants or photosynthetic activity and can be described as follow.

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

2.4 Agricultural Statistics Data

Agricultural Statistics data was collected from different concerned agriculture departments and organization, i.e. Punjab Agriculture Department Faisalabad and Food Agriculture Organization (FAO).

2.5 Field Data Collection:

Data collection from field required for this research work consists of two phases. First phase was to collect the data for LULC classification. Field data was collected through field visit in the Indus Basin area.

2.6 Classification

For classification of the year 2013, ground truthing data was used to develop spectral signature for supervised classification. Spectral signatures were formed for different classes and Ground truthing was done at random sites of the study area. NDVI profile of different classes during Kharif season plotted in Figure 1. After assigning spectral signature to specific classes maximum likelihood classification was used to categorize the layer stack image on the basis of season using the corresponding spectral signatures. Based on the 2013 classification and expert knowledge classification was done for the years of 2008 and 2010.

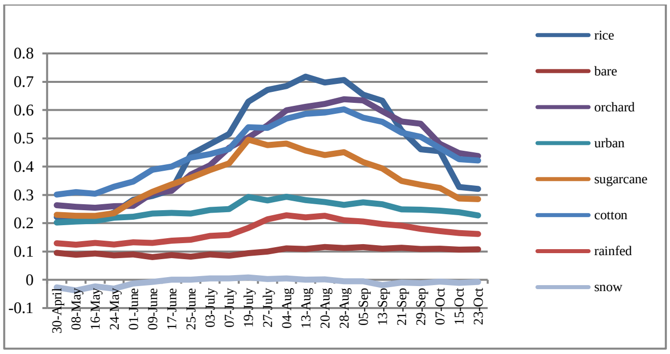

Figure 1: NDVI profile of different classes during Kharif season

2.7 Accuracy Check

It is pertinent, to assess the accuracy of map is fully documented. Different users can assess whether the maps can fulfill their requirement by having full post classification accuracy analysis. Normally, accuracy check can be done using error matrix that estimates the association between the two classes (i.e. mapped class and true class) for a sample drawn from the classified image. True class is normally established from the ground truthing at field survey. Statistical term (i.e. percentage overall agreement), user and producer accuracy are generally used methods of classification. Classification for which ground truthing points are not available statistical data of relevant organization can be used to verify the accuracy level of the classified images.

3. RESULTS AND DISCUSSION

3.1 LULC Mapping of Rabi 2007-08

LULC map of Rabi 2007-08 was developed which exposed that wheat crop covered an area of 18 mha, Sugarcane covered 2 mha while fodder covered 4 mha (Figure 2). The map results revealed that major portion of Northern region was covered by forest covering an area of 10 mha. Pastures and rainfed crops were also found on large area. Orchards, sparse vegetation and urban water were found covering area of less than 5 mha as shown in figure 2.

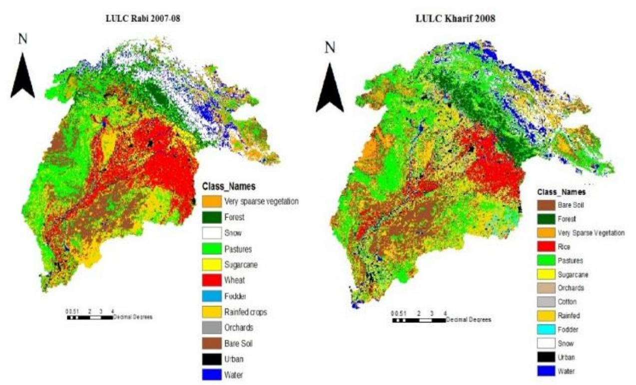

Figure 2: Showing LULC maps of Rabi and Kharif seasons for the year 2008

3.2 LULC Mapping of kharif 2008

LULC map of Kharif season 2008 was developed which revealed that rice crop covered an area of 12mha, Cotton crop covered area of 5mha while

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fodder and sugarcane were sown on area of 5.5 mha and 2.5mha respectively (Figure 2). Furermore, it was observed that major parts of the northern region were covered by forests which covered an area of 10 mha. Pastures also covered large part of land as these were found in an area of 31 mha. Bare soil, orchards, sparse vegetation and urban area were less than 10mha. Additaionly, water bodies were also mapped as shown in figure 2.

