Reliability of agricultural statistics in developing countries: Reflections from a comprehensive village survey on crop area statistics in India

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Abstract: Despite the importance of agriculture in developing countries, and the general recognition for strengthening data quality, very few studies examine the quality of available data and the data generation methods in agriculture. In this paper, we use data from an extensive deployment of geospatial technology, administrated concurrently alongside the conventional method in the Indian state of Karnataka, to assess the discrepancy between methods in the magnitude of difference in the crop area, type and number of crops grown. The crop area estimates based on alternative method, utilising the geospatial technology, exceeded that from the estimates based on conventional method. Conventional method seems appropriate for measuring crop area under staples but not for high value cash crops. This has wider implications for commercializing agriculture in the developing countries. Some research and policy implications are discussed.

1. Introduction

The recent World Development Report on “Agriculture for Development” demonstrates that agriculture is central to achieving the Millennium Development Goal of poverty reduction and environmental sustainability (World Bank 2008). Yet, the quality of available data and the data generation methods in agriculture are notoriously weak in several developing countries. Although there is a general recognition for long on strengthening data availability in developing countries (United Nations 1979; World Bank 2011; African Development Bank Group 2011), surprisingly little research exists examining the reliability of existing data and its method of collection (Beegle et al. 2012; Deininger et al. 2012). However, some recent studies examine the reliability of household consumption data (Sen 2000; Kulshrestha and

Kar 2005; Deaton and Kozel 2005), albeit the production side of agriculture still remains limited.

We are aware of only two recent contributions, examining the reliability of traditional recall-based survey method in the generation of agriculture production statistics. The evidence from these studies are mixed - Beegle et al. (2012) find little evidence of large recall bias in the agricultural data, while Deininger et al. (2012) note significant differences in the data generated between recall-based survey and production diaries. However, it is not clear yet which of these two methods can generate data that is closer to the true value, as the true value is unlikely to be known.

This paper contributes to this emerging literature in examining the reliability of agricultural statistics, by probing the data quality and data collection methods of the crop area statistics, which is both measureable and also independently verifiable using existing technology. We examine the reliability of crop area statistics from India, which has one of the best developed survey capacity in the world, and a long tradition of collecting data on a range of economic indicators (Deaton and Kozel 2005). Although Indian consumption data has been subjected to extensive scrutiny, agricultural statistics has eluded the attention of researchers, especially the data on crop area statistics. The information on crop area and land use, however, is vital for effective policy planning and design interventions to fully realize agriculture's potential strengths.

In this paper, we extend this literature by drawing on the extensive deployment of geospatial technology in the Indian state of Karnataka to collect crop area statistics in parallel to applying the contemporary data collection method. Having administered the geospatial technology to the crop area for the same households also included in the conventional method, we are able to compare the crop area estimates by the two methods.

The analysis here presents some interesting results. First, conventional method, which entails manually gathering data, does not capture the changing cropping patterns stirred by commercializing agriculture in a developing country. Comparing area under crops and the type and number of crops shows considerable discrepancies between both the methods. Conventional method provides information only for 13 of the 20 crops grown ignoring some of the vital high value cash crops in transitional agriculture. The crop area using alternative method significantly differ from estimates based on conventional method (by 56%) suggests that administrative data on crop area collected routinely are likely to be underestimate. This could significantly affect the projections of crop production in the following season, underestimating actual production. The resulting excess production, with no planning on utilisation in place, will result in rotting food stocks observed recurrently in India (Basu 2010).

Second, conventional methods seem appropriate for measuring crop area under staples but not for high value cash crops. The discrepancy in the area estimates between both methods for some continues cash crops are over 80%, for instance Arecanut (84%) and Tamarind (96%). Changes in the magnitude and direction of these differences across crops can help identify ways to improve the quality of area statistics.

Third, although the first application of geospatial tool is not cost effective, the cost of subsequent updating is even lower compared to the conventional method. Several recent applications of global positioning systems (GPS) in access to infrastructure and social services (Perry and Gessler 2000; Hong et al. 2006), household leaning (Conley and Udry 2010) and collection of household surveys (Landry and Shen 2005) have been reported, but improving agricultural statistics have not yet been examined.[1] This paper contributes to this

[1] See Gibson and McKenzie (2007) for a comprehensive survey of literature on several other applications of GPS for better economics and better policy

growing literature documenting the importance that GPS/GIS can make to improving agricultural statistics in developing countries.

The paper is structured as follows: Section 2 describes the conventional method used in the estimation of crop area, also highlighting the different challenges that exist using this method. Section 3 discusses the two alternative approaches and examines the appropriateness of each method. Section 4 presents the data collected using the alternative method proposed here. The next section compares the crop area data collected using both methods to evaluate the agreement between conventional and alternative methods in measuring the crop area. The last section presents some concluding observations.

2. Current approach and challenges

In the current approach, the collection of crop area statistics is assigned to the village level agency known as the *patwari* or village accountant, who provides timely information using conventional method, which involves manually gathering data about each crop in every village. Traditionally, the village accountant (VA) is the person responsible for gathering the entire crop information. About 4600 acres of land in one *gram panchayat* (GP) is allocated to each VA to collect crop information.[2] In order to corroborate and systemically document the conventional method, we carried out detailed interviews with two VA's from two different GP's in the Gubbi Taluk – Nallur and Marashetty Halli, chosen to adequately represent the spatial diversity of the data collection method in the Indian state of Karnataka.[3] Both interviews with the VA's were recorded using a voice recorder with prior permission from

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[2] *Gram panchayat* or GP is the smallest local government unit in rural areas in India comprising of 3-5 villages with total population of approximately 5000. A Taluk comprising of several GP's (generally 30-40 GP's but can be higher or lower depending on the size of the Taluk) is a sub division of a revenue district and a revenue district is a sub division of a state.

[3] A copy of the questionnaire can be requested from the corresponding author.

the respondents. However, the name and location of the respondents are kept anonymous here for ethical reasons.

Each VA is assigned to collect crop information in at least 50% of the 4600 acres allocated to him for all the three seasons in a year. The VA goes to the crop area and visually maps the crop area, and enters all the relevant details into the *pahani book* (Bhoomi 2012).[4] *Pahani* or record of Rights, Tenancy and Crops (RTC) contains details of land ownership, area measurement, soil type, nature of possession, liabilities, tenancy and crops grown. The VA is required to use one book for five years to store the details. This registered data is usually verified by the Revenue Inspector (RI) using previous year's crop area data. In case of no corrections, the data is sent back to the VA for further processing. The VA sends the verified data to the computer center (CC), which in turn sends the data to a private software firm for digitalization process. The private software firm takes about 20 to 30 days to digitalize and documents the data into a CD. The CD is given back to the CC for uploading the data on to an online database called *Bhoomi*. For illustration, a flow chart describing the conventional method is presented in the Appendix.

Realistically, considering the VA's work load, his potential to collect the crop information can be stretched at most to half of the total allocated area. Moreover, one month time allocated to complete the data collection process each season also seems inadequate. Consequently, the major drawback of the conventional method is the lack of quality information on crops grown. The crop area observed from the RTC for the current season and yield information, gathered from samples in the crop cutting experiment of the previous season, is used to estimate the production of crops in the forthcoming season to predict crop

[4] *Pahani* (RTC) is a book with listed attributes of land holdings, irrigation, property, crop type and area developed under the *Bhoomi* project. Bhoomi is the project of on-line delivery and management of land records in Karnataka.

prices. Hence, inaccurate crop area statistics has a direct bearing on the predicted prices, resulting in false policy making and erroneous procurement process (India's paradox of hunger amidst plenty), and thus inadequate preparedness to deal with fluctuating production, also affecting the farmers directly and significantly.

3. Appropriateness of the Alternative method

3.1. Geospatial methods

To address the problems of gathering accurate crop area information using conventional method as described in the previous section, in this section we consider two available technologies to improve the quality of crop area statistics. Apart from describing each method below, we also point out the potential challenges.

3.1.1. Satellite remote sensing

Remote sensing (RS) is a potential approach for collecting crop area data, crop area assessment and forecasts. It provides multi-spectral, synoptic and repetitive coverage with less scope for human intervention in the data generation process, reducing non-sampling errors. This method can be used for anomaly detection amid high temporal resolution with at least 5-6 observations per season (Ray, Panigrahy & Parihar 2008). RS technique gathers crop area information when the crop has sufficiently grown (Srivastava 2011). It can correlate soil physical properties such as soil water, organic matter and soil texture to spectral reflectance. It is also capable of integrating biophysical parameters (such as temperature or leaf area index). This method takes approximately 24-48 hrs to acquire, correct and process the data. However, time to process a given area depends on the resolution as 1m resolution data takes more time to cover the area than 60m resolution data. This in turn depends on the type of satellite used. In table 1, we list the type of satellites used in the Indian context with their associated resolutions.

Although this method has been widely used before in many countries[5], the Government of India (GOI) adopted this method with the launch of the program for Crop Acreage and Production Estimation (CAPE) in the year 1987, covering all the major cereals, pulses and oilseeds. Following huge losses in 1998 due to late decision about wheat import, this program was further strengthened with the commencement of forecasting agricultural output using space agro-meteorology and land-based observation (FASAL) in August 2006. FASAL provides in-season multiple forecasts using weather data, economic factors and land based observations, and is capable of producing multiple crop forecasts, starting from sowing to the end of the season (Parihar & Oza 2006). It also has the potential to provide changes in cropping pattern, soil moisture and rainfall. Key crops covered under the FASAL are rice, wheat, cotton, sugarcane, rapeseed/mustard, rabi-sorghum, winter-potato and jute.

