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Geospatial Investigation in Estimation of Gross Cropped Area using HR Mx. Satellite and Cadastral Data A Case Study of Birbhum District, West Bengal, India

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Abstract—*According to Food Policy Report titled "Climate Change – Impact on Agriculture and Cost of Adaptation" published by International Food Policy Research Institute (IFPRI), improvement in data collection, data dissemination and data analysis are outlined as few key recommendations. Following this, a local attempt using Remote Sensing Technology and Geographical Information System have been applied in three villages of Birbhum district to find out the Gross Cropped Area in terms of agriculture practice with respect to moisture content and ground water prospect of the area of interest at cadastral level.*

This paper is also an attempt to locally understand the use and different imprints of natural precipitation on agricultural practices and potential agricultural practice with artificial precipitation.

It may be mentioned here that this paper is an abstract version of two projects, i.e. "Space Based Information Support for Decentralized Planning" and "National Drinking Water Mission" both of which are national level projects coordinated by ISRO, DOS, GOI.

Three thematic layers in terms of Cadastral Layer (10K), Land Use/Cover (10K) and Ground Water Prospect (50K) are used as input data. Based on moisture content and other general guideline of image interpretation, the agricultural plots derived from land use/cover and cadastral plots have been separately demarcated and segregated into double crop, potential double crop and current fallow using high resolution satellite images. This output is further overlaid with ground water prospect layer to come up with plot level information on potential double crop with respect to good ground water prospect. Existing geo-processing tools of ARC GIS v10.3 have been used to generate the overlay analysis themes and statistics.

1. INTRODUCTION AND STUDY AREA

With nearly seventy two percent of the population living in rural areas, agriculture is the predominant occupation in the state of West Bengal with about 97.52 lakh hectares of Gross Cropped Area.

Agriculture in the state is farmer centric with 91 percent of the cultivators being small and marginal farmers who hold about 84 percent of the state agricultural land. Marginal operational holding with less than 1 hectare accounts for 88.8 percent of the total operational holdings. (NABARD)

With existing small holdings, farmers have very little scope of practicing capital intensive agriculture in relation to artificial precipitation.

These statistics compels the use of Cadastral data for understanding the impact of marginal holdings in gross cropped area of the region.

Rising temperature and changes in rainfall patterns have direct effects on crop yields as well as indirect effects through changes in irrigation water facility which means that Climate Change will have direct impact on water availability for irrigated crops (Nelson *et al*.2009),

In other words, natural moisture content of the surface plays dual role in daily agricultural practices by limiting yield fluctuations and limiting cropping practices.

In humid and sub-humid zones, irrigation has been used for some time to supplement rainfall as a tactical measure during drought spells to stabilize production, the process generally known as "supplemental irrigation" but more recently, the term "supplemental irrigation" has been used in arid zones to define the practice of applying small amount of irrigation water to winter crops that are normally grown under rain-fed condition. (Fereres, E. & Soriano, M.A., 2006).

Nevertheless, the focus of this paper is on understanding the geo-estimation of cropping area where practice of applying small amount of irrigation water to *Rabi* (Winter) crops and which are naturally moisture induced plots that are normally grown under rain fed condition.

Administratively, the study area comprises of three villages, namely, Kapasdanga (J.L.No.21) falling in Bharkata

Gram Panchayat. Alinagar (J.L.No.22) and Paschim Kalimkapur (J.L.No.23) falls in Sekeda Gram Panchayat. These together fall in Muhammad Bazar block of Birbhum district in the state of West Bengal.

