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ORIGINAL ARTICLE

# Study on Land Use Dynamics: Appropriate Methods for Change Estimation in Social Science Research

Sunil Nautiyal[1,2] · Harald Kaechele[2,4] · Pavan Tikhile[1] · Sruthi Subbanna[1] · Sangeeta Baksi[3]

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## Abstract

**Background** Studies on dynamics of land use change still rely on survey questionnaires to collect the data. This study was undertaken to explore the possibility of an appropriate method for estimating land use land cover (LULC) changes for temporal periods for which there is no direct evidence of change spatially explicit.

**Purpose** The hypothesis of this study is that the data on land use generated by official records, empirical field studies, and analysis of satellite imagery resemble with each other. However, in case of inconsistencies the aim of the present study was to identify a scientific and effective method for obtaining precise data on land use dynamics as part of developing appropriate strategies for a sustainable land use management.

**Methods** The land use information on taluk (block) level was collected from the official records. A questionnaire-based survey was done for collecting household data on land use during the period 2014–2016. Furthermore, satellite data were analysed for land use change estimation. In this study, the conventional methods as well as advanced techniques have been used for estimating crop area at various spatial scales. Per pixel classification techniques were used for generating thematic maps from raster data sets. Data collected from GPS were converted into a shape file for generating a signature file for classification of satellite data sets. While generating thematic maps, the maximum likelihood and parallelepiped classification methods were used.

**Results** The inconsistencies were found between land use data obtained from field studies/official records and the data obtained from analysis of remote-sensing imagery. The satellite data outputs are validated using ground-truth data. Various accuracy assessment metrics such as overall accuracy and kappa coefficient ($K_{hat}$) are computed from the validation procedure. The overall accuracy and $K_{hat}$ of the generated thematic maps on LULC are found to be ranging from 79 to 84% and 0.76 to 0.83 for various points of time. However, data obtained from official records and results obtained through questionnaire-based survey could not be cross-checked for an accuracy assessment as the physical conditions of land significantly differ year by year.

**Conclusion** An overall spatial and temporal assessment of land use data, using only a questionnaire-based survey, is not scientifically appropriate. Therefore, this study advocates a trans-disciplinary research in social science based on the convergence of social science and space science and technology.

**Keywords** Land use study · Questionnaire survey · Satellite data · Accuracy assessment

✉ Sunil Nautiyal
nautiyal_sunil@rediffmail.com

[1] Centre for Ecological Economics and Natural Resources, Institute for Social and Economic Change, Bangalore 560 072, India

[2] Institute of Socio-Economics, Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Straße 84, 15374 Müncheberg, Germany

[3] Department of Science and Technology (DST), Technology Information, Forecasting and Assessment Council (TIFAC), 'A' Wing, Vishwakarma Bhavan, Shaheed Jeet Singh Marg, New Delhi 110016, India

[4] University for Sustainable Development Eberswalde, Schicklerstraße 5, Eberswalde 16225, Germany

## 1 Introduction

The agricultural sector continues to play an important role in the Indian economy, with the Central Statistics Office estimating the contribution of agriculture and allied sectors at 13.7% of the gross domestic product (GDP) for 2012–2013 (Planning Commission of India 2014). As per 2011 census, about 263 million people are engaged in agriculture and allied activities, accounting for 55% of the total workers in the country. Further, the Agricultural Census reveals that there are 138.35 million operational land holdings in India extending over a total area of 159.59 million ha (Agriculture Census 2015) with an average land holding size in India working out about 1.5 ha per household. Indian agriculture organisations and other departments conduct crop area and production estimation surveys for three seasons in a year. Crop area estimation provides important information on food production, requirements and security. Further, land use data provide key information to policy makers for developing appropriate strategies for an overall development of the agricultural sector. In general, for agricultural crop acreage and production information, the Indian government organisations depend on primary surveys conducted by the Revenue Department, Economics and Statistics department and village level officers (Agricultural Statistics 2015).

The land use survey in India is divided into three broad categories. In the first category, 17 states and 4 union territories are covered, which are cadastrally surveyed, and all land use/land cover records are maintained by the revenue agencies of the respective states (Agricultural Statistics 2015). These states are known as “Land Record States” or temporarily settled states. The survey is done using the questionnaire method, where details are sought from the head of each household. This category, where the Timely Reporting Scheme (TRS) is functional, covers 86% of the reporting area in the country. The second category covers 7 states with a 9% reporting area, with the survey conducted coming under the scheme of Establishment of an Agency for Reporting Agriculture Statistics (EARAS) functioning in these states. The last category covers the hilly districts of the states and union territories, where no reporting agencies are available. The major districts surveyed under the last category are located in the states of Assam, Nagaland, Manipur, Mizoram, Tripura, Meghalaya and Goa, and in the union territories of Andaman and Nicobar, Daman and Diu and Lakshadweep (Agricultural Statistics 2015).

A village level government functionary known as Patwari or the village accountant is assigned for collecting crop area statistics and expected to provide timely information on area under various crops using conventional method (Naik et al. 2013). The collected land use and land cover records at the village level are forwarded to the next administrative level such as taluk (block), district and state for final output (Tian et al. 2014). Apart from conventional survey methods, India established Mahalanobis National Crop Forecast Centre (MNCFC) in 2012 as a part of space technology for a better agriculture related forecasting in the country. At present, MNCFC is forecasting agricultural output using space, agro-meteorology and land-based observations (FASAL) besides monitoring and estimating the area and production at district, state and national levels. The area estimation has been carried out for 8 major crops grown in the country. Apart from FASAL programme, MNCFC collaborates with National Agricultural Drought Assessment and Monitoring System (NADAMS) for assessing drought conditions at various levels across different states of the country (MNCFC 2012).

In India, most of the researchers in social and natural sciences still follow a questionnaire-based survey for obtaining information on land use data, which particularly relies on memory (Nautiyal et al. 2007; Nautiyal and Kaechele 2007). However, the accuracy of memory-based data is questionable. The change in cropping pattern is quick and conventional methods are unable to respond promptly to capture the changes and therefore, do not accurately record the area under variety of crops (Naik et al. 2013). Therefore, there is a need for bringing a convergence of the data generated through empirical field studies/conventional methods and advanced biophysical data available with national (National Remote Sensing Centre ‘NRSC’, and state remote sensing centers) and international (the United States Geological Survey ‘USGS’) organizations/agencies. In this context, the aim of the present study was to identify a scientific and effective method for obtaining precise data on land use as part of developing appropriate strategies for a sustainable land use management. A few methods were compared for their robustness and reliability in capturing the information on land use dynamics.

