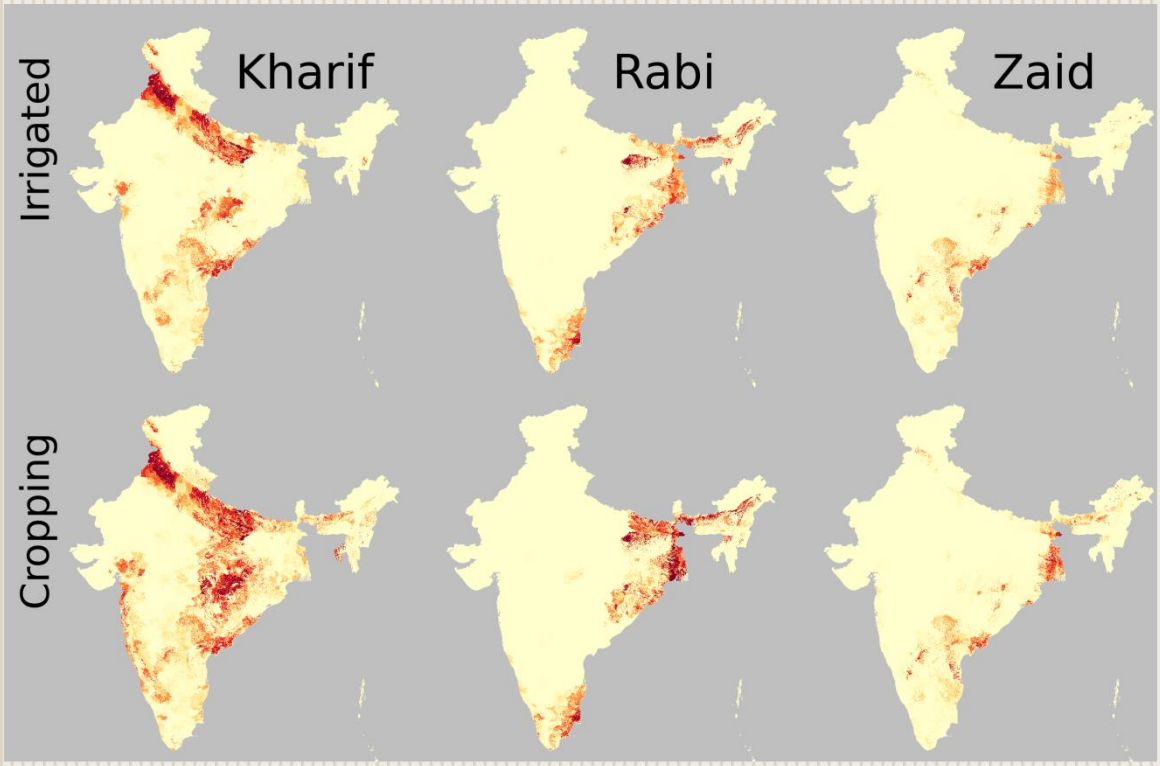
Crop Science Bonn

GEOSHARE

# Mapping of rainfed and irrigated agriculture in India – data inventory and documentation

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# Mapping of rainfed and irrigated agriculture in India – data inventory and documentation

**GEOSHARE pilot project**

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**December 20, 2014**

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This report provides technical details and meta data for geo-referenced datasets of irrigated and rainfed crop areas in India developed under the GEOSHARE pilot project. The data set depicts the spatial distribution of 21 crops under **irrigated and rainfed** conditions in three seasons, **Kharif, Rabi and Zaid**, for year 2005. The data set is provided at two spatial resolutions (500 m and 0.5 degree) and in three raster formats (ASCII Grid, ERDAS IMAGINE and NetCDF).