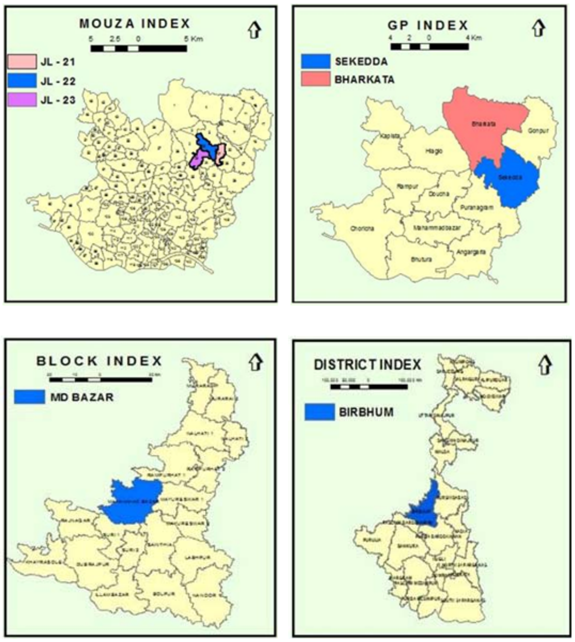

Fig. 1

2. DATA SOURCES & METHODOLOGY

Land Use/Cover (LULC) geo spatial layer is generated using High Resolution (Cartosat-1Pan + LISS-IV Mx.) ortho-rectified satellite Imagery under "Space based Information Support for Decentralized Planning SIS-DP" at 1:10K scale.

Crop identification and discrimination is based on the premise that each crop has a distinct and unique spectral response. Typical spectral reflectance of a crop canopy shows absorption due to pigments in the visible region (0.4 to 0.7µm) and high reflectance in the Near Infra Red (NIR) region (0.7 to 1.1 µm) because of the internal cellular structure of the leaves. The absorption of 1.45 µm, 1.95 µm and 2.6 µm spectral band is mainly due to leaf water content (Singh *et al.*, 2013). Typical spectral response characteristics of green vegetation are shown in Fig. 2.

Studies carried in India and elsewhere strongly advocate the use of Multi spectral remotely sensed data to identify major crops and determine their aerial extent. However, this paper attempts to identify the potential double crop purely using on-screen digitization technique in *Rabi* (winter) season and analyze it with respect to water availability and its impact to Gross Cropped Area.

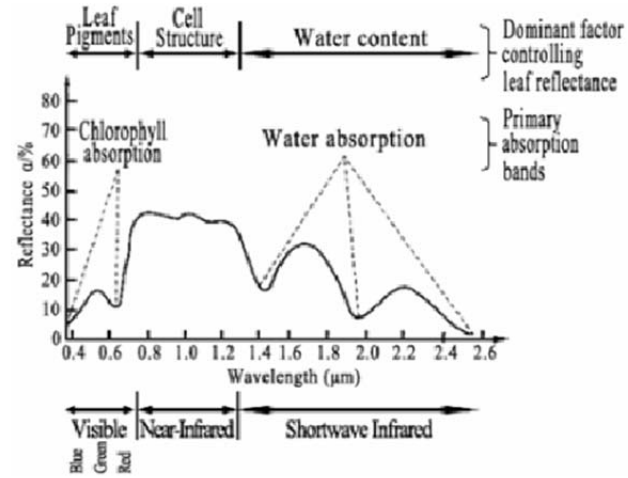

Fig. 2. Typical spectral response characteristics of green Vegetation (after Hoffler, 1978)

Cadastral geo spatial layer with Cadastral/Dag number is generated using High Resolution (GaoFen-2 Pan with 0.8m spatial resolution + GaoFen Mx with 3.2m spatial resolution) ortho-rectified satellite Imagery under the project "Generation of Cadastral Database of West Bengal" at 1:4K scale.

The cadastral data procured from L&LR, GoWB, are initially stitched on the basis of single village/mouza. This allows the user to locate sufficient ground control points during the process of geo-referencing of cadastral maps. General on screen digitization is used to demarcate the plot boundaries and cadastral/dag numbers in the form of polygon and point to generate a seamless cadastral output.

The third geo-spatial layer in terms of Ground Water Prospect of the region is generated from IRS 1C/D, LISS III data, District Resource Map, GSI, GOI and ground water data from Public Health Engineering Department, GoWB. under "National Drinking Water Mission Project" at 1:50K scale`

Overlay analysis of these three layers in GIS platform using Arc GIS v10.3 is executed. First of all, LULC layer is overlaid on Cadastral layer to segregate LULC on the basis of cadastral plot boundaries. Technically, it is not always possible to demarcate plot boundaries on the basis of LULC as there are many plots where further plot divisions are found or LULC boundary is not in the shape and size as seen in cadastral maps. There may be two different agricultural classes in one single plot and in such cases, the area plot boundary is further sub-divided on the basis of LULC on temporary basis. Whichever class in terms of area is more, then, that specific class is enlisted in that particular plot. These newly subdivided plots cannot be considered as individual plots because cadastral/dag numbers have not been demarcated and allotted officially.