## 2 Materials and Methods

In India, for generating information on land use, researchers across disciplines still follow questionnaire-based survey method for retrieving relevant information based on memory not only for the current year but also for past years. Appropriate method for the land use estimation is still not in use in many research studies. To begin with, land use information on taluk (block) level was collected from the official records. Three taluks, namely, Hosadurga, Krishnarajpet (KR Pet), and Hassan from three agro-climatic zones, Central Dry Zone, Southern Dry Zone and Southern Transitional Zone, respectively, were selected for the present study (Fig. 1).

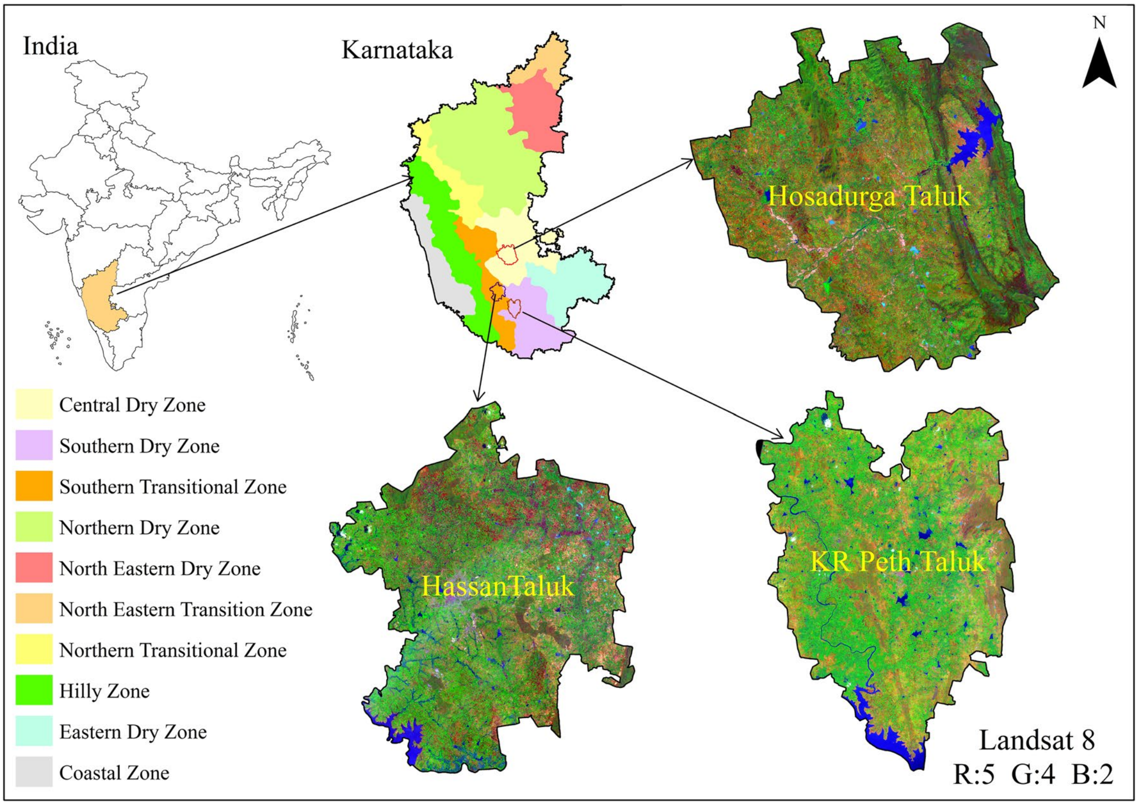



**Fig. 1** Location map of study region in Karnataka

Later a land use analysis was done using remote sensing data as part of locating the similarities in output data based on both the methods.

The study area was further narrowed down to the village level, and the data on land use were collected empirically by the researchers involved in this study. A questionnaire-based survey was also done for collecting household data on land use during the period 2014–2016, following the standard methods given in Nautiyal et al. (2007) and Nautiyal and Nidamanuri (2012). The data obtained with the help of a questionnaire were analysed for the final output. Further, satellite data at the village level were also analysed for land use change estimation. In this study, conventional methods as well as advanced techniques have been used for estimating crop area at the micro level by way of choosing three villages as units for the study. To obtain precise information, a hand-held GPS system with the accuracy of 3 m was used for recording the field characteristics. The ground data related to different crops in all the villages were collected for the entire cropping calendar.

Following the questionnaire-based survey, remote sensing data were used for land use change estimation. For the present study, Landsat 7 and Landsat 8 data were used for estimating the cropped area and land use in the selected villages. A detailed description of the data obtained through satellites is given in Table 1. Each band of satellite image is converted into a reflectance value, using the formula given by Chander and Markham (2003) and Chander et al. (2009). Finally, the reflectance output bands are used to generate multispectral images for the study period. In this article remote sensing, satellite data and satellite image(s) are used interchangeably.

The multispectral image output of Landsat 7 and 8 has a 30 m spatial resolution. To achieve a higher resolution, the multispectral image output was pan-sharpened with Landsat 8th number band. This panchromatic band with a 15-m spatial resolution is available from Landsat 7 onwards. The advantage of a pan-sharpened image is that it enhances spatial resolution and reduces classification errors (Crnojevic et al. 2014). The final output resolution from the merger technique was a 15 m multispectral image which used for further image processing in this study.

Per pixel classification techniques were used for generating thematic maps from raster data sets. Data collected from GPS were converted into a shape file for generating a signature file for classification of satellite data sets. While generating thematic maps, the Maximum Likelihood and Parallelepiped classification methods were used. For horticulture mapping, satellite data from February to April were obtained. The reason being that during this time, other agricultural crops are not grown by most of the farmers.