The satellite image associated with this method, however, has a major drawback of not being enlarged beyond 1:10000 (Tsiligirides 1997). Timely and reliable crop estimates cannot be given for areas having persistent cloud cover which blocks the satellite view. However, usage of Synthetic Aperture Radar (SAR) can identify the crop even during cloud cover. Integration of optical and SAR images would also increase the accuracy of crop mapping (McNairn,

[5] The use of RS for crop inventory began in United States (U.S) with Large Area Crop Inventory Experiment (LACIE) in late 1970's (Moran 2000). The experiment was a success in gathering the information. National Agriculture Statistics Service (NASS) of U.S provides timely and accurate statistics to U.S agriculture using RS as a valuable tool to improve accuracy. U.S uses Landsat, Resourcesat-1, NASA MODIS, etc for RS purposes. Kazakhastan began the use of RS in 1997 and it has approximately 14 million hectares of net sown area (GEO 2011). Due to its large field sizes, satellite images provide high accuracy in gathering crop area information. Netherlands had used sample ground survey data and high resolution image to gather crop inventory data (Gallego, 1999). Similarly, Canada uses optical imagery for mapping crop information and crop condition (McNairn, Ellis, Van Der Sanden, Hirose & Brown 2002). Brazil has approximately 54 million hectares of agricultural land and it had started using RS through Geosafras project in 2003 to improve crop monitoring, forecasts, etc. Landsat and CBERS – 2 were used for field mapping and area estimates. MARS-Stat provides accurate and timely crop information for European countries since 1992. It includes RS satellites such as; NOAA-AVHR, SPOT-VGT, MODIES, MSG. China started using RS to monitor agriculture in late 1970's. Later on it improved its capabilities with advancements in technology. RS is extensively used to provide agricultural statistics and monitor/manage agriculture in China. Other countries such as Argentina, Russia, etc also use RS as an important tool to improve accuracy of crop area information.

Champagne, Shang, Holmstrom & Reichert 2009). Besides, the accuracy of crop inventory using this method can be further improved when combined with field surveys (Mehta 2000). However, this method appears inappropriate in the Indian context owing to the heterogeneous nature of cropping pattern and small plot sizes (Ray, Panigrahy & Parihar 2008).

3.1.2. Geographical information systems and tools

The second geospatial technology considered here is the integrated approach involving both the geographical information system (GIS) and the global positioning system (GPS). The geographical information system (GIS) is an information system used for editing, storing and displaying geographic coordinates, while GPS is the tool which references the ground data using longitude and latitude coordinates. Here GIS acts as an interface to visualize geography in various layers. The coordinates can also be referenced using spatial grid maps; however, it can only be used if the area is intimately familiar. Since, GIS and GPS technologies were adaptable and easy to use compared to RS (Nelson, Orum, & Jaime-Garcia, 1999), they have been chosen as the alternative approach for this study. Also due to existence of small crop sizes and mixed crops in India, GIS/GPS system suites better than RS. Previous instances of successful experimentation with this technology have already been documented elsewhere.[6]

Under this method, the data is collected by traversing the crop area using a GPS device along with the owner of the land. For the geospatial application to provide accurate results, it is recommended that the first survey has to be implemented rigorously by traversing every single plot of land within a village. Corresponding irrigation facilities are also documented using the GPS device. If a single land parcel/ sub-parcel have more than one crop, the

[6] According to Reichardt, Jurgens, Kloble, Huter, & Moser (2009), GPS tool has been used successfully by a group of farmers in Germany for data collection. Sri Lanka used GIS to manage irrigation systems with the help of United Nations World Food programme. In New Zealand, the use of GPS/GIS devices helped in managing application of fertilizers. Usage of geospatial technology reduced 10 % of expenditure on fertilizers and it also avoided the harmful runoff of fertilizer into streams/canals (ESRI, 2008).

boundary of each crop plot needs to be traced using the GPS device for recording details of each crop. To improve the accuracy of the data, mapping of the entire geographical terrain within the village is recommended, including all the survey numbers, fallow land, scrub land, water streams, roads and water tank/pond. The data from the GPS device is uploaded to the server through internet whenever possible.

For this study, a specialized geospatial company Zoomin Infotech, developed the application and designed the knowledge data base using RTC records and village area maps. A seamless geographic database for understanding disposition of the lands was also developed that contains village, GP, taluk and district boundaries and location of village settlements. The GIS application developed by Zoomin Infotech updates the changes in server and functions as a Graphical User Interface (GUI) for the user. One advantage with this method is that it suffices to update and map for only those crop areas that are subject to seasonal flux, keeping the operational cost of data collection lower.

3.2. Comparing alternative approaches

The data collected from interviewing the VA's are transcribed and interpreted to identify the processes involved in the conventional method, which is then compared to the alternative method proposed in this paper. The key differences between the methods are briefly described here and documented in detail in the Appendix. The differences in the processes identified in both these approaches can be classified into three categories: (a) process of data collection (b) verification of data (c) digitization and dissemination of data.

3.2.1. Process of Data collection:

The process of data collection in the alternative approach is completely digitized, reducing the time for collection and dissemination of information. Under conventional method, crop area is gathered by the eye-balling technique and recorded manually in the *Pahani* book. In the alternative method, the data for crop area is gathered and recorded using a GPS device traversing the field along with the farmer, and then digitally transferring the information to the database. The automated process in the alternative method helps secure the accuracy of the data. Adequate provision of recording the corresponding irrigation facilities, missing previously, are available under the alternative method.

3.2.2. Verification of data

The data collected by conventional method is verified by the Revenue Inspector (RI) using previous RTC records. In the case of alternative method, the data is verified by digitized RTC records with the owner of the crop area while traversing.

3.2.3. Digitization and dissemination of data

The digitization of the crop area gathered by the VA using conventional approach takes about 20-30 days. However, in the alternate approach the process of data collection is digitized using GPS device, and the data uploaded to server instantaneously through internet. The other drawback in the conventional approach is the lack of a GUI in displaying crop area information. The GIS application gives micro details of the crop area data and this facilitates accurate crop area forecast.

4. Data

The geospatial crop area survey for this study using the GIS/GPS technology was carried out in partnership with the specialized geospatial company Zoomin Infotech. Zoomin Infotech assisted us in gathering and storing the crop information in about 2700 acres of land area, covering the entire Nallur village of the Nallur GP in the Gubbi taluk, Apart from mapping crop area, the survey also included fallow land, scrub land, water streams, roads, water tanks/ponds and habitation.

Due to the soaring cost of the first survey and limited budget, we limit the geospatial survey to one single village, however, implemented rigorously by comprehensively traversing every single plot of land within the Nallur village. It is the implementation of the first survey that is very expensive, but the cost of subsequent updating is lower. Surprisingly, this cost of subsequent updating is even lower than the cost of using conventional method (see appendix Table A1 for cost comparison under both methods).

Large scale print of the Nallur village map and the village land register for the Nallur GP is obtained from the Government for Planning, Karnataka State. Crop inventory as available in the RTC on Jan 2011 was also collected. The owner of the crop area was requested to show and walk along the boundary of his/her land. The field crew also walked along the boundary of the parcel with the GPS device. When the traverse was closed, the details were recorded and crop grown identified. The source of water supply for irrigation was also noted and the structure if any (i.e. bore well/open well/ canal) was located with the GPS device.[7]

Using the GIS application developed by Zoomin Infotech, information for each parcel of land was populated with information on the land ownership, crop area and the type grown, irrigation facility and survey number. The field notes used by Zoomin Infotech were used to identify the design, development and implementation of the geospatial survey. These field data were corroborated and supplemented with information collected from the interviews with the village accountant.

In the next section, we compare the crop area data collected using this alternative method (GIS/GPS technologies) with the administrative data collected using the conventional method (RTC records), described in detail in section 2.

[7] The snapshots and other details of the GIS application can be requested from the corresponding author.

5. Results

5.1. Comparing methods of measurement

Although the overall difference in the total crop area estimates between both methods is 56%, the discrepancies depend on the type of crop. The differences in crop area estimated for each crop using conventional and alternative methods are presented in Figure 1. The differences, reported here in acres, are measured for each crop along the ray from the centre. The differences are negligible for some crops like Groundnut, Eucalyptus, Chilly, Beans, Banana, Teak, Pepper, Flower, Beetle Leaf, Tamarind, Sapodilla and Sorghum. However, these in total constitute an insignificant crop area of 2.5% and 1.6% of the total crop area estimated from conventional and alternative methods, respectively.

The figure 1 shows that the largest absolute difference in crop area (54%) estimates between the methods is for Finger Millet. This short duration staple crop constitutes about 30% of the total crop area. For coconut, the under estimates by the conventional method is somewhat lower (27 percent), however, this crop constitutes a larger area of about 38% of the total crop area. The other crops that show considerable difference in estimates between the methods are for Arecanut and Mango.