# 1 Motivations and objectives

The spatio-temporal pattern of cultivated crops varies considerably in India and is strongly determined by varying balances of water supply and demand across regions and seasons. The positive balance between precipitation and potential evaporation in the Kharif (monsoon) season lasting from June to October allows to grow one rainfed crop in most parts of the country, while there is a high water deficit in the Rabi season (November to February) and in the pre-monsoon season (Zaid, March to May). Therefore, irrigation is essential for crops in the Rabi and Zaid seasons to reduce drought stress, while it is only supplementary in the Kharif season across most of the country. This kind of knowledge and information are vital for natural resources management and climate change impact assessments. This study aims to map the rainfed and irrigated cropping area for 21 crops by integrating remotely sensed land use and land cover (LULC) data, crop calendars and survey based census data.

# 2 Input data

## 2.1 Land use and land cover data

Time-series of land use and land cover (LULC) data for period 2004 - 2012 were downloaded from the Bhuvan Gateway to Indian Earth Observation (NRSC, 2014). The entire area was separated into 29 squared tiles. The spatial resolution for the tiled data is roughly 50 meter (0.000667°). The data layers included 19 land use classes and the agricultural classes 'Double-triple cropping', 'Plantations and Orchards', 'Kharif crops', 'Rabi crops', 'Zaid crops' and 'Fallow lands' were extracted. The different tiles were merged into one for the entire country (Fig. 1).

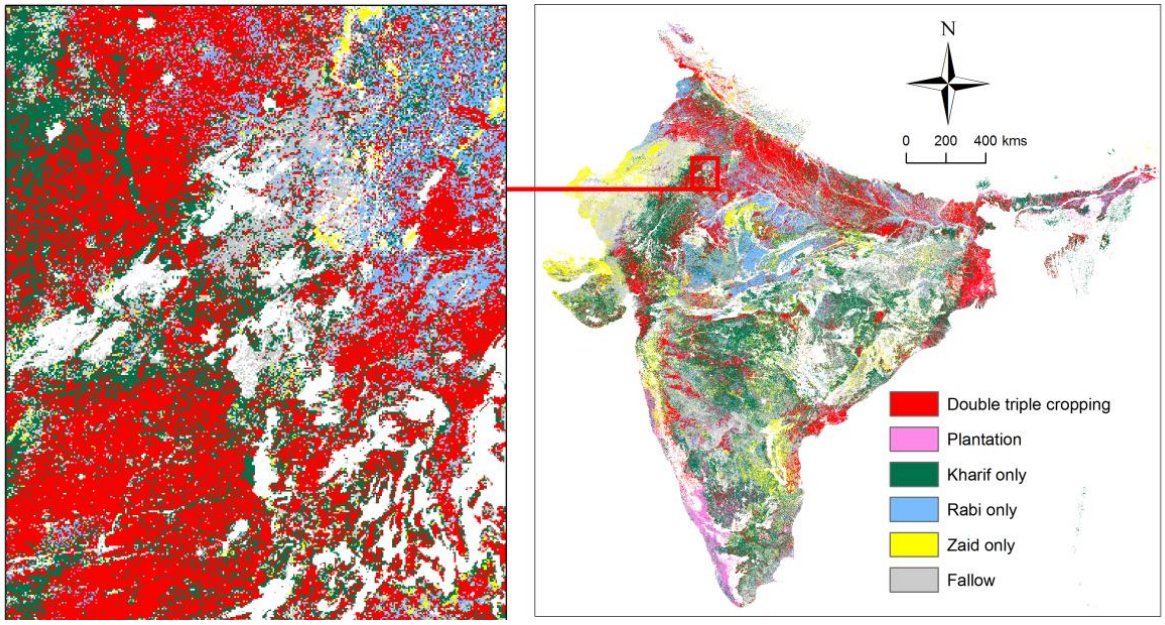



**Fig. 1** The land use data downloaded from the Bhuvan Gateway (example for year 2005). The blank area indicates that there is no agricultural lands in the grid cell.

To save memory and computing power, the LULC data was aggregated to a spatial resolution of 500 m by calculating the ratio of each type in the grid cell of the coarse resolution (Fig. 2). The aggregation guarantees that the total area of each agricultural land use type at coarse resolution equals to the total area at original high resolution.