**Table 1** Satellite data and sensor information were used in the study

| Sr. no. | Satellite | Path/row | Sensor | Date of passing | Spatial resolution (m) | Source |
|---|---|---|---|---|---|---|
| 1 | Landsat 7 | 145/50 | ETM+ | 31/10/2001 | Multispectral 30<br>Panchromatic 15 | USGS-Earth Explorer and USGS-GloVis |
| 2 | Landsat 7 | 145/50 | ETM+ | 23/03/2000 | | |
| 3 | Landsat 8 | 145/50 | OLI/TIRS | 10/04/2015 | | |
| 4 | Landsat 8 | 145/50 | OLI/TIRS | 17/11/2015 | | |
| 5 | Landsat 7 | 145/51 | ETM+ | 31/10/2001 | | |
| 6 | Landsat 7 | 145/51 | ETM+ | 23/03/2000 | | |
| 7 | Landsat 8 | 145/51 | OLI/TIRS | 01/09/2015 | | |
| 8 | Landsat 8 | 145/51 | OLI/TIRS | 12/04/2016 | | |
| 9 | Landsat 7 | 144/51 | ETM+ | 16/03/2000 | | |
| 10 | Landsat 7 | 144/51 | ETM+ | 20/10/2000 | | |
| 11 | Landsat 8 | 144/51 | OLI/TIRS | 05/04/2016 | | |
| 12 | Landsat 8 | 144/51 | OLI/TIRS | 28/10/2015 | | |

Most fields then are without crops, which helped to isolate the spectral responses of other vegetation or crops and map area under horticulture in the region with a high degree of accuracy (Mondal et al. 2014). Settlement areas, water bodies and forest boundaries were digitised, with an overlay of classified image as an area of interest (AOI) file, and the area converted into the correct class using fill algorithm in ERDAS software. Similar method was used for delineating agricultural lands from other land use types in the study region. The final thematic maps were converted into a vector format, and at the end of the analysis all the separate vector class files were merged into a single vector file for estimating area and also for carrying out an accuracy assessment. While assessing the accuracy of maps generated, commission error, omission error and Kappa co-efficient ($K_{\text{hat}}$) were calculated, using standard equations.

## 3 Results and Discussion

Estimation of crop acreage and land use is an imperative need for a country like India. In crop monitoring programmes where spatial information on crop acreage is to be estimated, providing on-time information on changes in crop area can be of immense help to policy makers. Agriculture plays a significant role in developing countries and emphasis is given for improvement in agriculture and related statistics. However, a very little research on this topic is available as a ready reference (Naik et al. 2013). In the present study, land use and land cover estimation was done for two points of time (2001 and 2015) across the selected regions. The land use statistics were procured from the official records at the taluk-level, while the village-level information on land use was collected based on a primary survey. The satellite data were further used for developing the land use map statistics at both the taluk and the village levels. The taluk-level data on land use were collected from the official records of Agriculture Census, Government of India (2000–2001) and Directorate of Economics and Statistics, Government of Karnataka (2014–2015) and are presented in Table 2.

Table 2 depicts the major crops grown in three taluks that include Ragi (*Eleusine coracana*), Maize (*Z. mays*), Sorghum (*Sorghum bicolour*), Potato (*Solanum tuberosum*), Paddy (*Oryza sativa*), Sugarcane (*Saccharum officinarum*), Coconut (*Cocos nucifera*) and Pomegranate (*Punica granatum*). The area under Ragi, one of the important crops of Karnataka shows a decline by 86% in Hassan Taluk, while area under paddy cultivation is found to be declined by 69% from 2001 to 2015. The land under Maize (174%), and Coconut (823%) displays an increasing trend for 2015 as compared to 2001. On the other side in KR Pet Taluk, the area under Ragi cultivation was found to be decreased by 54%, paddy 20% and sugarcane 57% in 2015 as compared to 2001. The area under Coconut cultivation was increased by 152% in 2015 as compared to 2001 in KR Pet Taluk. In Hosadurga taluk, the area under Ragi and Coconut was found to have increased by 47 and 21%, respectively. In 2015, a new crop, Pomegranate as per official records, had occupied an area of 3610 ha in Hosadurga Taluk and this was not reported in the statistics of 2001 (Table 2). The agriculture statistics for all the crops is available at taluk level. However, a few major crops, namely, Ragi, Maize, Sorghum Potato, Paddy, Sugarcane, Coconut and Pomegranate were considered for the comparison between the data obtained from official records and from analysis of satellite data.

An analysis of the satellite imagery data also throws up some interesting results with respect to dynamics of ecosystems in all the study regions. The satellite image analysis shows that in Hassan Taluk the area under Ragi was reduced 32% (6580 ha) in 2015 which was 9722 ha during 2001. Similarly, the area under Paddy found to be reduced by 76% from 14,503 ha in 2001 to 3485 by 2015. While the area

**Table 2** Data collected from Agriculture Census, Government of India (2000–2001) and Directorate of Economics and Statistics Government of Karnataka (2014–2015)

| Region | Hassan | | | KR Pet | | | Hosadurga | | |
|---|---|---|---|---|---|---|---|---|---|
| Crops | 2000–2001 | 2014–2015 | % change | 2000–2001 | 2014–2015 | % change | 2000–2001 | 2014–2015 | % change |
| Ragi | 24,369 | 3296 | − 86 | 22031 | 10,145 | − 54 | 20,147 | 29,630 | 47 |
| Maize | 8080 | 22,123 | 174 | 285 | 286 | 0% | | | |
| Sorghum | 0 | 0 | | 0 | 64 | | 7851 | 295 | − 96 |
| Potato | 12,188 | 9350 | − 23 | 0 | 0 | | 0 | 0 | |
| Paddy | 4140 | 1285 | − 69 | 12,675 | 10,160 | − 20 | 1684 | 11 | − 99 |
| Sugarcane | 85 | 138 | 62 | 4964 | 2134 | − 57 | 2 | 0 | − 100 |
| Coconut | 521 | 4807 | 823 | 4653 | 11,724 | 152 | 15,137 | 18,243 | 21 |
| Pomegranate[a] | 0 | 0 | | 0 | 0 | | | 3610 | |

Area in hectare

[a]Pomegranate data for the year 2000–2001 not available

under Maize, Potato and Coconut display an increasing trend over the period from 2001 to 2015. In 2015, Maize is found to have covered an area of 17099 ha than what had for the year 2001 with the area under its cultivation increased by 87% (Table 3). Therefore, the data obtained from official records are not consistent with the data obtained based on remote sensing images in case of Hassan Taluk (Tables 2, 3).

In KR Pet Taluk the area under Ragi which was about 27,071 ha in 2001 has increased by 4% by 2015, While the area under Paddy cultivation which was about 16,727 ha in 2001 has declined to 14,939 ha by 2015 (i.e. a decline by 11%). On the other hand the area under Sugarcane and Coconut show an increase by 19 and 24%, respectively, for 2015 as compared to 2001. These data are not again consistent with the data obtained from official records, either in terms of the total area or the trend (Table 3).

Based on a satellite data analysis, in respect of Hosadurga Taluk, the area under Sorghum and Ragi shows a decrease by 65 and 38%, respectively, for 2015 as against 2001. However, it is interesting to note that the official records indicate an increase of 47% in area under Ragi in Hosadurga Taluk (Table 2), while area under Sorghum is found to have decreased based on both the data sets; however, the area at two points of time differs in the analysis (Tables 2, 3).