Note that except for Finger Millet, all the other crops showing considerable divergence in area estimates between the methods are for high value long duration cash crop. Since these cash crops constitute about 63% of the total crop area, it is paramount to investigate the reasons for divergence. This is surprising, given that long duration crops can be easily predictable using conventional method as they remain planted for several years, while short duration crops could potentially vary between seasons. However, discussion with farmers pointed to the changing cropping pattern as the key reason. Over the years, the crop areas under all the three cash crops have expanded, while the area under Finger Millet has contracted. These changing cropping patterns, not captured and reflected in the administrative data collected using conventional method, have wider implications for crop loan and insurance, and also could potentially pose serious threat to food security.

A comparison of crop area between methods shows that conventional method, in general, underestimates crop area and is not appropriate for capturing the changing cropping pattern. This is an enormous concern for a developing country with its agriculture sector in transition towards commercialization and adoption of high value crops. Are the differences in crop area estimates from the two methods statistically significant? In the next section, we examine this question using the Bland-Altman approach evaluating agreement between conventional and alternative measurement methods. The key emphasis of this approach is on a direct comparison of the results obtained by the different methods. The aim of the following section is to examine whether low cost conventional method is comparable to the highly expensive alternate method, to the extent that one might replace the other with sufficient accuracy in measuring the area under each cultivated crop.

5.2. The Bland-Altman method

The method underlying the Bland-Altman approach, used extensively in the medical sciences to test between measurement methods (Bland and Altman 1983, 2012), can be represented as follows:

$$y_{mi} = \alpha_m + \mu_i + e_{mi} \quad e_{mi} \sim N(0, \sigma_m^2)$$

with y_{mi} denoting measurement by method m on individual i. Here m signify two methods of measuring crop area (i) conventional method c and (ii) alternative method a. The difference in measurement between the methods, $d_i = y_{ci} - y_{ai}$ being identically distributed with mean $\alpha_c - \alpha_a$ and variance $\sigma_c^2 + \sigma_a^2$, independent of the averages $\bar{y}_{.i}$ if $\sigma_c = \sigma_a$ or r = 0, where r is the correlation between mean and variance. The Bland-Altman plot between d_i and

$\bar{y}_{.i}$ is used to inspect visually whether the difference and its variance is constant as a function of the average. From this plot, it is much easier to assess the magnitude of disagreement, spot outliers, and see whether there is any trend. If the measurements from both methods are comparable (agree), the differences should be small and centred around zero, showing no systematic variation with the mean of the measurement pairs.

The Bland-Altman analysis is supplemented with a more formal test, Pitman's test of difference in variance (Pitman 1939; see Snedecor and Cochran 1967), comparing two correlated variances in paired samples to test the agreement between conventional and alternative methods for measuring the crop area. The results from this test are presented in Table 2 for all the crops.

The Bland-Altman plot for the total crop area presented in figure 2 shows the presence of outliers, and existence of association between the difference and the size of the measurements. However, the log transformation did not alter the results considerably. The plot displays considerable lack of agreement between the conventional and alternative methods, with discrepancies stretching the limits of agreement (-2.1 and 2.9) beyond acceptable levels (Table 2). The limits of agreement are not small enough for us to be confident that the conventional method can be used in place of the alternative method. The results from the test of independence (null hypothesis of $r = 0$), presented in table 2, shows a significant relationship between the methods difference and the size of measurement ($r = 0.21$, $p = 0.00$). It confirms the lack of agreement between the methods for all crops.

Similar results are also observed for all the long duration high value crops - Arecanut, Coconut and Mango. The bias, shown by the mean difference in table 2, is the largest for Arecanut with 0.81, while a lower r ($r = 0.12$, $p < 0.10$) is observed for Coconut, however, significant only at 10% level. For these crops, the mean differences indicate a bias toward underestimation for the crop area from the conventional method in comparison to the alternative method.

As also noted in the previous section, somewhat surprising are the results for the short duration staple crops – Sorghum, Paddy and Finger Millet, reported in figures 5, 7 and 8, respectively, and also in table 2. The mean difference of 0.05 for Paddy reported in figure 6 and also in table 2 shows negligible bias. The mean differences for Sorghum and Finger Millet, however, are beyond acceptable levels, indicating a bias toward underestimation of the crop area from the conventional method in comparison to the alternative method. However, the pitman's test showed no significant difference between variances in the conventional and alternative method for all the three crops, accepting the null hypothesis of no correlation between the methods difference and the size of measurement, hence, demonstrating good agreement between the two methods.

6. Concluding discussion

Despite the significance of agriculture in developing countries and the general recognition of improving agriculture and rural statistics in these countries, surprisingly little research on this topic exists. This paper contributes to this literature by focusing on how agricultural statistics can be strengthened in developing countries using new geospatial tools taking the case of rural Karnataka in India. We implemented a comprehensive survey of crop area using the GPS/GIS tools in parallel to the conventional method to document any differences between the methods in the crop area estimates for the same plots of land.

Results presented here suggests that conventional method do not seem to capture the changing cropping patterns stirred by commercializing agriculture in developing countries, however, seems appropriate for measuring crop area under staples but not high value cash crops. Although this paper demonstrates the merit of using geospatial technology in collecting crop area information, there are potential payoffs in routinely deploying this technology for household surveys, household asset and resource mapping, geo-referencing of village infrastructure, geo-referenced poverty mapping, etc. With falling costs of this technology and increasing evidence of the potential benefits, this technology will see wider applications within developing countries.

Some analytical caveats remain, however. First, although the results presented in this paper are specific to Nallur village in the Indian state of Karnataka, the implications and issues raised are highly relevant to the rest of India, where conventional method is still widely used in gathering crop area statistics. A second critique is on the usage of GIS/GPS technology, which requires manually traversing the crop area accompanied by the crop owner. However, an unscrupulous crop inventor could choose to ignore the directions of the crop owner. This geospatial survey was subjected to strict quality controls, requiring presence of the crop owner and also independently monitored by a supervisor. This was a comprehensive survey where each plot of land within the village was accounted for.

Third, more generally, GIS/GPS technology cannot be a panacea as are the other technologies, because the success of the technology depends also on the proper use, data management and transfer system. This specific geospatial survey by Zoomin Infotech required considerable resources, refining the application based on the inputs from the RTC records and village area maps, to design the knowledge base. For the geospatial survey to be robust, this technology requires traversing every plot of land within each village for the first survey. Hence, budget considerations may limit the use of this technology. However, with time the cost of technology may fall enabling wider use of this technology strengthening a range of statistics.

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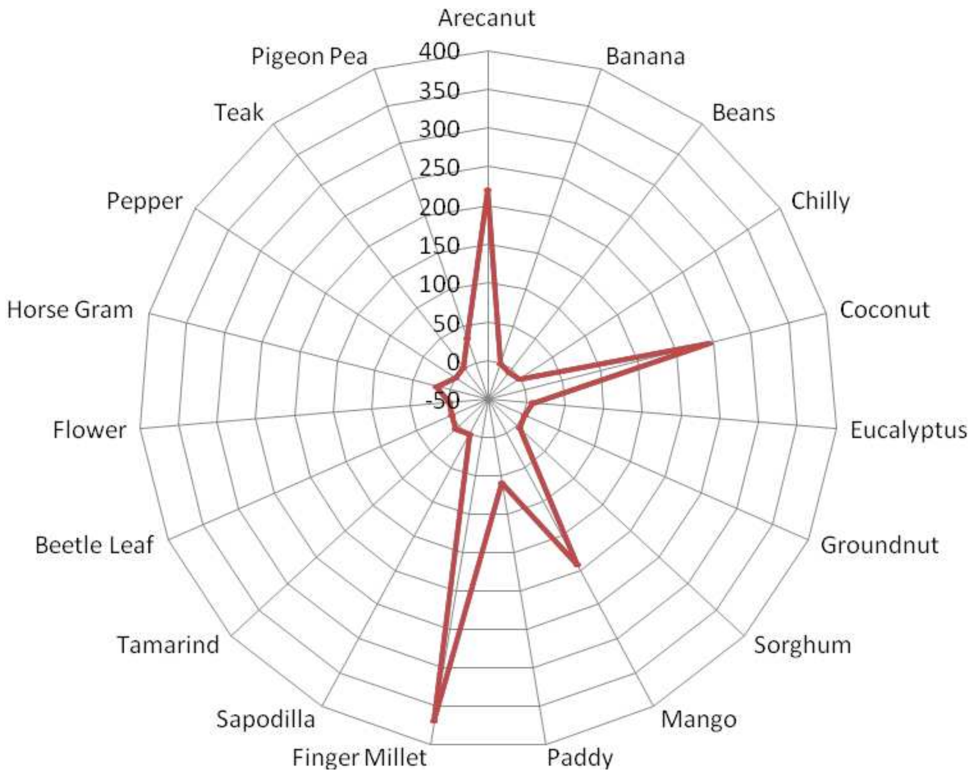
Figure 1: Difference in crop area obtained by conventional (c) and alternative methods (a) for the year 2011



Note: The crop area in acres obtained by alternative method is the simple average of the estimates obtained twice, first during January and again in November 2011.

