Remote Sensing and GIS Based wheat Crop Acreage and Yield Estimation of District Hyderabad, Pakistan

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RECEIVED ON 26.07.2014 ACCEPTED ON 17.10.2014

ABSTRACT

Pre-harvest reliable and timely yield forecast and area estimates of cropped area is vital to planners and policy makers for making important and timely decisions with respect to food security in a country. The present study was conducted to estimate the wheat cropped area and crop yield in Hyderabad District, Pakistan from the Landsat 8 satellite imagery for Rabi 2013-2014 and ground trothing. The required imagery of district Hyderabad was acquired from GLOVIS and was classified with maximum likelihood algorithm using ArcGIS 10.1. The classified image revealed that in district Hyderabad wheat covered 10,210 hectares (9.74% of total area) during Rabi season 2013-2014 against 15,000 hectares (14.3% of total area) reported by CRS (Crop Reporting Services), Sindh which is 30% less than that of reported by CRS. A positive linear relation between the wheat crop yield and the peak NDVI (Normalized Difference Vegetation Index) with coefficient of determination R^2=0.91 was observed. Crop area and yield forecast through remote sensing is easy, cost effective, quick and reliable hence this technology needs to be introduced and propagated in the concerned government departments of Pakistan.

Key Words: **ArcGIS, Hyderabad, Crop Yield, Area Estimation, GPS, Geo-Referenced.**

1. INTRODUCTION

Accurate and timely estimates of cropped area and crop yield before harvest at regional, national and international level are vital for both developing and developed countries because for timely initiating food trade, secure the national food demand and timely organize food transport within countries [1]. A variety of techniques from visual field estimates and area frame based sample surveys to crop-simulation models and regression approaches have been used for pre-harvest crop yield estimates with varying degrees of success [2-3]. Traditionally estimates of the cropped area at a district level are obtained through complete enumeration of fields, whereas, the average crop yield is estimated through GCES (General Crop Estimation Surveys), on the basis of crop cutting experiments conducted on a number of randomly selected fields in sampled villages of the district. Derivation of land use/cover and estimation of agricultural area and production through classical methods are costly, time consuming, resulting in post-harvest information and subject to a variety of errors in terms of types and sources. Recent developments in

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GIS and Remote sensing technologies and crop modelling have created promising opportunities for improving agricultural statistics. Application of remote sensing technology in monitoring of crop condition has been widely used for timely assessment of changes in growth and development of agricultural crops. Thus, satellite remote sensing, due to its synoptic, timely, accurate and repetitive coverage, has proved a useful tool in monitoring of the crop growth and estimation of cropped area and yield [4-7].

Wheat (*Triticum aestivum L.*) is one of the most important staple food crops produced in throughout the world. It is cultivated on 220 million hectares in the world with production of 690 million tons, with an average of 3000 kg grain per hectare [8]. Wheat is sown on an area of 9.0 million hectares in Pakistan with total annual wheat production of about 25.28 million tonnes per year [9]. Thus, Pakistan ranks 8th position in wheat production in the world. The wheat intake in total household consumption in Pakistan is about 9% [10].

In Sindh, crop area and yield estimates are based on sample surveys type of crop and crop cuttings undertaken by the statistical staff of the CRS, Agriculture Department. The consolidated information is then examined by a sub-committee comprised of representatives of the Provincial Revenue, Agriculture, Irrigation and Bureau of Statistics Departments. The final estimates are checked by a sub-committee comprising of representatives from the Provincial Department of Agriculture, Revenue, Irrigation and Planning & Development and after approval from the Provincial Agriculture Statistics Coordination Board, the figures are made public after a few months of the crop harvest.

Wheat crop production forecasts/estimates are generally depicted from the product of two components: cropped area and crop yield per unit area. Thus, the accurate forecasting/estimation of both harvested area and yield are equally important in ensuring the accurate forecast of the crop production. In Pakistan, especially in Sindh, only negligible/limited work has been done on early estimates of wheat cropped area and yield forecast using temporal satellite imagery.

Keeping in view the importance of pre-harvest cropped area and crop yield forecast for planners and decision makers to enable the government to put in place strategic contingency plans for the export or import wheat, the present study was conducted in District Hyderabad, Sindh to estimate wheat cropped area and yield forecast from the Landsat satellite imagery, GLAM (Global Agriculture Monitoring Project) and ground trothing.