3. TECHNICAL DISCUSSIONS

This SIS-DP classification of agricultural crops is further categorized into three sub-classes, i.e. double crop potential double crop and current fallow. Potential double crop is categorized based on the moisture content of the plots as visually interpreted from satellite images.

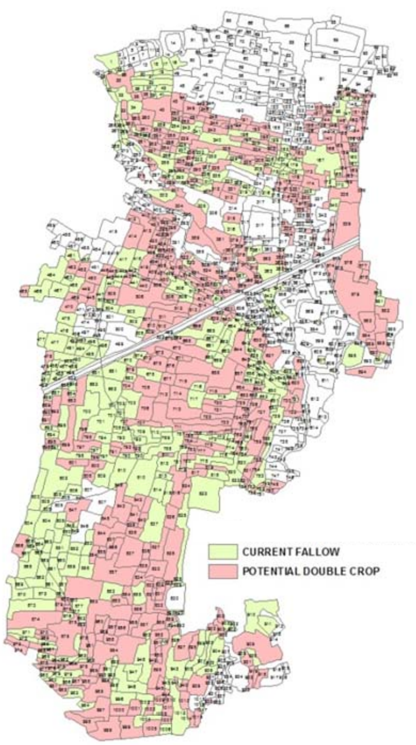

Fig. 3 Land Use/Cover with dag numbers

Cadastral plots where poor or nil moisture content is found is then categorized into current fallow. Similarly, plots as found with double crop are accordingly categorized. As mentioned earlier, general on-screen digitization method was adopted for classifying the sub agricultural plots. A snap shot for JL No. 21 is given in Fig. 3.

Apart from other land use/cover classes, the geo-statistics generated from this layer will then provide information on three major agricultural classes (double crop, potential double crop (PDC) and current fallow) at cadastral level enhancing the statistical analysis. See Table 1.

The percentage of double and PDC along with current fallow is calculated with respect to individual total agricultural area. Since the attempt of this paper is to estimate PDC, it is found that there are as many as 424 (JL:21), 341(JL:22 and 258(JL:23) PDC plots accounting to 67.3 Ha,(JL:21), 41Ha (JL:22) and 33.56 Ha (JL: 23) respectively. In total, there are 1023 plots measuring 141.8 Hectares of agricultural plots that can be generally grown as double crop under rain fed condition or by applying small amount of irrigation.

Table 1: Land Use/Cover & Cadastral Statistics.

VARIABLES	JL No. 21	JL No. 22	JL No. 23
Total No. of Plots	1098	1790	1700
Total Area (Ha.)	169.2	271.6	230.9
No. of Agricultural Plots	1069	1414	1236
Total Agricultural Area (Ha.)	122.8	157.2	155.5
No. of Current Fallow Plots	351	275	417
Current Fallow Area & %age	51.3ha/30.3%	30.8ha/11.34	48.26ha/20.89
No. of Double Crop Plots	294	798	561
Double Crop Area & %age	4.2ha/24.35%	85.4ha/31.45%	73.7ha/32.0%
No. of PDC Plots	424	341	258
PDC Area & %age	67.3ha/39.8%	41.0ha/15.06%	33.56ha/14.5%
No. of DC & PDC Plots	718	1139	819
DC & PDC Area	41.5ha/64.15%	126.4ha/46.5%	107.2ha/46.5%

These agricultural plots are in need of some form of small irrigation where double crop can be practiced. This is where geospatial layer of ground water potential can come into play to find out the expected yield of ground water available at various depths.

The ground water availability is mapped on the basis of rock formations having different hydro-geological properties. However, in general terms, the combinations of four factors, i.e. Lithology, Landform, Structure and recharge conditions are primarily responsible.