**Table 3** Details of land use land cover (LULC) of the study region based on analysis of the satellite data

| Region | Hassan | | | | | KR Pet | | | | | Hosadurga | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 2001 | | 2015 | | % change | 2001 | | 2015 | | % change | 2001 | | 2015 | | % change |
| LULC classes | Area[a] | % | Area[a] | % | | Area[a] | % | Area[a] | % | | Area[a] | % | Area[a] | % | |
| Ragi | 9722 | 10 | 6580 | 7 | − 32 | 27,071 | 30 | 28,078 | 31 | 4 | 23,748 | 17 | 14,732 | 10 | − 38 |
| Maize | 17,099 | 18 | 32,003 | 34 | 87 | | | | | | | | | | |
| Sorghum | | | | | | | | | | | 12,369 | 9 | 4313 | 3 | − 65 |
| Potato | 11,526 | 12 | 13,697 | 15 | 19 | | | | | | | | | | |
| Paddy | 14,503 | 16 | 3458 | 4 | − 76 | 16,727 | 19 | 14,939 | 17 | − 11 | | | | | |
| Sugarcane | | | | | | 3644 | 4 | 4519 | 5 | 24 | | | | | |
| Other crops | 4118 | 4 | 9230 | 10 | 124 | 3757 | 4 | 10,267 | 11 | 173 | 3067 | 2 | 6278 | 4 | 105 |
| Fallow land | 8830 | 9 | 2835 | 3 | − 68 | 11,783 | 13 | 3974 | 4 | − 66 | 35,208 | 24 | 42,931 | 30 | 22 |
| Coconut | 12,169 | 13 | 13,750 | 15 | 15 | 11,910 | 13 | 14,220 | 16 | 19 | 12,165 | 8 | 17,649 | 12 | 45 |
| Pomegranate | | | | | | | | | | | | | 7027 | 5 | |
| Open land | 1380 | 1 | 4192 | 0 | − 70 | 141 | 0 | 2356 | 3 | 1571 | 3172 | 2 | 2304 | 2 | − 27 |
| Settlement | 912 | 1 | 1663 | 2 | 82 | 529 | 1 | 804 | 1 | 52 | 569 | 0 | 933 | 1 | 64 |
| Vegetation | 8040 | 9 | 6331 | 7 | − 21 | 9403 | 11 | 7456 | 8 | − 21 | 46,058 | 32 | 43,373 | 30 | − 6 |
| Water bodies | 4851 | 5 | 3184 | 3 | − 34 | 4565 | 5 | 2916 | 3 | − 36 | 7414 | 5 | 4231 | 3 | − 43 |
| Total area | 93,151 | | 93,151 | | | 89,530 | | 89,530 | | | 143,770 | | 143,770 | | |

[a]Area in hectare

The area under Coconut which was 12,165 ha in 2001 and 17,649 ha in 2015 (as per the data obtained based on satellite image analysis) shows an increase by 45%. However, as per official records, the area under Coconut which was 15,137 ha registered an increase by 21% to 18,371 ha for the year 2015. For the year 2001, the area under pomegranate cultivation is not reported as per data available from official records and also data obtained based on a satellite image analysis. However, for the year 2015 the satellite data show the area under Pomegranate cultivation in Hosadurga Taluk being about 7027 ha (Table 3), while as per the official documents recorded 3610 ha (Table 2).

It is pertinent to note here that the data obtained from both the sources (official records and satellite imagery data) do not show consistent results. The inconsistency in the data output could be due to a variety of factors, for example, flaws in methodology, getting precise information from the questionnaire-based survey, etc. Therefore, it was decided to confine the field study at village-level for land use data collection as part of overcoming the data reliability associated with the secondary sources.

Thus for village level data collection, an inventory of crops grown was made (the land use pattern of the study regions is given in Table 4). The results obtained based on the empirical field study indicate that more than 90% of the farmers in Hosadurga Taluk have Ragi fields followed by Sorghum as food crops. As part of cash crops, 30% of the farmers grow Groundnut (*Arachis hypogaea*) followed by Maize (20%). Approximately 90% of the farmers are engaged in the cultivation of other crops. About 88% of the farmers grow Coconut and 63% cultivate Pomegranate in Hosadurga Taluk. In Hassan Taluk, 90% of the farmers cultivate Ragi followed by Sorghum (38%) and Paddy (23%). About 58% of the farmers grow Ginger (*Zingiber officinale*) followed by Floriculture (23%) and Maize (18%) as cash crops. In KR Pet Taluk, 88% of the farmers grow Ragi followed by Paddy (38%), Sorghum (30%) and Red gram (*Cajanus cajan*) (23%). As part of cash crops, 40% of the farmers cultivate Sugarcane, followed by Floriculture (33%), Maize (23%) and Ginger (10%). Thus, the results based on the empirical data show that Ragi or Finger millet continues to be a dominant crop grown in all the study regions.

With the help of a questionnaire-based survey, information on land use was obtained for two points of time (year 2001 and 2015) for a better understanding of the changes in area under various crops. The survey relied on farmers' memory for answers, and 15 years seemed a reliable time frame for farmers to recollect the relevant information. A team of experienced researchers was involved in collecting data with the help of a questionnaire.

The village-level quantified land use data and the data obtained from satellite images are given in Table 5. It is important to note here that the land use data generated at two points of time with the help of questionnaire and satellite images are found to be quite inconsistent. The data collected by a team involved in this study are not comparable with the data obtained based on the analysis of the satellite images. Satellite data show Ragi being cultivated only over 11 ha of land for 2015, while the village-level field data reveal the area under Ragi being cultivated in 53 ha in a village located in Hassan Taluk for the said year. As per satellite data the area under Ragi shows a reduction by 77%, while the empirical field data show a decline by 11%. Satellite data shows the area under Ragi cultivation being more than 500 ha in a village of KR Pet Taluk which, decreased by 10% over the period 2001–2015. However, questionnaire-based data depict that in a village of KR Pet Taluk, Ragi covered 98 ha in 2001 and 84 ha in 2015, thus a reduction by 14%. A similar picture is observed in the case of a village located in Hosadurga Taluk. This variation is observed based on the final output obtained from a questionnaire and satellite data analysis for almost all crops of the village ecosystems of the study region. The results obtained from an empirical field study and satellite data are also not found consistent with the area under cultivation of any of the crops, as in the case of a data comparison of official records and satellite data for a larger landscape (taluk level). The problem associated with the empirical field study is related to methodology and the variables, which tend to influence the degree of accuracy. A solution to this could be an appropriate sample selection and the total number of interviews and skills of both the interviewer and interviewee.