2. MATERIALS AND METHOD

2.1 Study Area

Hyderabad is considered an important wheat producing district of Sindh with 14,250 hectares of land under wheat crop and total production of 55,400 tons. The whole district Hyderabad was selected for the present study. The district Hyderabad is situated in Sindh province of Pakistan. It is located at longitudes 68° 17' 30" – 68° 38' 40" E and Latitude 25° 09' 30"- 25° 33' 12" N at a mean elevation of about 23 m above the MSL (Mean Sea Level) as shown in Fig. 1.

The total geographical area of the district Hyderabad is 104,877 hectares while the total population of Hyderabad district in 2012 was 4.5 million, of which 60.07% were urban, making it second-most urbanized district of Sindh. The city of Hyderabad is where the district headquarters are located and the district government is seated. Hyderabad District is administratively subdivided into 04 talukas (Tahsils) with 52 union councils. Three Talukas of the district, Hyderabad city, Latifabad and Qasimabad, are settlement areas whereas only Taluka Hyderabad rural is Agricultural area. Some union councils of Hyderabad, Latifabad and Qasimabad talukas have some cropped area.

2.2 Field Survey

A GPS based field survey was conducted from December 2013 to February 2014. Before field visits, a

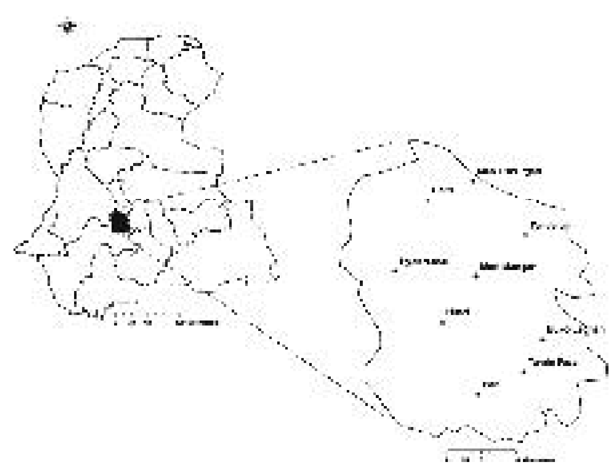

FIG. 1. LOCATION OF STUDY AREA (DISTRICT HYDERABAD)

proforma for collecting required data was prepared. The geo-referenced proforma contained longitude, latitude, name of union council name, name of Taluka, and crop type. Using Garmin GPS 62S, geo-referenced proforma was filled. Geo-referenced data was collected from almost all the union councils of the district where agricultural activities are practiced. The spatial location of the field data sampling points are shown in Fig. 2.

2.3 Acquisition of Satellite Data

Area under wheat crop in district Hyderabad during Rabi 2013-2014 was estimated using Landsat 8 imagery. Landsat imagery is considered as a valuable resource for monitoring global surface change [11-13] and is a main source of medium spatial resolution earth observations used in decision-making. Landsat 8 imagery of WRS-2 path 152, row 42, processing L1T was used in the present study. The imagery was acquired from United States Geological Survey portal (GLOVIS) for the month of February 2014 when the wheat crop attains peak growth. The Landsat 8 satellite takes images of the entire Earth every 16 days in an 8-day offset from Landsat 7. Data collected by the satellite instruments are available to download at no charge from GloVis, EarthExplorer and via the LandsatLook Viewer within 24 hours of reception.

2.4 Image Processing with ArcGIS

Landsat 8 imagery of WRS-2 path 152, row 42 acquired on February 19, 2014 was processed with ArcGIS 10.1. Extract by Mask tool was run in ArcGIS 10.1 by adding shape file of district Hyderabad as a mask to extract the image of only required area (district Hyderabad). The extracted image of district Hyderabad (Fig. 3) was classified using a maximum likelihood algorithm in ArcGIS 10.1 software. For this, the entire district was trained for wheat crop using geo-referenced field survey data. From training area samples, a signature file was prepared which was then used in running maximum likelihood algorithm. The area under wheat crop was computed by converting the raster data into polygons and then summing the area of all polygons in ArcGIS 10.1.

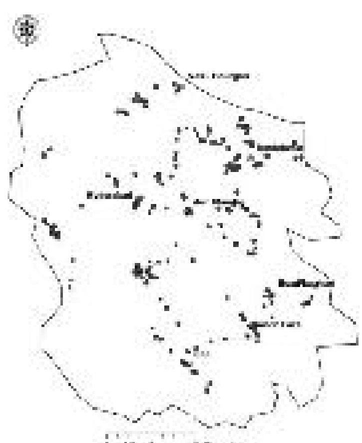

FIG. 2. LOCATIONS FROM WHERE THE DATA SAMPLES WERE COLLECTED FROM DISTRICT HYDERABAD

2.5 NDVI

NDVI is an indicator used to assess whether the area under study contains vigorous green vegetation or not. It is normally calculated from the visible and NIR (Near Infrared) light reflected by vegetation. Computations of NDVI for a given pixel always result in a number that ranges from -1 to +1. A zero means no vegetation while NDVI close to +1(0.8-0.9) indicates the lush green leaves. The NDVI can be calculated using following relation [14].