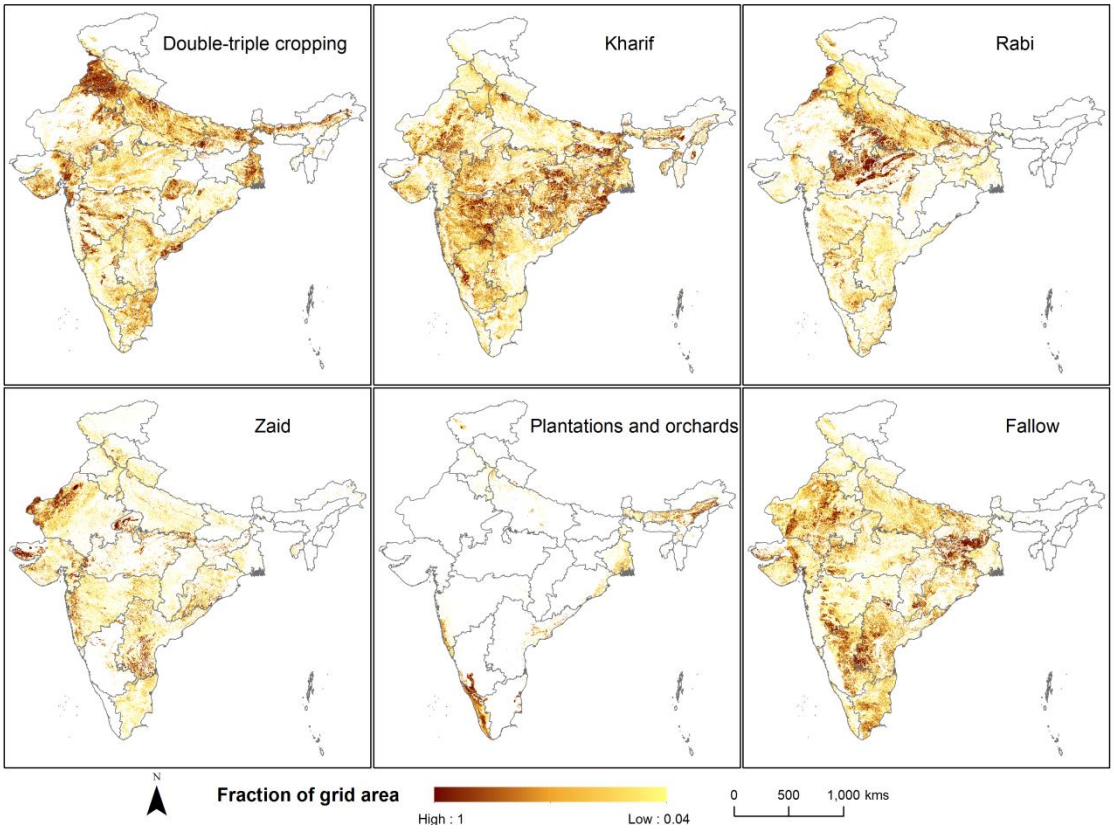



**Fig. 2** The fraction of each agricultural land use type at the spatial resolution of 250 m (example for year 2005).

## 2.2 Census data on net area sown and extent of irrigated and rainfed crops

Survey based census data on net area sown and the extent of 21 irrigated and rainfed crops or crop groups, in India were downloaded from the website of the NIC Land Use Statistics Information System (NIC, 2014). The 21 crops and groups include wheat, maize, rice, barley, sorghum, pearl millet (Bajra), finger millet (Ragi), chick pea (Gram), pigeon pea (Tur), soybean, groundnut, sesame, sunflower, cotton, linseed, sugarcane, tobacco, fruits + vegetables, condiments + spices, rapeseed + mustard, and fodder crops. The data were available at district level as annual time series for the period 1998 to 2012. We found that the data for more recent years, e.g. 2010, have still not been complete and gaps existed for several federal states. Since the data for year 2005 were found to be almost complete, this year was selected as the reference year for our inventory. In the case of missing data for year 2005 the gap was filled with data for preceding or subsequent years. To map the district level survey data or to compare them to the remotely sensed land use, a shapefile with administrative unit boundaries for year 2005 consistent to the survey data was required. We used district boundaries for year 2001 (datameet.org, 2014) consistent to the Administrative Atlas of India (Government of India, 2011) and adjusted district boundaries and names according to the changes between years 2001 and 2011 reported in the Atlas. Unfortunately, a unique district ID was not provided by the NIC so that it was necessary to link the district boundaries and the crop data provided by NIC by the name of the district. District boundaries and the names of the districts change frequently in India and differ depending on the data provider. We matched the district names from the NIC Land Use Statistics Information System to the names contained in the Administrative Atlas of India as shown in Table 1.