Figure 2: Difference in methods against their mean for total crop area

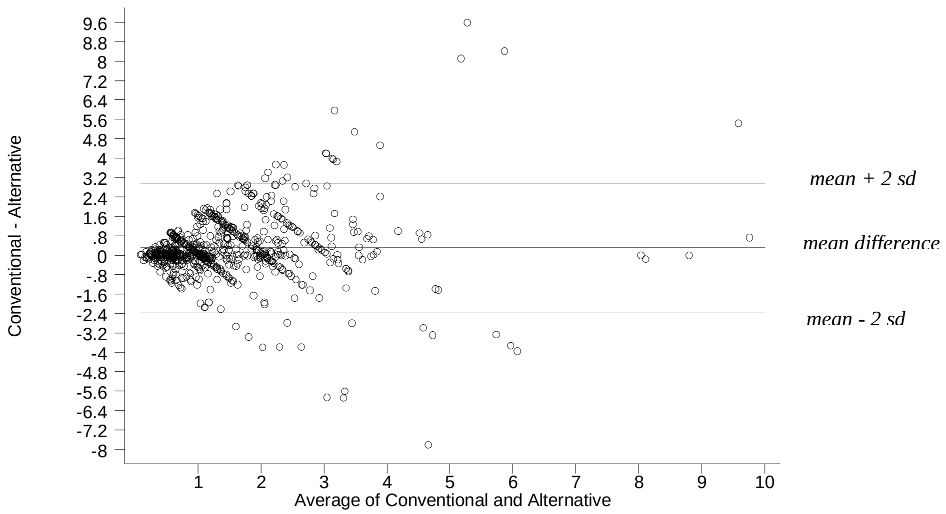


Figure 3: Difference in methods against their mean for Areca nut crop area

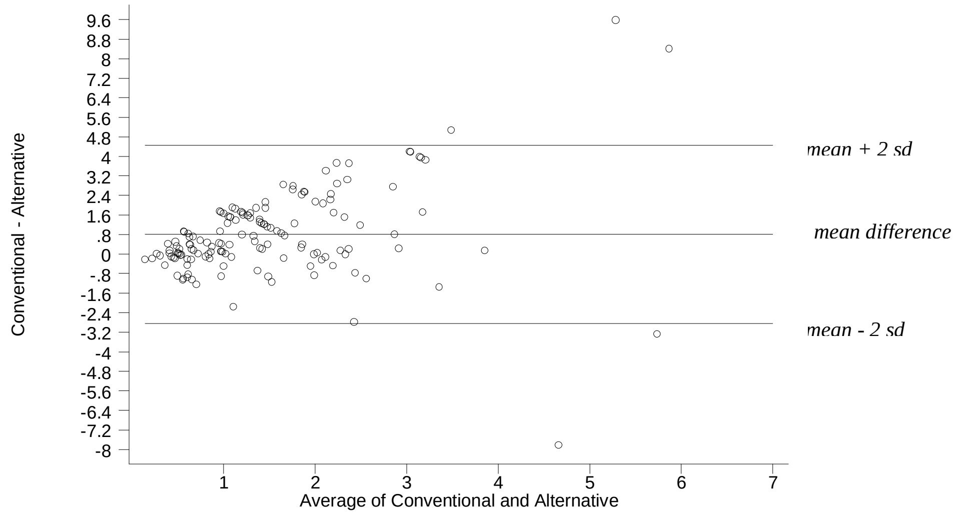


Figure 4: Difference in methods against their mean for Coconut crop area

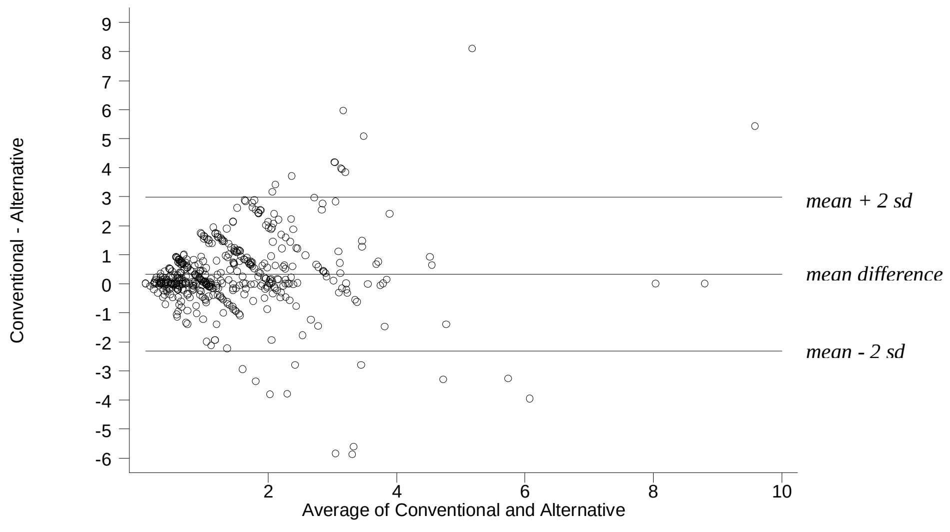


Figure 5: Difference in methods against their mean for Sorghum crop area

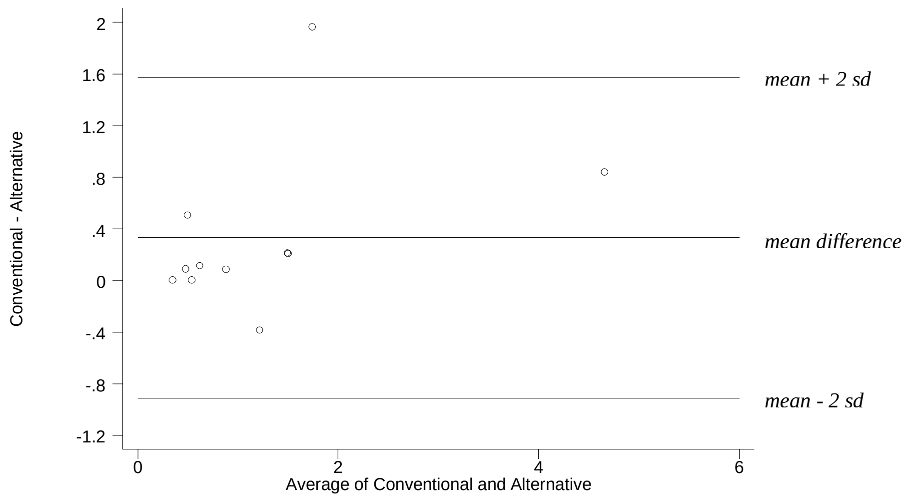


Figure 6: Difference in methods against their mean for Mango crop area

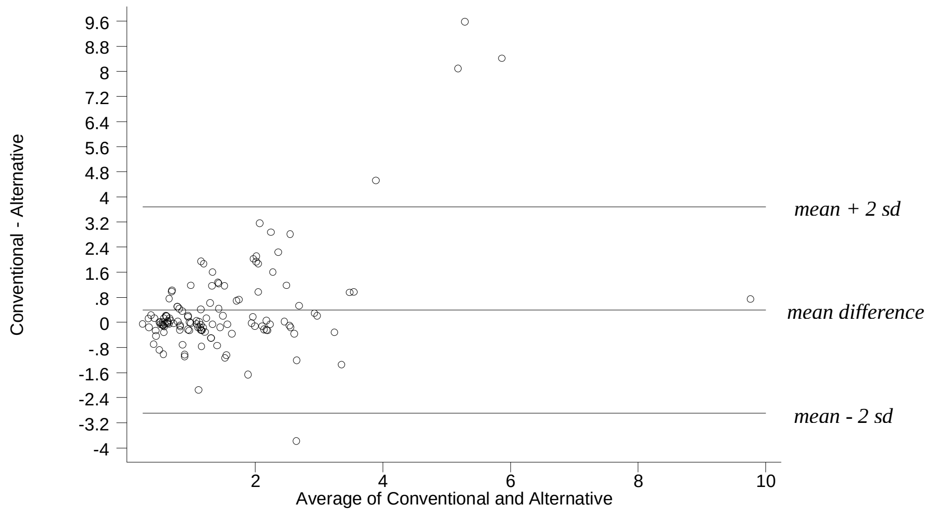


Figure 7: Difference in methods against their mean for Paddy crop area

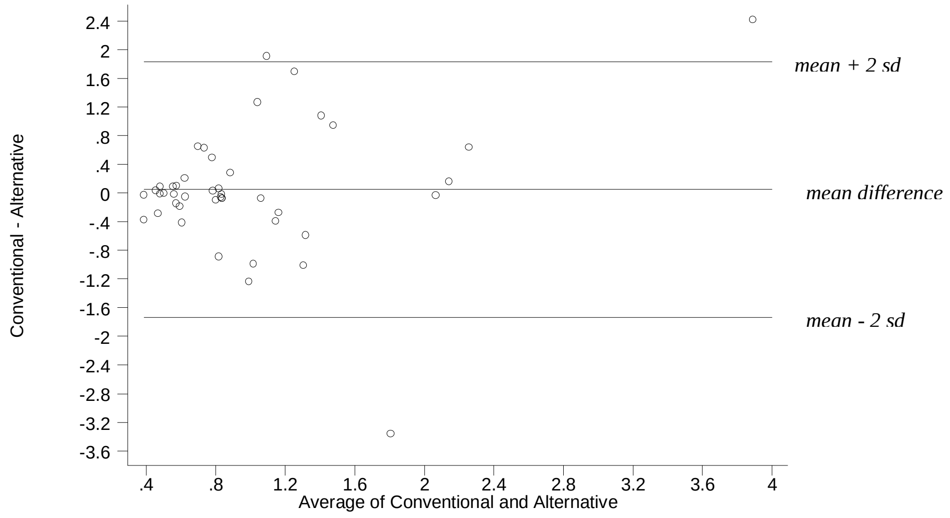


Figure 8: Difference in methods against their mean for Finger Millet crop area

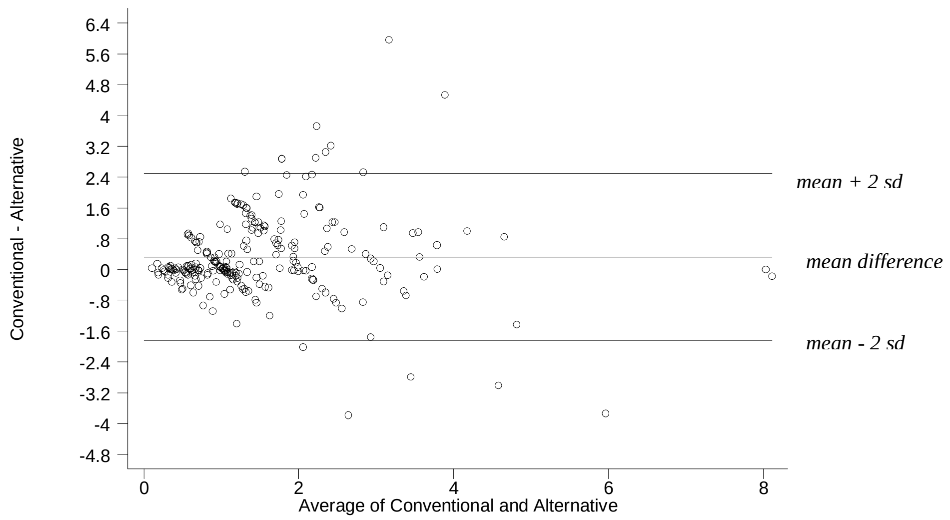


Table.1 RS satellites and their resolution

Satellite Name	Resolution
IKONOS	1m
IRS Pan	5.6m
Resourcesat -1	6m (multi spectral)

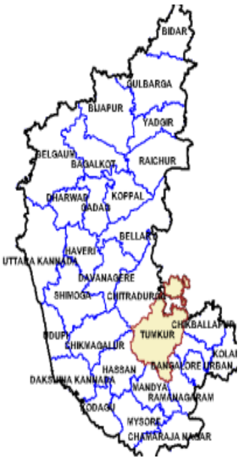
Table 2: Comparison of methods for estimating crop area

Crop	Mean difference		Limits of agreement	Pitman's test of difference in variance	
	Mean	95% CI		r value	p value
	1	2	3	4	5
Arecanut (n = 148)	0.81	0.51 to 1.10	- 2.83 to 4.45	0.34	0.000
Coconut (n = 458)	0.33	0.21 to 0.45	-2.32 to 2.99	0.12	0.009
Sorghum (n = 11)	0.33	-0.08 to 0.75	-0.91 to 1.57	0.43	0.180
Mango (n = 127)	0.40	0.11 to 0.68	-2.89 to 3.69	0.49	0.000
Paddy (n = 44)	0.05	-0.22 to 0.32	-1.73 to 1.83	0.25	0.089
Finger Millet (n = 249)	0.32	0.18 to 0.45	-1.84 to 2.49	0.00	0.886