The terms of expected yield, liters per minute (LPM) is broadly classified into nine categories. They are yield range of wells with >800LPM (Violet), 400-800LPM (Indigo), 200-400LPM (Blue), 100-200LPM (Green), 50-100LPM (Yellow), 10-50LPM (Orange), 20-30LPM (Brown), 10-20LPM (Pink) and >10LPM (Red) with almost nil prospects. The yield as listed is represented by different colors in the map. The depth range of wells in meters (M) is represented by means of hash in the map and is classified into three broad categories, i.e., Shallow with <30M depth range (horizontal hash), Moderate with 30-

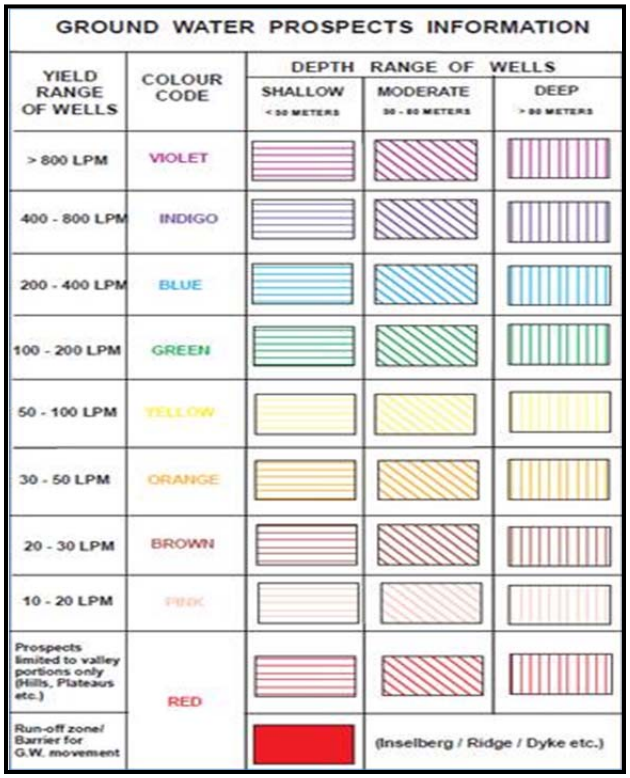

Fig. 4

80M depth range (diagonal hash) and Deep with >80M depth range (vertical hash) all depending on hydro-geological and other conditions of the terrain (NRSC, 2008). Fig. 4.

The earlier generated cadastral based land use/cover data is overlaid with ground water prospect layers using geo processing tools to derive another output where information pertaining to cadastral data, land use/cover data and ground water prospect data are derived from one single output. The earlier classified PDC will now contain information of the corresponding ground water prospect along with cadastral or plot numbers. This will now enable us to understand the actual potential double crop with respect to ground water availability which are generally grown as double crop under rain fed condition or by applying small amount of irrigation.

Snap shot of the output is given in Fig. 5 where JL No. 21 is displayed. Note the index provided in Fig. 6, as information regarding land use/cover, ground water prospect and hydro-geomorphology is also provided. The map in Fig. 5 represents the information at cadastral/plot level.

The index where LITH-GEOM is denoted comprises of alpha-numeric codes. The alphabets denotes the geomorphology and the numerical values represent the lithology. The classes represents different land use/cover classes while the ground water (p) denotes the ground water expected yield of water at suggested depth.

The derived table from the thematic map as provided in Table 2 where classified plot information like the number and type of agricultural plots with its total area and corresponding ground water prospect is provided at village/mouza level.

From the table, it appears that ground water is available at moderate depth range with 30-80m deep and yield of water varies east to west in decreasing trend