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}} \quad (1)$$

Where ρ_{nir} = NIR band, and ρ_{red} = Red band

However in the present study, NDVI of wheat crop for district Hyderabad from 2006-2014 were obtained from GLAM (http://pekko.geog.umd.edu/glam/pakistan/zoom2.php) and are summarized in Table 1.

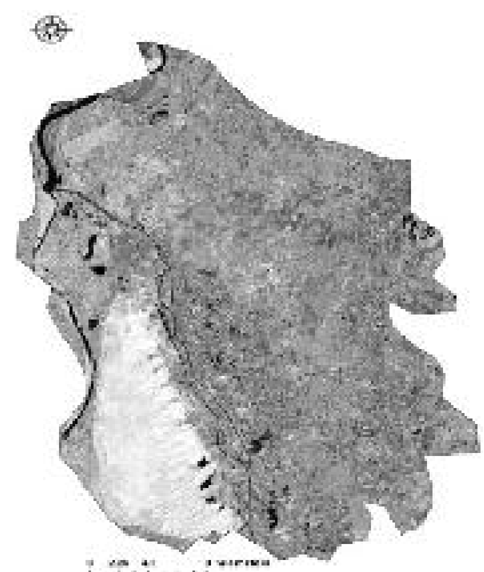

FIG. 3. EXTRACTED IMAGE OF DISTRICT HYDERABAD FROM LANDSAT IMAGERY ACQUIRED ON FEBRUARY 19, 2014

2.6 GLAM

GLAM is a joint research project, initiated in 2002 and is funded jointly by USDA-FAS and the NASA Science Applications Program. The GLAM project aims to enhance the agricultural monitoring and the crop-production estimation capabilities of the FAS using the new generation of NASA satellite observations, building one of the most comprehensive data management systems for remotely-sensed based global agricultural monitoring [15]. This system for Pakistan currently provides MODIS *(*Moderate Resolution Imaging Spectroradiometer*)* vegetation indices (2000–present). The NDVI of Hyderabad district for Rabi crop from 2006-2014 was obtained from GLAM portal after applying Pakistan wheat crop mask.

2.7 Data and Statistical Wheat Yield Models

The data on wheat crop acreage (hectares), yield (tons/ha) and total production (Tons) of Hyderabad District from 2006-2014 was obtained from CRS, Sindh (Table 1). Wheat crop yield was plotted against respective peak NDVI (February of each year) and by adding a linear regression trend line, an NDVI based statistical regression wheat yield model for district Hyderabad was developed. Similarly, a wheat yield model based on wheat cropped area was also developed.

3. RESULTS AND DISCUSSION

3.1 Crop Acreage

Fig. 3 shows the unclassified satellite image of district Hyderabad captured on February 19, 2014. The image of district Hyderabad was extracted from the original image of Landsat 8 (path 152, row 42) using ‘Extract by Mask tool’ in ArcGIS 10.1 tool box. The classified image is shown in Fig. 4.

The image reveals that during Rabi 2006-2014 the wheat crop in district Hyderabad was sown on about 10,210 ha of land (9.74% of total area of district) and other crops were cultivated on 50,213 ha (47.88% of total area of district). While 42,350 ha (40.38% of total area of district) and 2,102 ha (2.0% of total area of district) were occupied by towns/villages/ hill/bare land and water respectively. The area under wheat crop, computed from the image, is about 30% less than that of reported by CRS, Sindh. Wheat cropped area estimated from satellite imagery deviated 20-30% from that of estimated by CRS, Sindh. It might be due to application of old area sampling techniques by CRS which are more likely to have statistical errors. Wardlow and Egbert [16] reported deviation of 1-5% in cropped area estimated from classified imagery and cropped area reported by USDA at the USA state level.