The questionnaire-based data for land use dynamics follow a memory-based approach and are found to be

**Table 4** Cultivation of crops by farmers of the study region (2015)

| Crops | Hassan (%) | KR Pet (%) | Hosadurga (%) |
|---|---|---|---|
| Food crops | | | |
| Ragi | 90 | 88 | 93 |
| Paddy | 23 | 38 | |
| Red gram | 08 | 23 | 08 |
| Sorghum | 38 | 30 | 38 |
| Other crops[a] | 85 | 78 | 90 |
| Cash crops | | | |
| Groundnut | | 08 | 30 |
| Maize | 18 | 23 | 20 |
| Ginger | 58 | 10 | |
| Flower | 23 | 33 | |
| Sugarcane | 08 | 40 | |
| Horticulture | | | |
| Pomegranate | | | 63 |
| Coconut/areca nut | 83 | 90 | 88 |

[a]Green gram, horse gram, save, avare, sesame, niger seed, cotton, sunflower, turmeric and vegetables

**Table 5** Villagewise land use data at two points of time (2001 and 2015) based on empirical field study and satellite data analysis

| Crops | Empirical field data | | | Satellite data | | |
|---|---|---|---|---|---|---|
| | 2001 (ha) | 2015 (ha) | % change | 2001 (ha) | 2015 (ha) | % change |
| Hassan | | | | | | |
| Ragi | 78 | 53 | − 32 | 48 | 11 | − 77 |
| Maize | 26 | 47 | 81 | 191 | 170 | − 11 |
| Potato | 29 | 28 | − 3 | 4 | 37 | 825 |
| Paddy | 44 | 19 | − 57 | 63 | 73 | 16 |
| Other crops | 108 | 146 | 35 | 86 | 193 | 124 |
| Coconut | 65 | 84 | 29 | 165 | 173 | 5 |
| KR Pet | | | | | | |
| Ragi | 98 | 84 | − 14 | 563 | 505 | − 10 |
| Paddy | 66 | 64 | − 3 | 241 | 199 | − 17 |
| Sugarcane | 45 | 54 | 20 | 83 | 115 | 39 |
| Other crops | 107 | 144 | 35 | 98 | 138 | 41 |
| Coconut | 91 | 128 | 41 | 296 | 408 | 38 |
| Hosadurga | | | | | | |
| Ragi | 513 | 457 | − 11 | 708 | 307 | − 57 |
| Sorghum | 113 | 97 | − 14 | 330 | 79 | − 76 |
| Other crops | 580 | 520 | − 10 | 23 | 236 | 926 |
| Pomegranate | – | 376 | | – | 301 | |
| Coconut | 386 | 440 | 219 | 219 | 334 | 53 |

Rayapura village in Hassan Taluk; Govindanhalli in KR Pet Taluk and GN Kere in Hosadurga Taluk

questionable due to a variety of factors and hence may not provide accurate information. The following methods can be used for land use estimation (1) field data collection; (2) use of remote sensing; (3) secondary data from the survey and official Government records (4) on-field land measurement. The first approach includes site selection and representative selection of site—followed by a survey-based approach. However, accuracy cannot be achieved as measuring field condition is quite lengthy. The second approach of using satellite data also may not ensure absolute accuracy without in-depth field knowledge. Third approach is collecting the information from secondary sources and relying on the same for the analysis. The fourth approach has the potential of giving absolute information, but this requires substantial resources, money and time. Therefore, a hundred percent on-field land measurement is not possible.

Therefore, the two approaches including representative site selection and satellite data use in land use change estimation seem feasible for the researchers. However, if both of them are used in isolation, it can lead to differing results (Table 6). In the case of questionnaire-based survey, various factors tend to influence the degree of accuracy. The sample selection from a given area could always be a core issue in making a perfect choice. The education of the interviewer and his/her awareness about the land use could also influence the obtaining of accurate information. The knowledge system of the interviewee and his qualitative assessment can also influence the information which he/she provides to the interviewer. And finally, how the interviewer organizes an interview is also one of the factors that can have an impact on data gathering.

Conversely, in satellite data a complete estimation of the land utilisation in the form of digital images is available, provided enough ground-truth data are generated. The accuracy of land use data obtained by satellites is reliable due to the availability of accuracy assessment methods in digital image

**Table 6** Shortcomings associated with the memory-based survey (using questionnaire) and remote sensing data, respectively

| Sr. no. | Memory-based survey (using questionnaire) | Remote sensing data |
|---|---|---|
| 1. | Difficult to remember the past information on various types of land use | Only using remote sensing data may not provide ground information with a maximum reality |
| 2. | The selection of representative site is not necessary to have representation from the larger area | Difficult to segregate land use types, while only relying on remote sensing data |
| 3. | The outcome of such a survey could be far from reality | The outcome of using only remote sensing data may not provide accurate information on land use type |

processing techniques. Digital image processing software provides tools to assess the error and accuracy of thematic maps generated. Based on the randomly selected GPS points accuracy assessment of thematic data was done to estimate the error and accuracy in respect of classified data. Overall, the accuracy and $K_{\text{hat}}$ of the generated thematic maps are found to be 79% and 0.76 (year 2001); 83% and 0.82 (year 2015) in respect of Hassan Taluk. KR Pet Taluk shows an overall accuracy and $K_{\text{hat}}$ of 81% and 0.78 for the year 2001, and 84% and 0.81 for 2015, while Hosadurga Taluk, shows an overall accuracy and $K_{\text{hat}}$ of 79% and 0.76 for 2001; and 85% and 0.83 for 2015.

Estimating the error and accuracy of the surveyed field data is a difficult task and there is a lack of techniques for evaluation. Therefore, the accuracy of the field data cannot be provided. Based on the surveyed data and satellite data convergence, it is possible to generate precise statistics on land use for research and planning. This is because a hundred per cent land measurement is not at all possible; however, this could provide absolute results. Further, to crosscheck the area estimation done using the primary data based on farmers' recall, separate experiments have to be developed and designed where the procedure for physical estimation of current land use can be measured. This physical estimation further needs to be crosschecked with the information given by the farmers, but this is a very time and resource consuming method.