**Table 1** Match of district names between the NIC Land Use Statistics Information System and the Administrative Atlas of India .

| NIC | Adm. Atlas | NIC | Adm. Atlas | NIC | Adm. Atlas |
|---|---|---|---|---|---|
| BHATINDA | BATHINDA | PAUMPARE | PAPUMPARE | SANT KABIR NGR | SANT KABIR NAGAR |
| NAWAN SHEHAR(S.B.S. Nagar) | NAWANSHAHR | EAST SINGHBHUM | PURBI SINGHBHUM | HAZAIBAG | HAZARIBAG |
| D & N Haveli | DADRA & NAGAR HAVELI | ANUPPUR | ALIRAJPUR | Jaintia Hills | JAINTIA HILLS |
| JHARSUGDA | JHARSUGUDA | HOWRAH | HAORA | LOHARDAGGA | LOHARDAGA |
| AHMEDABAD | AHMADABAD | A & N Islands | ANDAMANS | ANGUL | ANUGUL |
| LAWANGTLAI | LAWNGTLAI | KANPUR (S) | KANPUR NAGAR | MAHARAJ GANJ | MAHARAJGANJ |
| RI-BHOI | RI BHOI | TEHRI GARWAL | TEHRI GARHWAL | KARBI-ANGLONG | KARBI ANGLONG |
| SINGHBHUMI(E) | PURBI SINGHBHUM | KANYA KUMARI | KANNIYAKUMARI | BURDWAN | BARDDHAMAN |
| PAURI GARHWAL | GARHWAL | N C HILLS | NORTH CACHAR HILLS | KAMRUP(Rural) | KAMRUP |
| SAHEBGANJ | SAHIBGANJ | PORBANDER | PORBANDAR | SONEPAT | SONIPAT |
| JUNAGARH | JUNAGADH | DARJEELING | DARJILING | BANDIPORA | BANDIPORE |
| RANGAREDDY | RANGAREDDI | BAGPAT | BAGHPAT | MONGHYR | MUNGER |
| RAEBARELI | RAE BARELI | AURAGABAD | AURANGABAD | SHOPIAN | SHUPIYAN |
| BEED | BID | UDIPPI | UDUPI | DINAJPUR (NORHT) | UTTAR DINAJPUR |
| MAHASMUND | MAHASAMUND | MIDNAPUR (WEST) | PURBA MEDINIPUR | FATEHGARH | FATEHGARH SAHIB |
| BOUDH | BAUDH | WYNAD | WAYANAD | UTTARAKANNADA | UTTARA KANNADA |
| West Khasi Hills | WEST KHASI HILLS | WEST SINGHBHUM | PASHCHIMI SINGHBHUM | BADWANI | BARWANI |
| KATANI | KATNI | DANGS | THE DANGS | TIRUVARUR | THIRUVARUR |