All Crops (n = 655)	0.36	0.27 to 0.46	-2.16 to 2.90	0.21	0.000

Note: The total number of observation under All Crops (last row) does not match with the addition of observations across crops due to mismatch in cultivated crops recorded under both methods across all the crops. Apart from the crops listed in this table, All Crops also includes Banana, Beans, Chilly, Eucalyptus, Groundnut, Sapodilla, Tamarind, Teak and Pigeon pea. These crops were excluded from the disaggregated analysis due to insignificant crop area under each of these crops. The first two columns show the estimated bias with the expected intra-individual difference's 95% confidence interval (CI) limits'. The third column shows the mean difference plus or minus 2 standard deviation ($\bar{d} \pm 2$sd). The Pitman's test is reported in column 4 and 5 with correlation between difference in methods and their average denoted as r and the next column reports the p-value of a test with the null hypothesis that there is no significant difference in variances between the conventional and alternative methods.

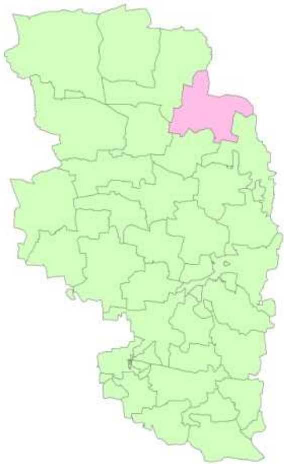
Appendix A

Figure AI. Map of the Karnataka State, Gubbi Taluk, Nallur GP and Village

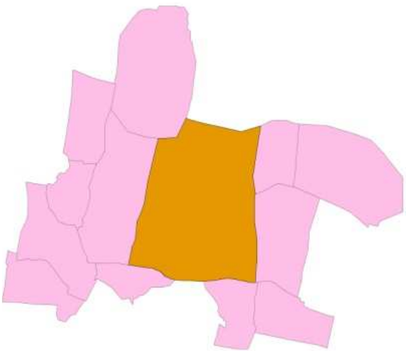


Karnataka State

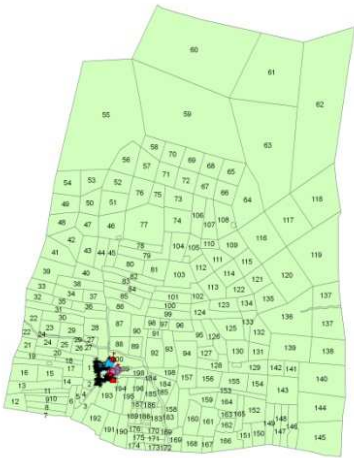
Gubbi Taluk inTumkur District



Nallur GP in Gubbi Taluk



Nallur Village in Nallur GP



Nallur Village map

Figure A2. Summary of the conventional method

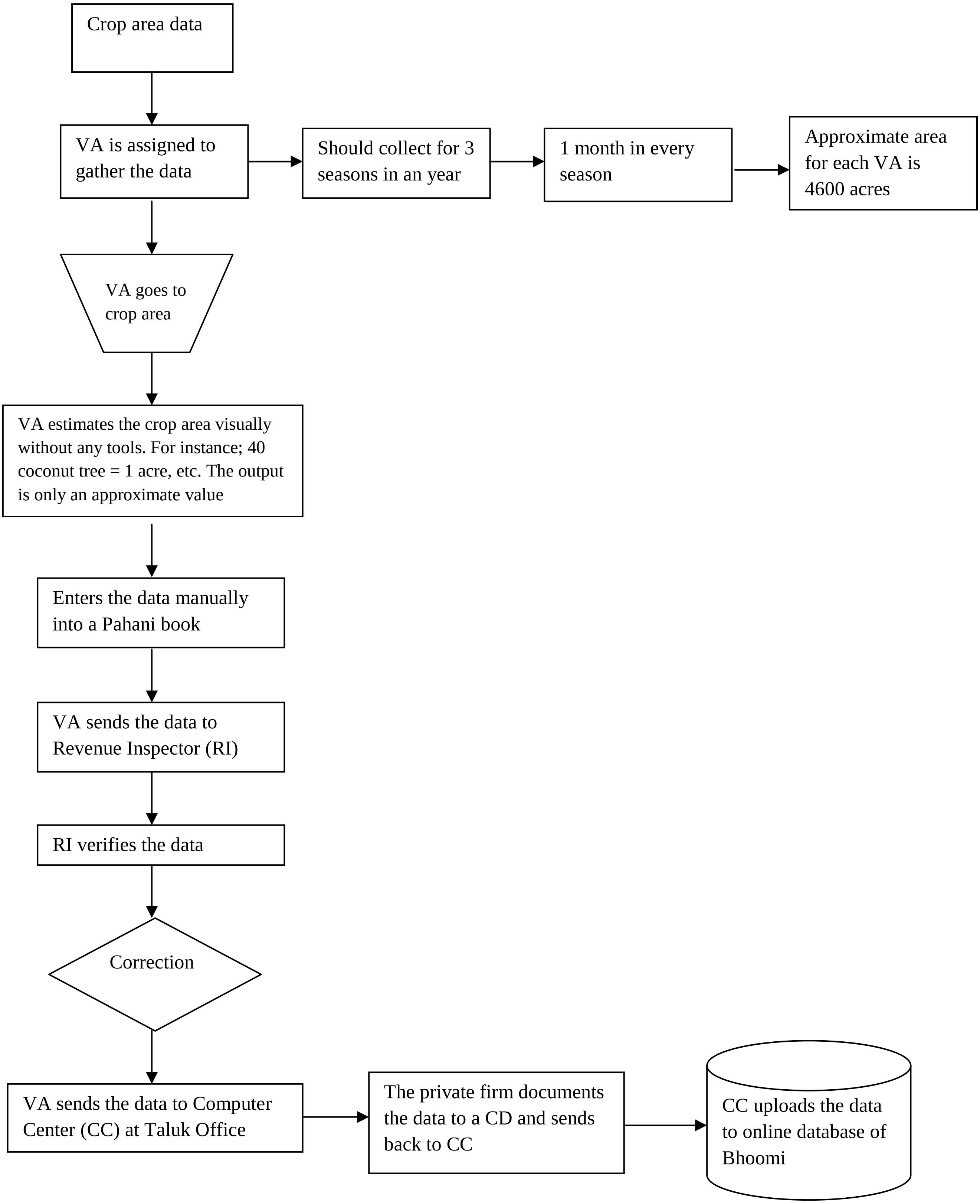
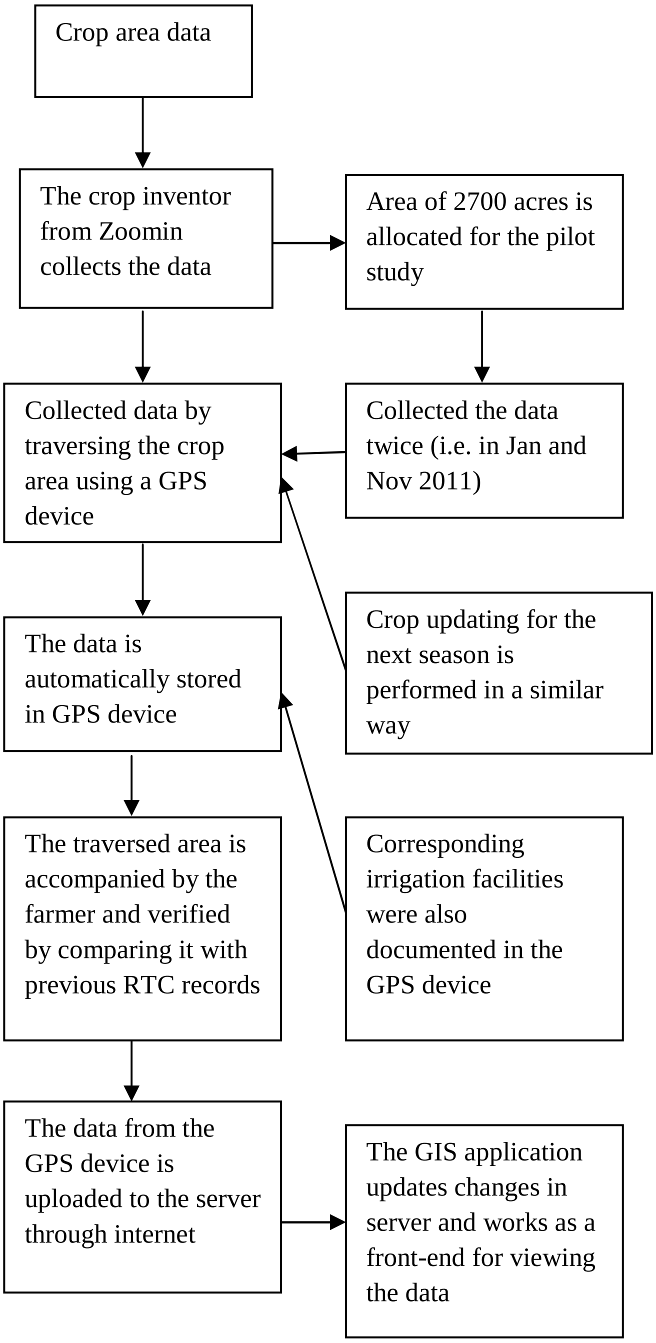