Land use/land cover maps for two points of time across three taluks are presented in Fig. 2a, b (Hassan Taluk), Fig. 3a, b (KR Pet Taluk) and Fig. 4a, b (Hosadurga Taluk). Remote sensing technology has the potential to generate higher accuracy maps with the help of field data collected through conventional survey methods (Nautiyal and Nadamanuri 2012). The availability of accurate information on crop area and distribution is useful for many applications. Earth observation satellites have been widely used in agriculture monitoring for crop area estimation and production forecasting. Monitoring of crop area is highly relevant, especially in food-insecure areas (Rembold et al. 2015). Mapping and monitoring changes in crop area on a large scale using remote sensing images provide a source of reliable and continuous data. The information provided by satellite sensors is useful not only for crop monitoring, but also for many crop management studies (Tenkorang and Lowenberg-DoBoer 2008; Singh et al. 2015). At a different level, remote sensing techniques are also highly useful in detecting an early crop stress during the growing season and forecasting final yield (Meroni et al. 2013; Newlands et al. 2014).

Indian organisations need to utilise remote sensing technology for agricultural monitoring programmes in view of the enormous geographical area, geographical diversity and crop diversity. With the availability of high resolution IRS satellites developed by ISRO, there is a need for strengthening the monitoring programme too. IRS Resourcesat satellite series carrying three sensors at different resolutions (LISS-III, LISS-IV and AWiFS) are useful in crop monitoring and area estimation at different scales (Dadhwal et al. 2002; Oza et al. 2008). The advanced LISS-IV sensor with a spatial resolution of 5.8 m and 5-day revisit capability is a superior source for generating spatial data on crop acreage estimation at the cadastral level (Singh et al. 2013). The remote sensing data will help reduce human resources engaged in agricultural surveys besides providing higher accuracy real time data at shorter time limits. Therefore, crop acreage estimation using satellite and ground data is more precise than data generated based on ground surveys alone (George et al. 1980). Currently, researchers are exploring the use of Unmanned Aerial Vehicle (UAV) technology in agricultural monitoring for various applications (Shen et al. 2015; Zhang et al. 2014). UAV technology has a great potential in crop monitoring and area estimation surveys at the cadastral level with the advantage that, whenever data are needed, one can generate it without much effort and inputs. It involves only a one-time cost for the purchase of the vehicle, thus making it economically more beneficial than other survey methods. A study was conducted by Gallego et al. (2014) to examine the cost efficiency, using different satellite images as part of crop area estimation. The results indicate that only Landsat data are cheaper and more cost-effective than other satellite images including AWiFS and LISS-III (IRS satellites) sensor data. Landsat data are available globally free of cost or at nominal charges, whereas IRS satellite data cost more and are demand based. Satellite data need input reference data based on ground survey for any type of analysis, and the survey cost is added to the cost of output data products. The availability of free Landsat data ensures that the researcher is able to generate affordable thematic maps due to zero or nominal cost of data purchasing. Google has also made available many of its satellite images through Google Earth, which is also a good option for researchers. ISRO needs to reduce data costs to affordable levels for the individual user and other agencies engaged in the agriculture sector for an efficient use of IRS data. The Indian government also needs to provide infrastructure to governmental organisations and institutions for adopting remote sensing technology for agricultural monitoring and mapping programmes so as to facilitate improvements in planning and management policies.

## 4 Conclusion

The research results based on both the methods are not found to be inconsistent due to flaws in methodology. There are significant differences in land use estimation as evidenced by the outputs of three methods and therefore,

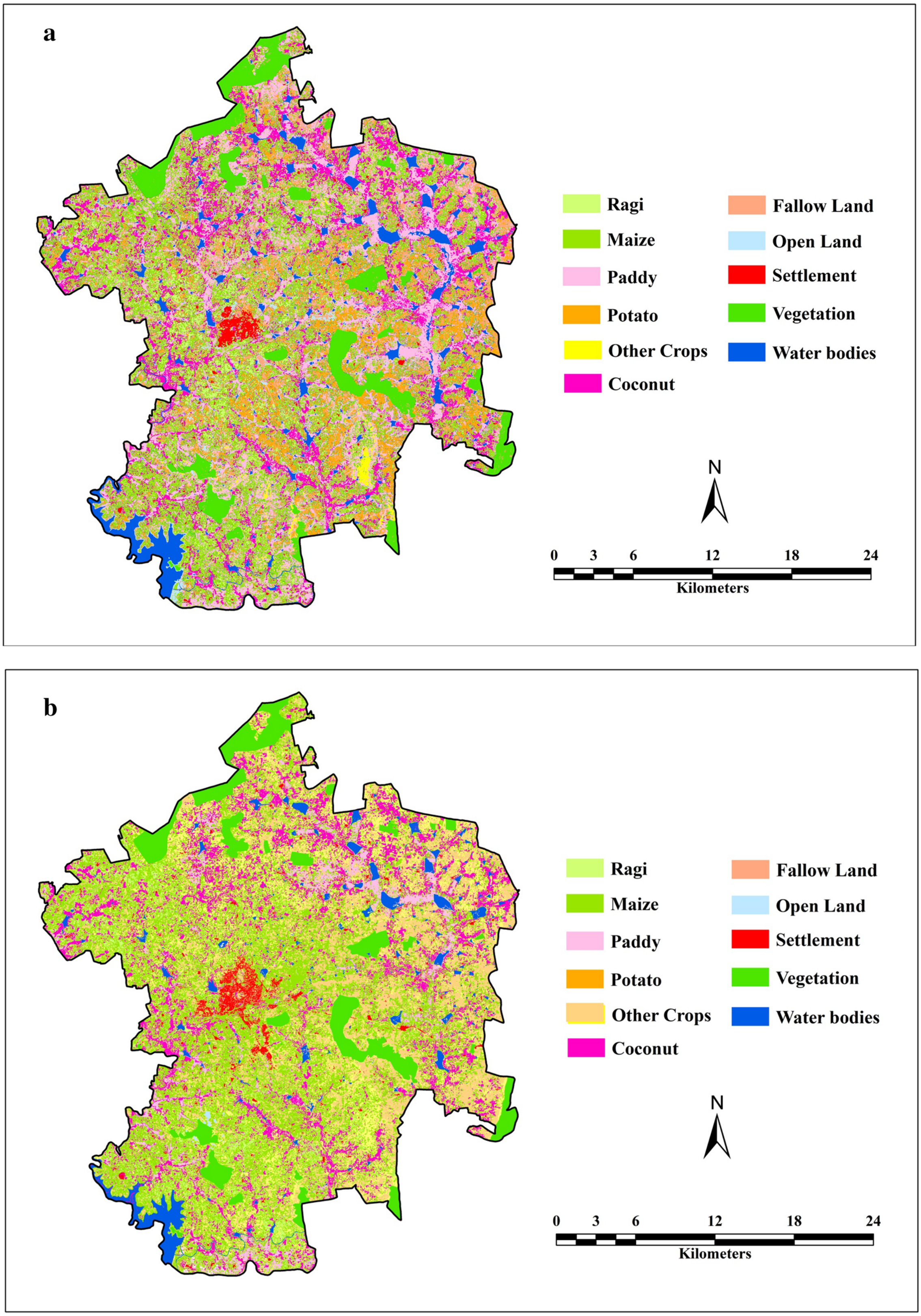



**Fig. 2** **a** Land-use/land-cover classification map of Hassan Taluk for the year 2001. **b** Land-use/land-cover classification map of Hassan Taluk for the year 2015