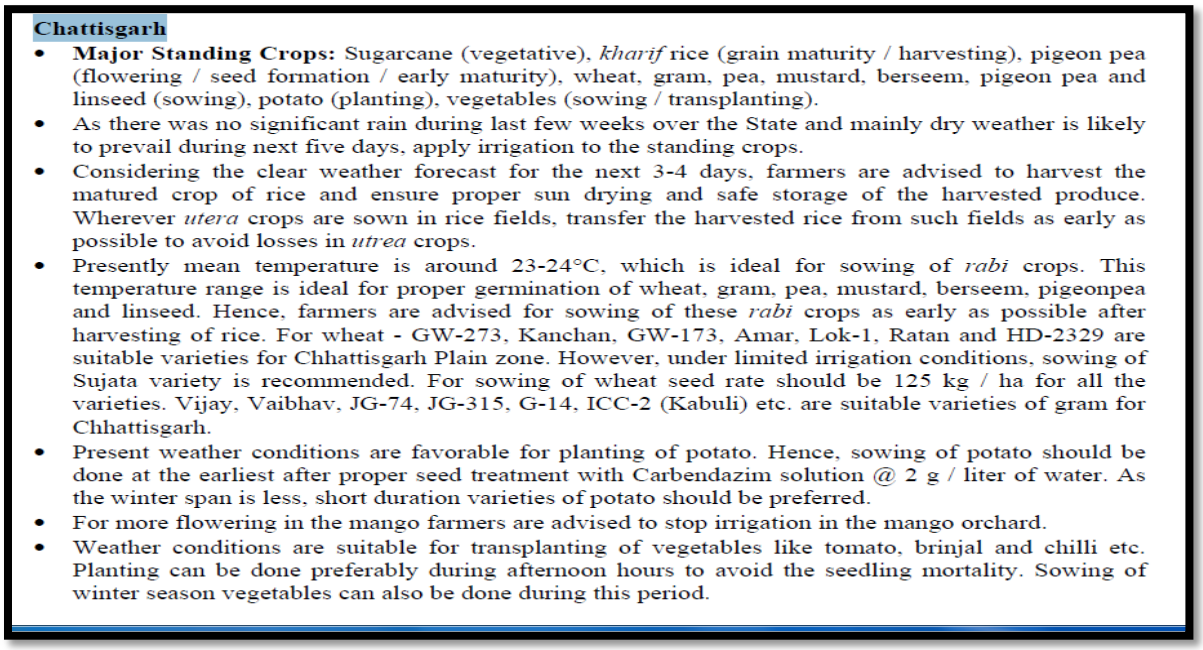
Input data

| NIC | Adm. Atlas | NIC | Adm. Atlas | NIC | Adm. Atlas |
|---|---|---|---|---|---|
| BULDHANA | BULDANA | BARAMULLA | BARAMULA | GAJAPATTI | GAJAPATI |
| BADAUN | BUDAUN | KEDRAPARA | KENDRAPARA | RAJOURI | RAJAURI |
| GAGAD | GADAG | YAMUNA NAGAR | YAMUNANAGAR | KULU | KULLU |
| MIDNAPUR ( EAST) | PASCHIM MEDINIPUR | VIZIANAGRAM | VIZIANAGARAM | MAHABOOBNAGAR | MAHBUBNAGAR |
| UMARIYA | UMARIA | S.RAVI DAS NGR | SANT RAVIDAS NAGAR | VIZIANAGARM | VIZIANAGARAM |
| LAHAUL & SPITI | LAHUL & SPITI | SINGHBHUMI(W) | PASHCHIMI SINGHBHUM | VILLUPURAM | VILUPPURAM |
| East Garo Hills | EAST GARO HILLS | CHENGALPATTU | KANCHEEPURAM | DEHARDUN | DEHRADUN |
| MAHABUBNAGAR | MAHBUBNAGAR | CHHIMTUIPUI | CHAMPHAI | SONEPUR | SONAPUR |
| N.C. Hills (Dima Hasao) | NORTH CACHAR HILLS | FEROZPUR | FIROZPUR | NARSIMPUR | NARSIMHAPUR |
| KODAGU(COORG) | KODAGU | TIRUCHIRAPALLI | TIRUCHIRAPPALLI | MORIGON | MARIGAON |
| THIRUVANTRUM | THIRUVANANTHAPURAM | KEONJHAR | KENDUJHAR | ARVAL | ARWAL |
| MAHENDRA GARH | MAHENDRAGARH | YEVATMAL | YAVATMAL | PODUKKOTTAI | PUDUKKOTTAI |
| PULWANNA | PULWAMA | ANANTPUR | ANANTAPUR | SIVHAR | SHEIKHPURA |
| PURULIA | PURULIYA | UDHAM SINGH | UDHAM SINGH NAGAR | AMROHA(JBFLUE NAGAR) | JYOTIBA PHULE NAGAR |
| NAWORANGPUR | NABARANGAPUR | CHITTORGARH | CHITTAURGARH | KANPUR-D (RAMABAI NAGAR) | KANPUR DEHAT |
| MALDA | MALDAH | KARULI | KARAULI | KOLLAM(QUILON) | KOLLAM |
| NAWADHA | NAWADA | SUBARNAPUR(Sonepur) | SONAPUR | SIMLA | SHIMLA |
| DINDUGUL | DINDIGUL | FATEHBAD | FATEHABAD | JAJPUR | JAJAPUR |