3.3 LULC Mapping of kharif 2010

LULC Map of Kharif 2010 was also developed which showed that (Figure 3) cotton crop covered an area of 4.5 mha, Sugarcane and fodder covered 3 mha and 5 mha area respectively and forests spread over area of 10 mha whereas rainfed crops covered 18 mha. Pastures occupied an area of 32 mha while sparse vegetation, water, and urban area were found to be less than 5mha as shown in figure 3.

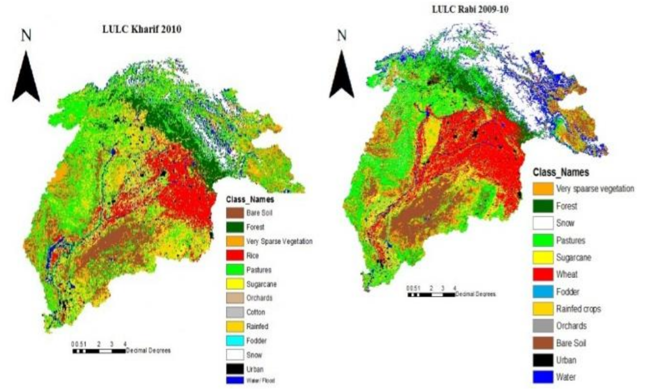

Figure 3: Showing LULC maps of Rabi and Kharif Season for the year 2010.

3.4 LULC Mapping of Rabi 2009-10

LULC Map of Rabi 2009-10 was developed which revealed that wheat was occupying an area of 19 mha, Sugarcane and fodder covered area of 2.5 and 4 mha respectively as shown in figure 3. Pastures and Rainfed were present in an area of 32 and 17 mha respectively. Furthermore, the map showed that water was present in least amount i.e. in an area of 0.87mha. In 2010 flood was occurred in Indus Basin. A separate class was also mapped that covers an area of 1 mha in basin.

3.5 LULC Mapping of Rabi 2012-13

LULC Map of Rabi 2012-13 was developed which depicted that wheat crop was grown on an area of 20 mha while sugarcane covered 2.5mha and fodder were grown on area of 5 mha as shown in figure 4. Forests covered 9 mha. Rainfed crops occupied an area of 18 mha while pastures covered area of 32 mha. Snow was present in an area of less than 12 mha. Orchards, sparse vegetation, water and urban area were less than 5 mha.

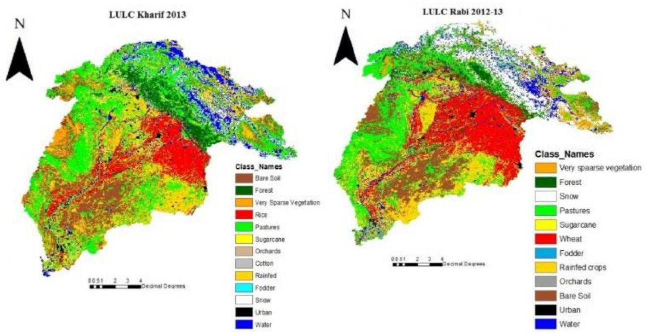

Figure 4: Showing the LULC maps of Rabi and Kharif season for the year 2013.

3.6 LULC Mapping of Kharif 2013

LULC Map for Kharif season 2013 showed that cotton was grown on an area of 6 mha whereas sugarcane and fodder were present on an area of 3mha and 6 mha respectively. Forests cover a large area of 9 mha. Rainfed crops occupied an area of 19 while orchards were present on area of 4 mha. Water bodies occupied minimum area of 1.2 mha as shown in figure 4.

Results of LULC showed area changes of different crops whereas approx. 2 mha of wheat area increased in 2013 as compared to 2008 (Figure 5). 1 mha of area under rice crop was increased within time period of five years (i.e. 2008 to 2013). Furthermore, it was noticed that cotton crop area greater than before by 1 mha and sugarcane crop added 0.5 mha of area in 2013.