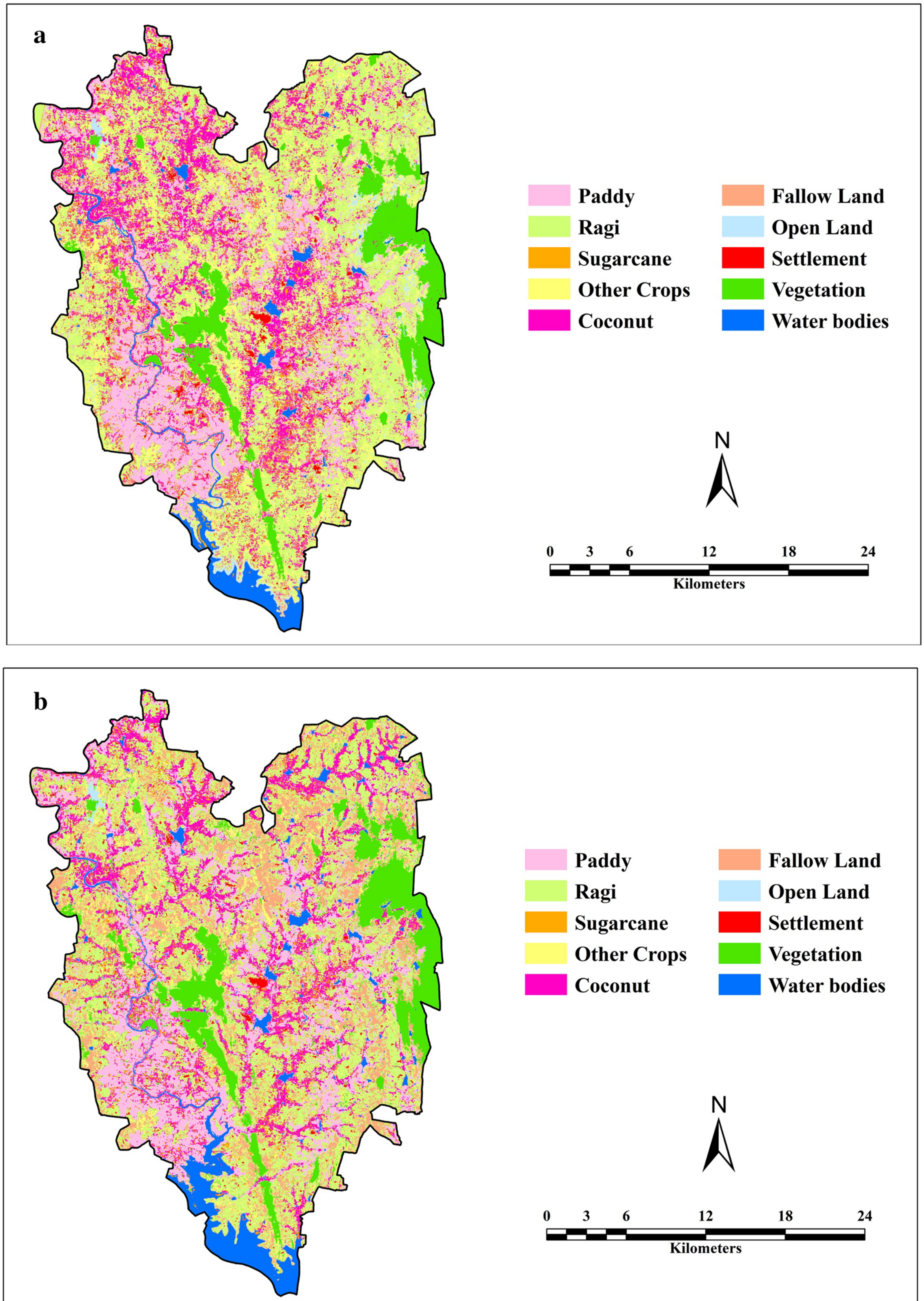
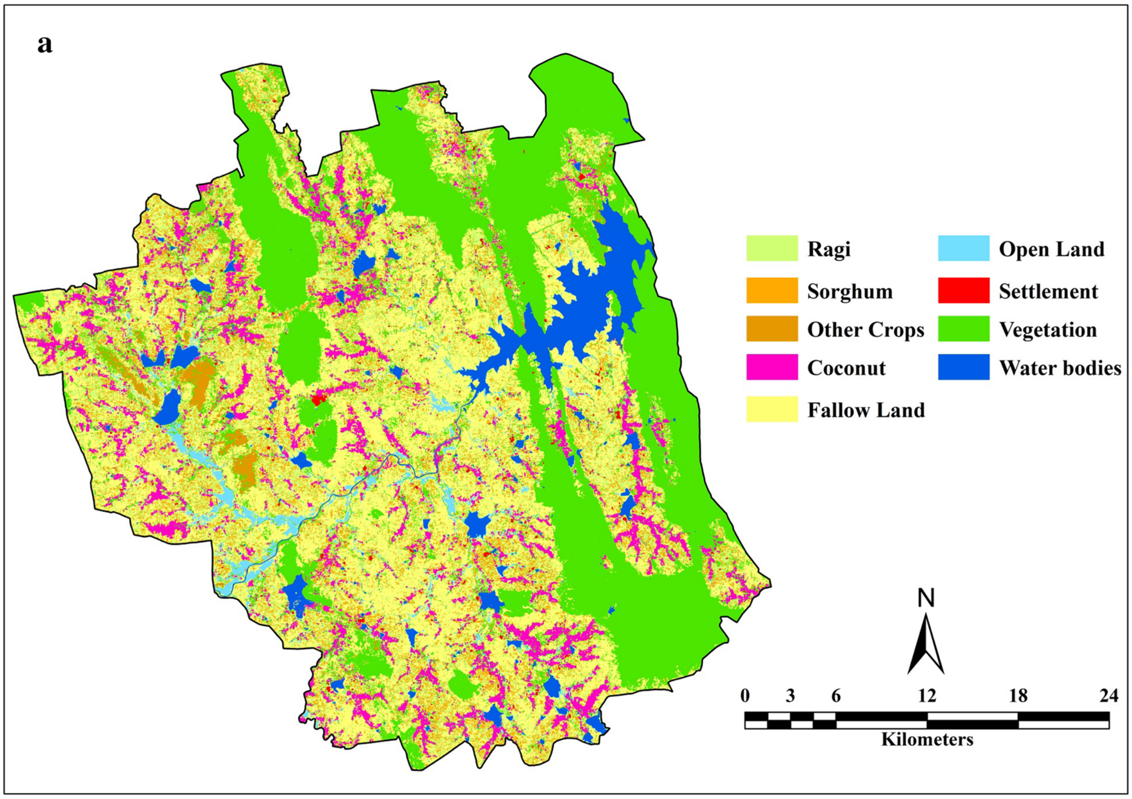