| JAGATSINGPUR | JAGATSINGHAPUR | AHMEDNAGAR | AHMADNAGAR | ASHOK NAGAR | ASHOKNAGAR |
| KASARGOD | KASARAGOD | DAHOD | DOHAD | DANTEWARA | DANTEWADA |
| EAST NIMAR (KHANDWA) | EAST NIMAR | SIDHARTHA NAGAR | SIDDHARTHNAGAR | KANCHIPURAM | KANCHEEPURAM |
| MUMBAI SUB | MUMBAI | POONCH | PUNCH | HATHARAS | HATHRAS |
| JHAJJER | JHAJJAR | MUZAFARPUR | MUZAFFARPUR | JAHANABAD | JEHANABAD |
| AIZWAL | AIZAWL | CHHINDWARA | CHINDWARA | PURNEA | PURNIA |
| VIRUDUNAGAR | VIRUDHUNAGAR | RUPNAGAR(ROPAR) | RUPNAGAR | RAIGAD | RAIGARH |
| SABARKANTHA | SABAR KANTHA | KHURDA | KHORDHA | KOPAL | KOPPAL |
| DINAJPUR (SOUTH) | DAKSHIN DINAJPUR | DAKSHINAKANNADA | DAKSHINA KANNADA | BASTAR | BASTER |
| JALORE | JALOR | LAKSHADWEEP | LAKSHDWEEP | BHABHUA | KAIMUR (BHABUA) |
| HARIDWAR | HARDWAR | KAWARDHA (KABIRDHAM) | KAWARDHA | HAZARIBAGH | HAZARIBAG |
| CHINDWARA | CHHINDWARA | KURKSHETRA | KURUKSHETRA | MANSHA | MANSA |
| NASIK | NASHIK | KODERMA | KODARMA | VADORA | VADODARA |
| SHRAVASTI | SHRAWASTI | NIMACH | NEEMUCH | BOLANGIR | BALANGIR |
| East Khasi Hills | EAST KHASI HILLS | PONDY(DISTRICT) | PONDICHERRY | West Garo Hills | WEST GARO HILLS |
| JHUNJHUNU | JHUNJHUNUN | JANJGIR-CHAMPA | JANJGIR - CHAMPA | DEOGARH | DEBAGARH |
| CHAMPARAN(WEST) | PASHCHIM CHAMPARAN | TUENSANG | TUENSANG | TRISSUR | THRISSUR |
| KANPUR (D) | KANPUR DEHAT | CHAMPARAN(EAST) | PURBA CHAMPARAN | GADHWA | GARHWA |
| LEH | LEH(LADAKH) | ANANTNAGH | ANANTNAG | CHITRAKUT | CHITRAKOOT |
| TUTICORIN | THOOTHUKKUDI | GUMALA | GUMLA | JBFLUE NAGAR | JYOTIBA PHULE NAGAR |
| FEROZABAD | FIROZABAD | PHULBANI | KANDHAMAL | HISSAR | HISAR |