Figure A3. Summary of the alternative method



Since, all the crops are not subjected to change during each season; the crop inventor updates the crops which are subjected to change using previous season's crop area map as a reference

Table A1. Methods comparison

Parameters	Conventional method	Alternative method
Cost per season for the total area of 4600 acres (assigned to each VA)	Costs 538.88 US$ (1 US$ = Rs. 55.67) Cost breakdown: 2 months VA salary= 2 X 269.44 US$	Costs 485.86 US$ Cost breakdown*: cost of updating = 414 US$ (0.09 US$ price paid for traversing per acre X 4600 acres) + 26.94 US$ is the user cost of a hand held device + 44.92 US$ paid for verification of data
Connectivity	The digitized data is available in *Bhoomi* database (*Bhoomi* database is operated by govt.) which can be accessed by all stakeholders	The data is directly transferred to the server which can be accessed using GIS application
Capacity	According to VA, collecting 4600 acres in one month is a tough task. Therefore, VA can only collect 50% of the data in one month	The crop inventor had covered 2700 acres in one month
Adequate	The information collected by VA is used by government since many years. Therefore, it should be adequate. However, the quality of the data has deteriorated in recent year	The information collected by crop inventor is capable of providing adequate information using GPS/GIS
Reliable	The data collected by VA is through eye-balling technique and it is stored manually in *Pahani* books which is later digitized and transferred to *Bhoomi* database	The crop inventor collects the data using GPS device and transfers the data to server using internet
Timely	The time required by VA to collect the data is 30 days. It again takes 20-30 days for digitization	The crop inventor collected accurate data in less number of days then VA. The data collected is in digitized format
Security	The data is collected manually and stored in *Pahani* books which can be subjected to risks. The data is then verified by RI. The data is digitized by a third party (i.e. a private player) and is transferred to *Bhoomi* database	The data collected is not manually stored in records, which reduces human intervention. The crop area is traversed using GPS device. The GPS device transfers the data to a server which is accessed authentically
Better Planning of Government	The collection and dissemination of data takes nearly 60 days. The accuracy is poor and the technique for data collection is not reliable	The collection and dissemination of data occurs on the same day. Data has high accuracy and the technique for data collection is also reliable
Effective Delivery	The delivery of data is instantaneous after digitization. However, the delay in digitization and poor accuracy are some of the the drawbacks	The delivery of data is instantaneous after collecting the data using GPS device. There is no delay in digitization and the accuracy is above 90%. GIS application provides various

		options for viewing the data
Easy Monitoring and Evaluation	The data can be easily monitored and evaluated after the data is uploaded in the *Bhoomi* database	The data is easy for monitoring and evaluation from the beginning of the process (i.e. during data collection using GPS device)
Frequency of data collection	The data is collected by VA once every season and is capable of collecting data during anytime of the year	The data is collected by crop inventor during every season. Additional updating is also possible at anytime of the year, irrespective of the climate

Note: * Further disaggregation of the costs and their justifications can be requested from the corresponding author.