TABLE 1. AREA CROP YIELD, TOTAL PRODUCTION AND NDVI OF WHEAT CROP CULTIVATED IN DISTRICT HYDERABAD FROM 2006-2014

Year	Area (hac)	Production (Tons)	Yield (Tons/hac)	NDVI
2006	12350	34630	2.80	0.557
2007	11700	37100	3.17	0.58
2008	14100	54500	3.87	0.615
2009	14300	55400	3.87	0.625
2010	15000	57600	3.84	0.618
2011	16500	63600	3.85	0.622
2012	14900	56800	3.81	0.601
2013	14940	56840	3.80	0.608
Mean	**14224**	**52059**	**3.63**	**0.60**
STDV*	1542	10377	0.41	0.02
CI*	1068	7191	0.28	0.02

*STDV = Standard Deviation, *CI = Confidence Interval

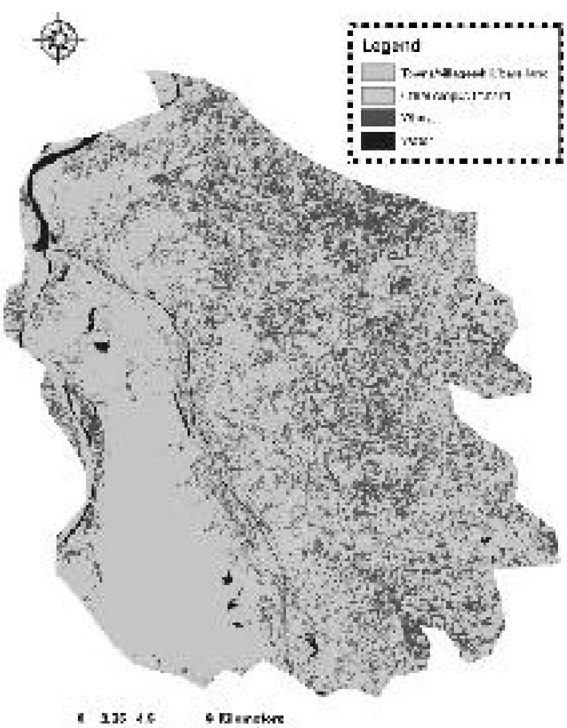

FIG. 4. CLASSIFIED LANDSAT IMAGE OF DISTRICT HYDERABAD

3.2 NDVI and Crop Yield

Table 1 represents Area, crop yield, total production reported by CRS, Sindh and peak NDVI of wheat crop for district Hyderabad from 2006-2013 obtained from GLAM portal. It shows that mean area under wheat crop in the district from 2006-2013 was 14224 ± 1068 ha, while crop yield and production during those days were 3.63 ± 0.28 Tons/ha and 52059 ± 7191 Tons respectively.

NDVI of wheat crop cultivated in Hyderabad districted from 2006-2013 was obtained from GLAM and are presented in Fig. 5.

It shows that NDVI for wheat crop increases from November of each year and attains peak level in the last week of February or last week of March. Mean NDVI for wheat crop from 2006-2007 to 2013-2014 of Hyderabad district is 0.60±0.01.

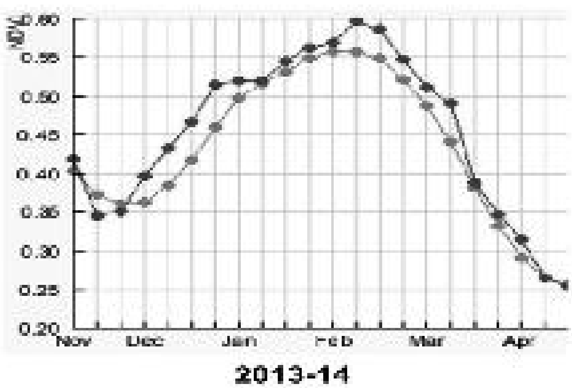

FIG. 5. NDVI OF WHEAT CROP IN DISTRICT HYDERABAD, SINDH FOR THE YEAR 2013-2014

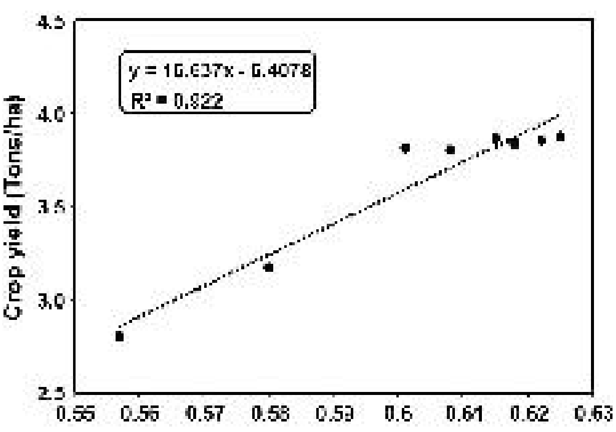

FIG. 6 WHEAT CROP YIELD OF DISTRICT HYDERABAD, SINDH FROM 2006-2013 PLOTTED AGAINST NDVI OF CROP OF RESPECTIVE YEARS. X AND Y GIVEN IN GRAPH EQUATION REPRESENTS X COORDINATE (NDVI) AND Y COORDINATE [CROP YIELD (TONS/HA)] RESPECTIVELY