**Fig. 3** **a** Land-use/land-cover classification map of KR Pet Taluk for the year 2001. **b** Land-use/land-cover classification map of KR Pet Taluk for the year 2015



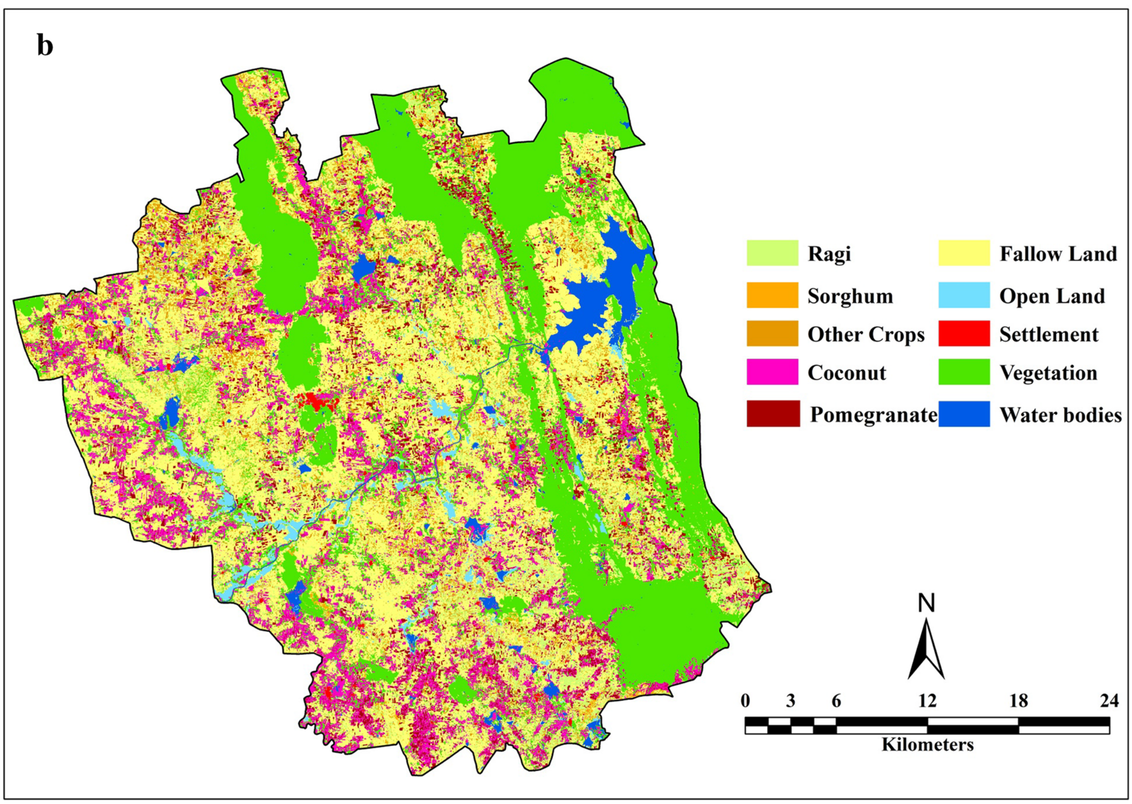




**Fig. 4** **a** Land-use/land-cover classification map of Hosadurga Taluk for the year 2001. **b** Land-use/land-cover classification map of Hosadurga Taluk for the year 2015

the results need rectification. The data collected from official records and data obtained by a team of researchers are not close to the land estimation provided by the satellite data analysis. The question—is the method with remote sensing data analysis robust or not? The remote sensing methods alone cannot be considered as a robust method; however, linking ground level data to remote sensing technology could provide more meaningful results. As already discussed, this method has an accuracy assessment provision and the accuracy of land use data generated with the help of remote sensing is calculated to be more than 78%. Even if researchers go for a 78–80% accuracy, the data generated could be more meaningful. As possible proof, our own experiment related to land use data estimation for the year 2015 provides more idea regarding the robustness of remote sensing data with a strong ground level data support. The survey methods are not to be undermined, as they are very important from a broader perspective. In the case questionnaire-based survey, while converting the sample survey results to the next level, no techniques are available for estimating the margin of error in the final results.

On the other hand, remote sensing technology provides a comprehensive biophysical data at various scales. The major advantages of satellite data are spatial coverage and spatial and temporal resolution. The output data obtained from satellite images have the potential to generate high accuracy data at different scales. The results obtained by using satellite images also provide more accurate maps, depending on the ground data. Due to a higher estimated accuracy and lower errors in respect of the classified data, they are more reliable than the conventional survey-based method. Remote sensing, as a technology, has an immense potential in the field of research. Especially India has a massive opportunity to adopt it for agricultural crop acreage estimation. The availability of IRS satellite images provides information that can reduce the dependency on human labour and help create an independent information source and base.

Therefore, based on this study it is argued that for land use related studies mixed approaches or methods could be more meaningful. In a mixed approach, a strong ground data assemblage with remote sensing data could provide high accuracy information as compared to the survey-based method generally followed by the researchers or the government agencies. A better accuracy can certainly lead to better policy formulations. In addition, the Indian government organisations, research and teaching institutions need to prioritize the use of remote sensing as a tool in conducting the field research. This could ensure an efficient utilisation of space technology for generating accurate data. The state remote sensing agencies need to make thematic data affordable to government organisations and institutions as part of facilitating better research outcomes.

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