Figure A4. Survey numbers in Nallur village

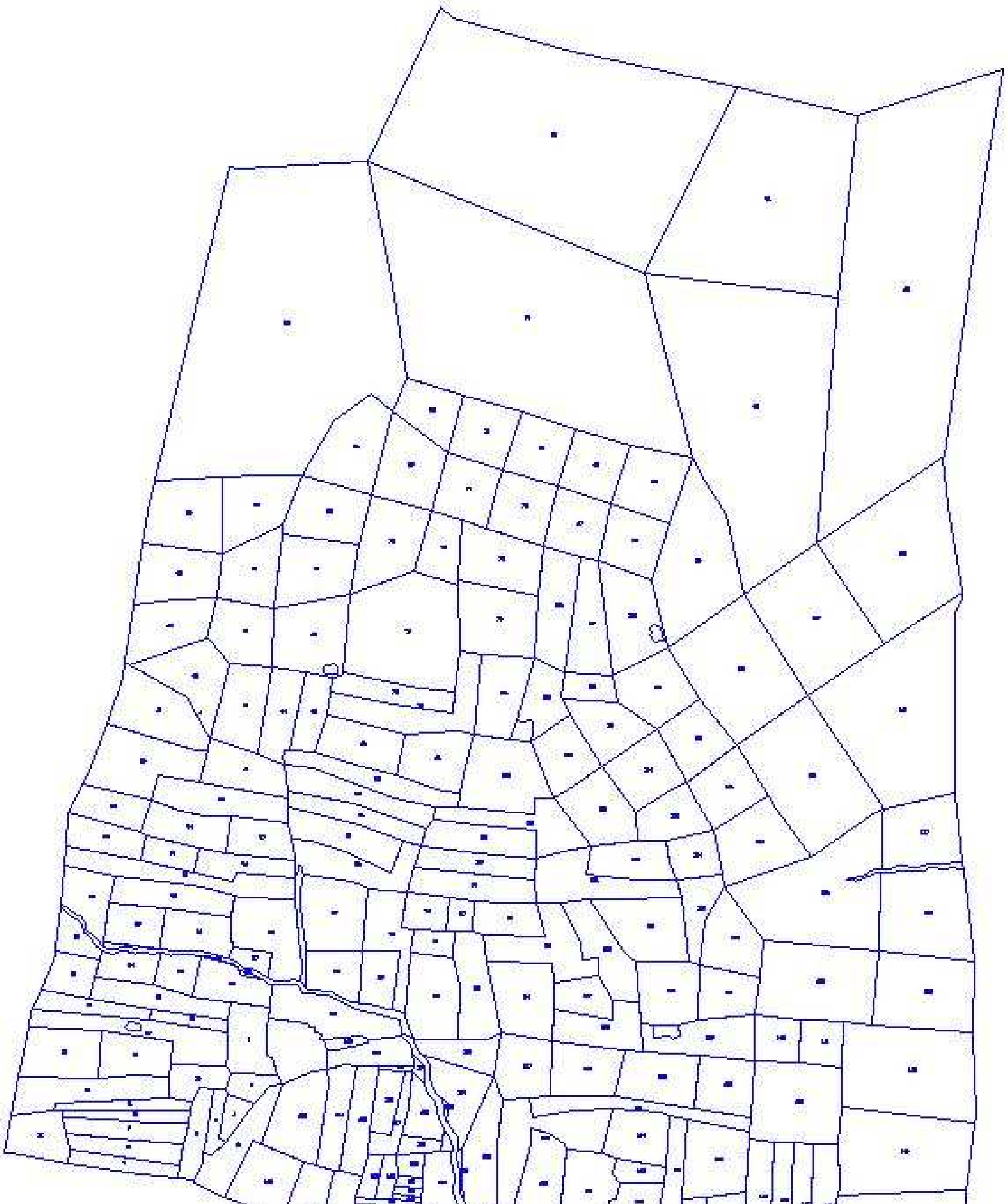


Figure A5. Plotting of crop area using GPS

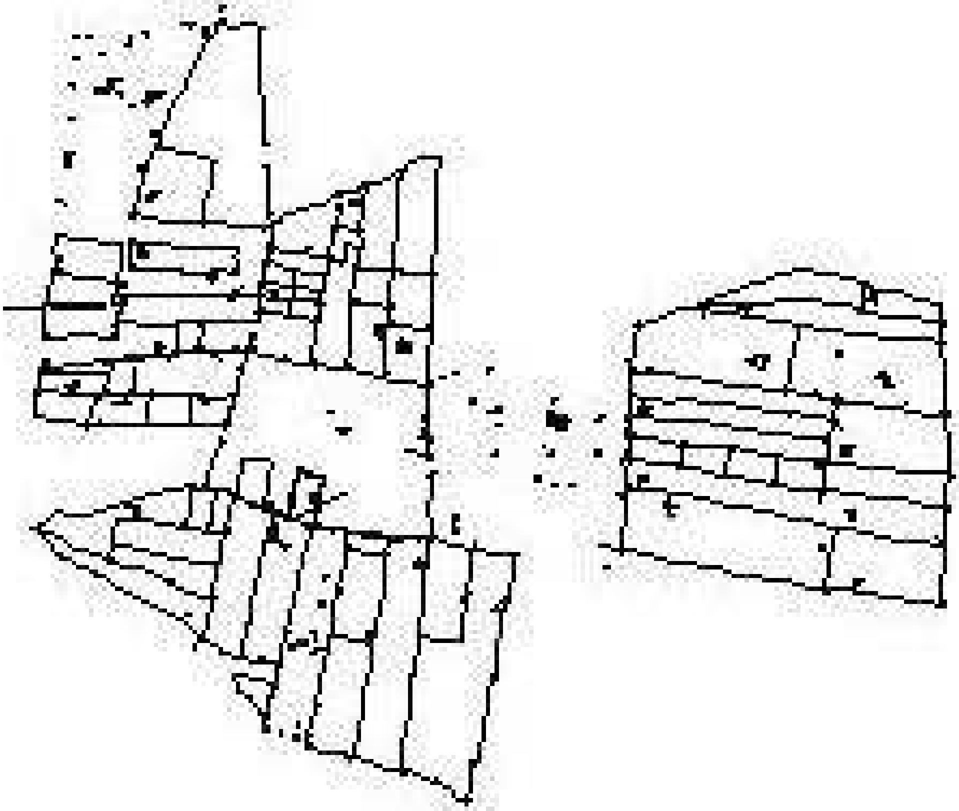


Figure A6. GIS application presenting different crops in Nallur village

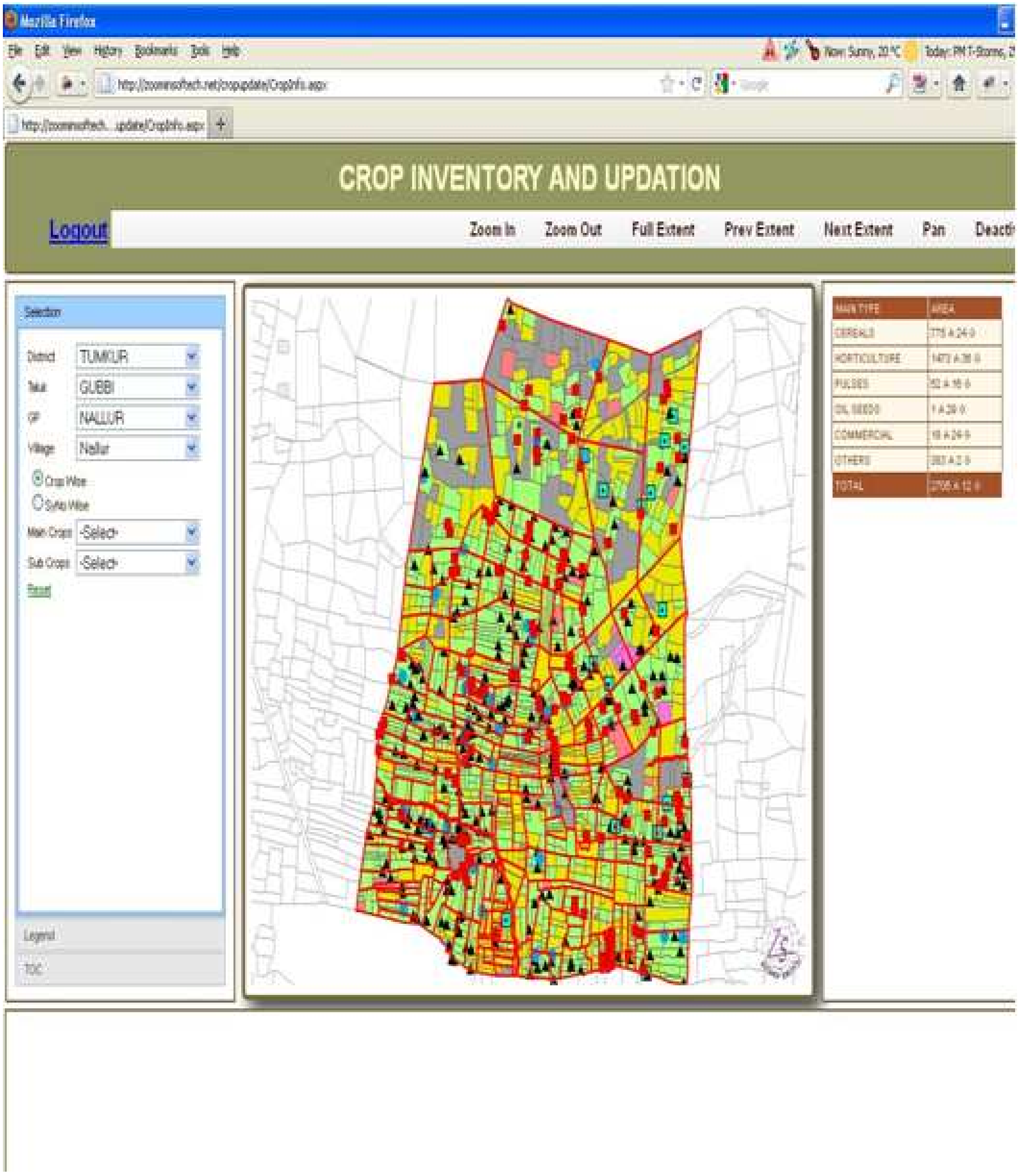


Figure A7. GIS application presenting Horticulture crops in Nallur village