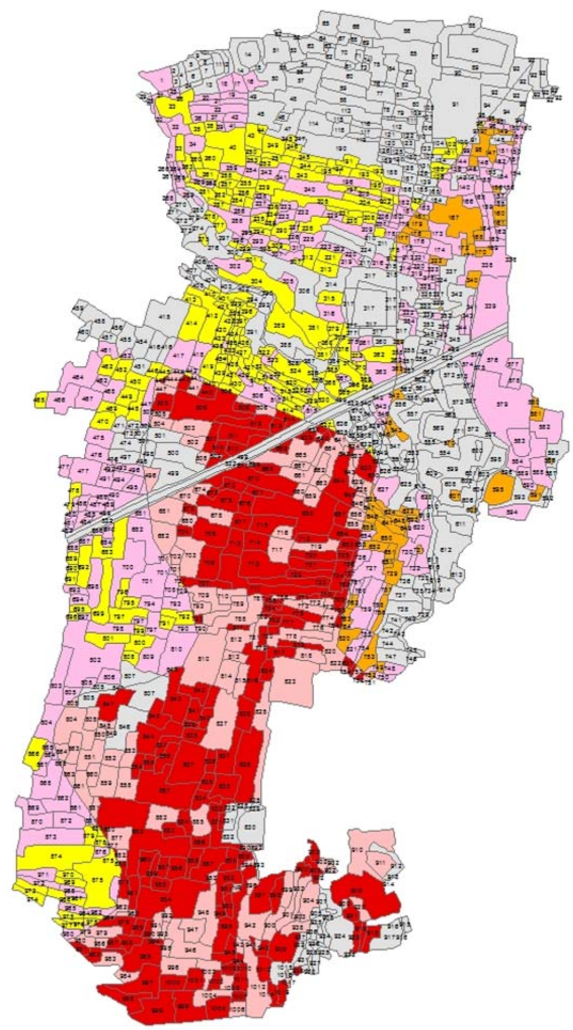

Fig. 5: Thematic view of Cadastral, Land Use/Cover and Ground Water Prospect for JL.No. 21

CLASS	LULC	LITH-GEOM	GROUND WATER (P)
	CF	APO13 VFS34	100-200LPM (30-80M)
	PDC		
	CF	LP211 PL34	50-100LPM (>80M)
	PDC		
	PDC	PL34	30-50LPM (30-80M)

Fig. 6: Thematic Index of for Fig. 4

This is because of the landform in the east is comprising of older alluvium followed by the undulating lateritic terrain towards west.

However, shallow irrigation is not applicable in the region as moderate depth range of wells is suggested. It is also found that the possibility of converting PDC into double crop is quite substantive. There are all together 84

Table 2. Ground Water Prospect (GWP) & Agricultural Plot Statistics.

GWP	JL No. 21	JL No. 22	JL No. 23
100-200 LPM 30-80M	T=309P/57Ha	T=91P/6Ha	T=11/1Ha
	CF=168P/23Ha	CF=25P/2Ha	NA
	PDC=7P/1Ha	PDC=66P/27Ha	PDC=11/1Ha
50-100 LPM 30-80M	T=162P/17Ha	NA	NA
	CF=91P/12Ha	NA	NA
	PDC=71P/1Ha	NA	NA
30-50 LPM 30-80M	T=395P/57Ha	T=616P/65Ha	TL=671P/80Ha
	CF=140P/23Ha	CF=292P/23Ha	CF=414P/45Ha
	PDC=255P/1Ha	PDC=324P/36Ha	PDC=257P/35Ha

plots measuring about 29 hectares which can be converted to double crop where both natural moisture content and ground water prospects are favorable. As far as those plots where moisture content is very poor but favorable ground water prospect are concerned, it accounts to about 193 plots measuring about 25 hectares. These plots can be converted to double crop by providing small amount of ground water irrigation.

It may also be mentioned that the general trend of ground water irrigated agriculture is on increasing mode since 1995-96 to 2010-11 in Birbhum district. It is found that irrigated area under surface water as percentage of GCA has declined and irrigated area under ground water as percentage of GCA has increased in Birbhum district during 1995-96 to 2010-11 (Konar & Dey, 2015)

The rest of the plots as found from the table does not look very encouraging as ground water yields and depth ranges suggest substantial investment required in extracting ground water as these are basically spread as lateritic uplands.

4. FINDINGS

The land use/cover statistics at cadastral level in relation to ground water prospect, when compared, results in high differences in statistics. Based on natural moisture content of the plots, it is found from Table 1 that there are about additional 1023 cadastral plots measuring about 141.8 hectares which can be grown as winter crops besides already existing winter crops.

However, when this finding is related to ground water prospect condition, the resultant number of additional favorable plots from Table 1, falls from 1023 plots measuring 141.8 hectares to 227 plots measuring 54 hectares which is about, 22 per cent of the plots and 38 per cent of the area.

Further analysis suggests that only 84 plots (8%) measuring 29 hectares (20%) with respect to Table 1 are considered truly favorable and which can be considered additional plots where both moisture content and ground water conditions are favorable for practicing *Rabi*(double) crop.

5. ACKNOWLEDGEMENTS

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