Relationship between wheat crop yield and peak NDVI were plotted and are graphically presented in Fig. 6.

It shows a clear positive linear trend between the wheat crop yield and the peak NDVI of the crop with coefficient of determination R^2=0.922 and a regression yield prediction model given in Equation (2):

$$Yield\ (Tons/ha) = 16.637 \times NDVI - 6.4078 \quad (2)$$

A similar linear positive trend between crop yield and peak NDVI is also reported by [17-21].

Wheat production of district Hyderabad, Sindh, Pakistan from 2006-2013 was plotted against wheat cropped area of the respective years and is shown in Fig. 7.

It shows a positive linear relationship between the total what production and the wheat cropped area with coefficient of determination R^2=0.921. From this relationship, an area based statistical production model was also developed and is given in Equation (3).

$$Production\ (Tons) = 6.4582 \times Area - 39801 \quad (3)$$

Once area under wheat crop in district Hyderabad is known, then one can easily forecast the total wheat production in the district using above relation. A linear relationship between wheat crop production and cultivated area is also reported by Farooq, et. al. [22].

The crop yield (Tons/ha) and production (Tons) for the year 2014 were predicted using Equations (2-3). The peak NDVI of wheat crop (0.597) and estimated area under wheat crop (10,210 ha) were used as input

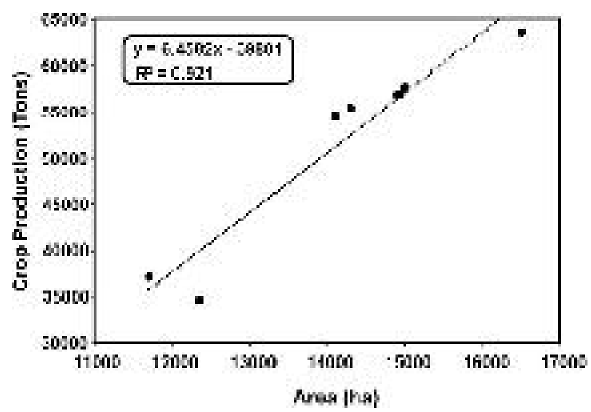

FIG. 7 WHEAT PRODUCTION OF DISTRICT HYDERABAD, SINDH FROM 2006-2014 PLOTTED AGAINST WHEAT CROPPED AREA OF RESPECTIVE YEARS. X AND Y GIVEN IN GRAPH EQUATION REPRESENTS X COORDINATE [AREA (HA)] AND Y COORDINATE [CROP PRODUCTION (TONS)] RESPECTIVELY

parameters to predict the crop yield (Tons/ha) and production (Tons) for the year 2014. The results showed that the predicted wheat yield of Hyderabad district for 2014 is 3.54 (Tons/ha) while total estimated production is 26200 Tons.

4. CONCLUSION

Accurate, reliable and timely information of the cropped area and yield forecast in the country is vital for timely initiating food stock to secure the national food demand and timely organize food trade with different countries of the world. The present study was thus conducted to estimate crop yield, production and area under wheat crop in district Hyderabad Pakistan from the ground trothing and Landsat 8 satellite imagery for Rabi 2013-2014. The classification of the Landsat imagery of district Hyderabad for Rabi 2013-2014 revealed that wheat was sown on an area of 10210 hectares (9.74% of total area) which is about 30% less than that of reported by CRS, Sindh. There was a positive linear relationship between the wheat crop yield in Hyderabad district and its peak NDVI with coefficient of determination R^2=0.91. It is concluded that space technology through satellites can be successfully used for crop area and yield estimations. It is a cost effective tool which is quick and reliable, hence this technology needs to be introduced and propagated in the concerned government departments of Pakistan.

ACKNOWLEDGEMENTS

The authors would like to express their thanks to Sindh Agriculture University, Tandojam, and Mehran University of Engineering & Technology, Jamshoro, Pakistan, for giving them an opportunity to pursue this study.

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