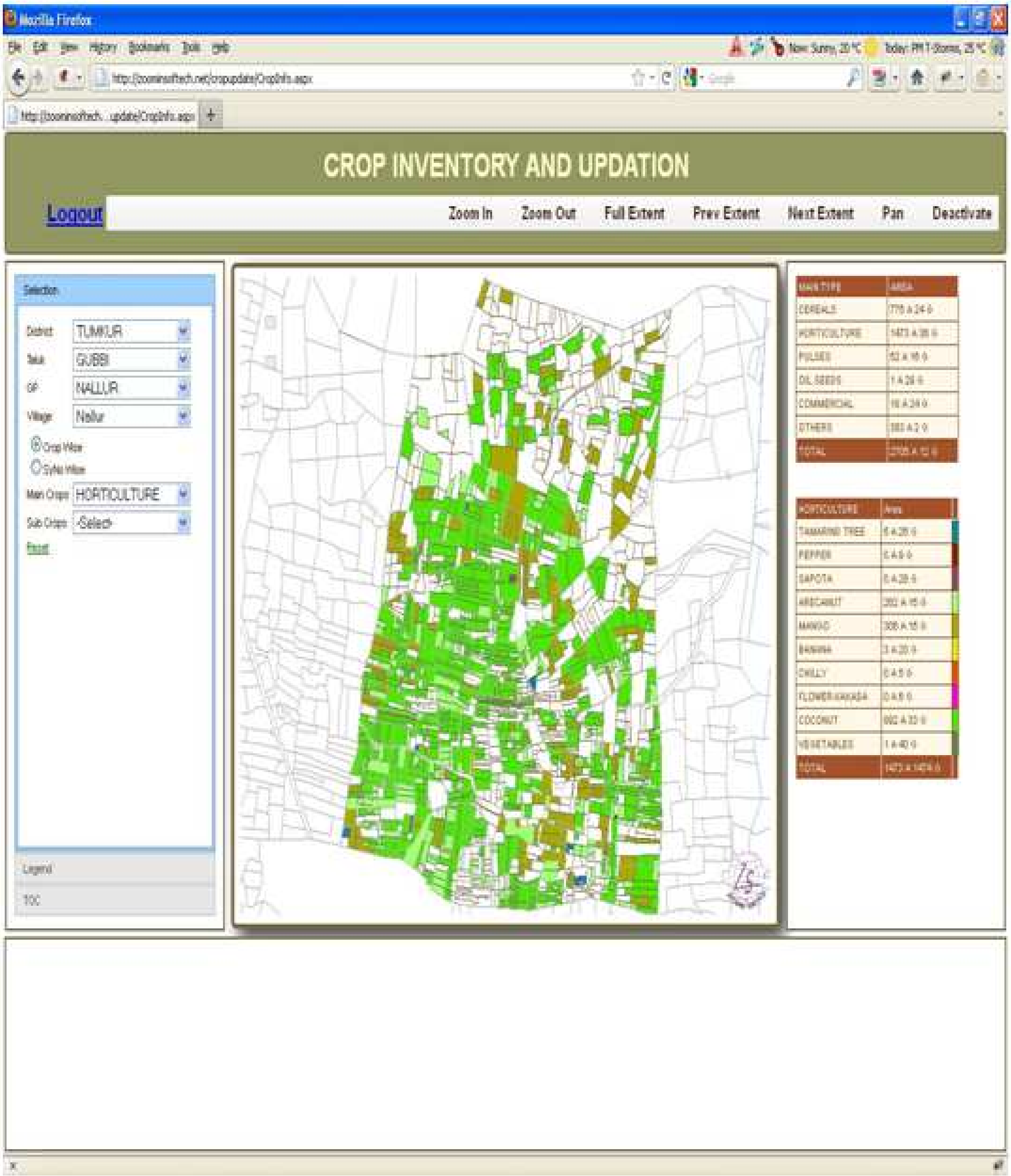


Figure A8. GIS application presenting Cereal crops in Nallur village

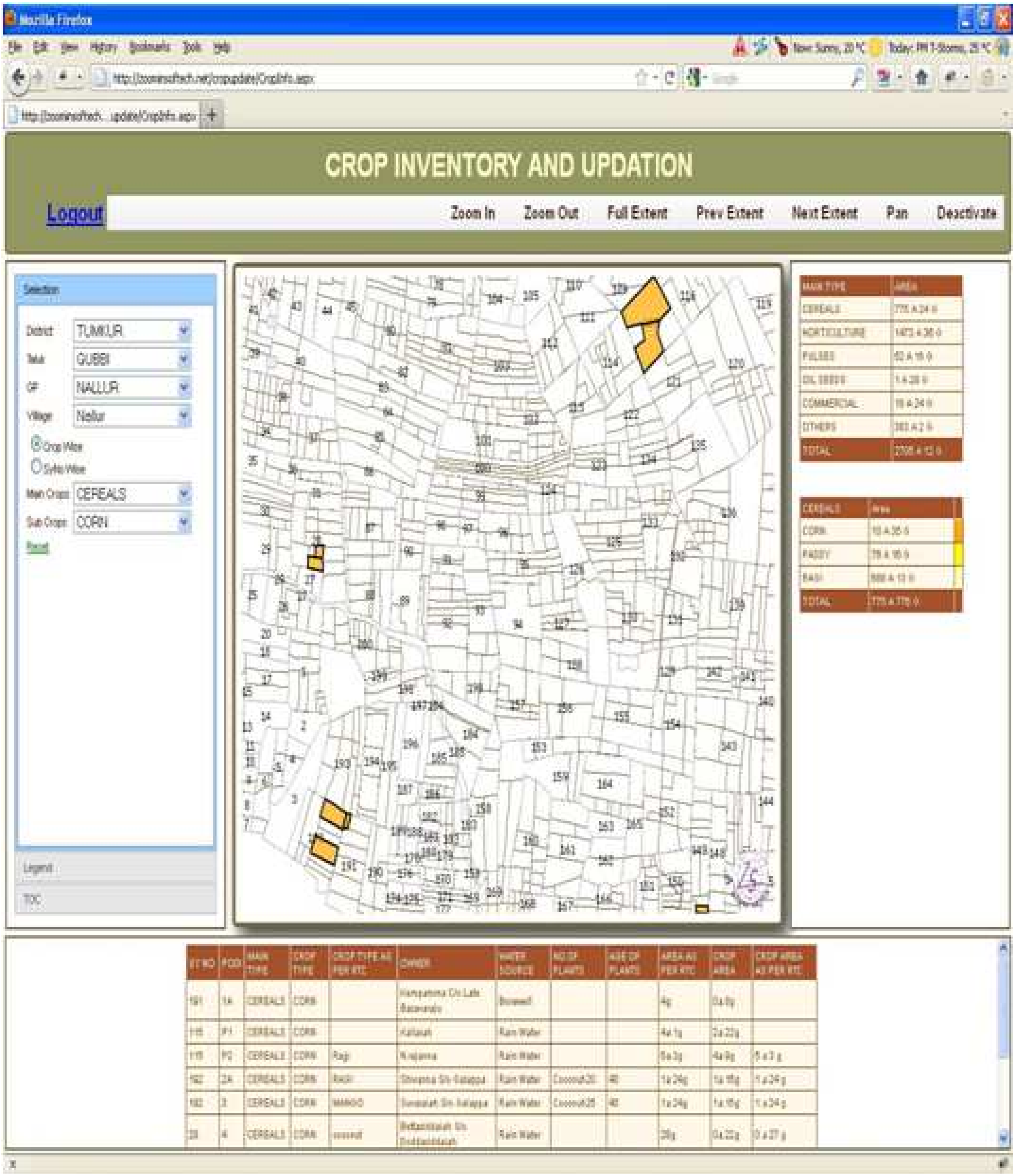


Figure A9. GPS locations traversed during November 2011

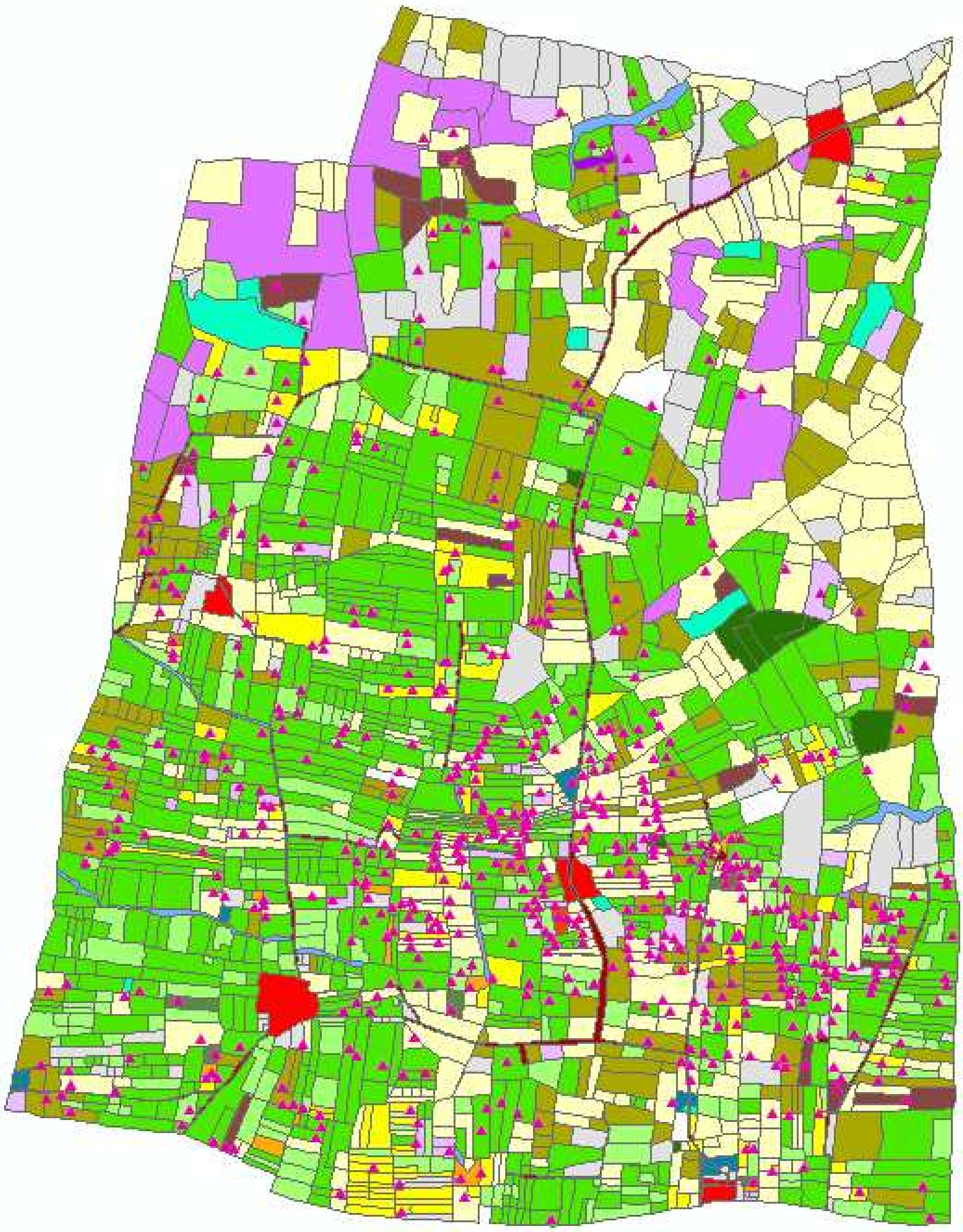


Figure A10. Crop map for both seasons separately

January 2011 November 2011