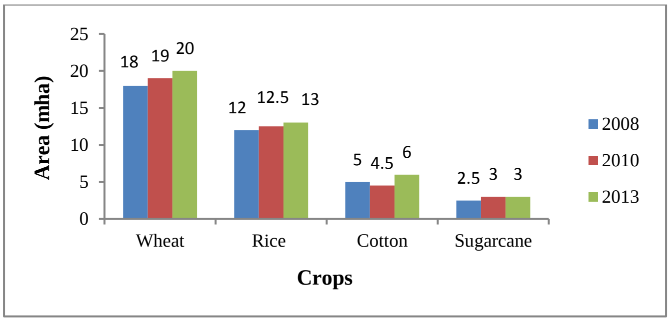

Figure 5: Change detection in crop area within Indus Basin Transboundary

Figure 6 shows graphical comparison between LULC mapped data and available statistical data of province Punjab-Pakistan. The LULC cover map gives relatively higher results as compared to the statistical data but the map accuracy assessment was in good agreement with the previous studies.

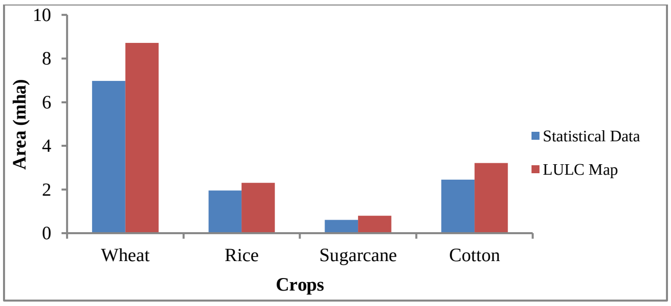

Figure 6: Crop Area Comparison of Punjab province for the year 2010

Table 1: Error matrix for Kharif season during 2013.

CLASS	1	2	3	4	5	6	7	8	9	10	11	12	
1	3												3
2		2											2
3			20				1	2	2		1		26
4				3									6
5				1	5					3			9
6					1	11	1	1	3				17
7				2			9						11
8				1		1	1	20		2	1		26
9					3	2	1	1	10				17
10								2		22	1	1	26
11							1		2		30		33
12							1	2	1	2	3	40	49
	3	2	20	7	9	17	15	28	18	29	36	41	225

Ground truthing examination and to discover error matrix investigation a total of 225 and 136 points were collected for Kharif and Rabi season respectively. Twelve (12) classes of LULC were visited for kharif season while ten (10) LULC classes were visited for Rabi season. Each and every error matrix class has at least two (02) observation points. Overall classified mapped accuracy was 77.8% and 77.2 % for Kharif and Rabi season respectively as shown by error matrix (Table 1-2).

Table 2: Error matrix for Rabi season during 2013.

CLASS	1	2	3	4	5	6	7	8	9	10	
1	20		5								25
2		6				2					8
3	2		20								22
4	1		2	10	1						14
5	1		1	1	10				1		14
6		2				5	1		3		11
7							5		2		7
8							1	10	1		12
9							2	2	15		19
10										4	4
	24	8	28	11	11	7	9	12	22	4	136

These accuracy levels coincides with (Thunnissen and Noordman, 1997; Kiptala et al., 2013) who worked on crop detection and different land uses moreover suggested that at regional level minimum 70% of classification accurateness can be achieved. 77.3% and 84% accuracies were achieved from 500m and 250m MODIS imagery respectively (Giri and Jenkins, 2005; Wardlow and Egbert, 2008). This further revealed that the classification accuracy of current study work is in line with the previous studies.

4. Conclusion

This research work was done in the Transboundary of Indus Basin that covers four countries i.e. Pakistan (53%), India (33%), china (8%) and Afghanistan (6%). Current work was performed during 2008-2013 for Rabi and Kharif seasons with main objectives to map LULC classification of Indus Basin's Transboundary, to assess different cropping area within transboundary and to detect the changes happen from 2008 to 2013. Normalized difference vegetation index (NDVI) was used to monitor and to evaluate physical features. Error matrix approach which expresses higher efficiency up to 84% was used to assess the accuracy level. Coefficient of determination (R^2) statistics for rice, cotton, sugarcane and wheat were 0.81, 0.80, 0.79 and 0.78 respectively. Such type of approaches can be used as a tool by policy formulators and government organizations for improved and timely management of resources. Furthermore, through current study work it is recommended that LULC maps using higher resolutions (i.e. 30m and 10m) could be used for more accuracy and precision in the development of maps at basin level.

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