| NIC | Adm. Atlas | NIC | Adm. Atlas | NIC | Adm. Atlas |
|---|---|---|---|---|---|
| Chandigarh | CHANDIGARH | NAWAN SHEHAR(S | NAWANSHAHR | MADHUPURA | MADHEPURA |
| BALASORE | BALESHWAR | WESTNIMAR(KHARGAON) | WEST NIMAR | HATHRAS(MAHAMAYA NAGAR) | HATHRAS |
| KOSHAMBHI | KAUSHAMBI | PAKUR | PAKAUR | BULLANDSHAHR | BULANDSHAHR |
| BURAGARH | BARGARH | DHOLPUR | DHAULPUR | TIRUVANNMALAI | TIRUVANNAMALAI |
| HOOGHLY | HUGLI | DEVANAGRRE | DAVANGERE | COOCH-BEHAR | KOCH BIHAR |
| NAWAPARA | NUAPADA | BUDGAM | BADGAM | | |

## 2.3 Crop calendar information

Growing areas of rice, Jowar, other cereals and millets, and other pulses, are reported in the NIC Land Use Statistics separately for the three seasons Kharif, Rabi and Zaid, while for the other crops the season in which the crops are grown were not indicated. Therefore, crop development stages were extracted from weekly reports of the Agromet Advisory Services (India Meteorological Department 2008-2012). The reports are published within weekly intervals and describe the weather and crop conditions for each 28 states and 7 union territories of India (Fig. 3). In these crop advisories, the states and union territories are grouped in six geographical regions (Fig. 4). We assigned sowing and harvest dates reported for the geographical regions and the different crops to each of the states belonging to the corresponding geographical region. In this way, the season specific crop growing areas reported in the land use statistics (Fig. 5) could be compared to the crop coverage detected for the different seasons by remote sensing (Fig. 1).



**Chattisgarh**

- **Major Standing Crops:** Sugarcane (vegetative), *kharif* rice (grain maturity / harvesting), pigeon pea (flowering / seed formation / early maturity), wheat, gram, pea, mustard, berseem, pigeon pea and linseed (sowing), potato (planting), vegetables (sowing / transplanting).
- As there was no significant rain during last few weeks over the State and mainly dry weather is likely to prevail during next five days, apply irrigation to the standing crops.
- Considering the clear weather forecast for the next 3-4 days, farmers are advised to harvest the matured crop of rice and ensure proper sun drying and safe storage of the harvested produce. Wherever *utera* crops are sown in rice fields, transfer the harvested rice from such fields as early as possible to avoid losses in *utera* crops.
- Presently mean temperature is around 23-24°C, which is ideal for sowing of *rabi* crops. This temperature range is ideal for proper germination of wheat, gram, pea, mustard, berseem, pigeonpea and linseed. Hence, farmers are advised for sowing of these *rabi* crops as early as possible after harvesting of rice. For wheat - GW-273, Kanchan, GW-173, Amar, Lok-1, Ratan and HD-2329 are suitable varieties for Chhattisgarh Plain zone. However, under limited irrigation conditions, sowing of Sujata variety is recommended. For sowing of wheat seed rate should be 125 kg / ha for all the varieties. Vijay, Vaibhav, JG-74, JG-315, G-14, ICC-2 (Kabuli) etc. are suitable varieties of gram for Chhattisgarh.
- Present weather conditions are favorable for planting of potato. Hence, sowing of potato should be done at the earliest after proper seed treatment with Carbendazim solution @ 2 g / liter of water. As the winter span is less, short duration varieties of potato should be preferred.
- For more flowering in the mango farmers are advised to stop irrigation in the mango orchard.
- Weather conditions are suitable for transplanting of vegetables like tomato, brinjal and chilli etc. Planting can be done preferably during afternoon hours to avoid the seedling mortality. Sowing of winter season vegetables can also be done during this period.

**Fig. 3** A sample of the National Agromet Advisory Bulletin of IMD, India

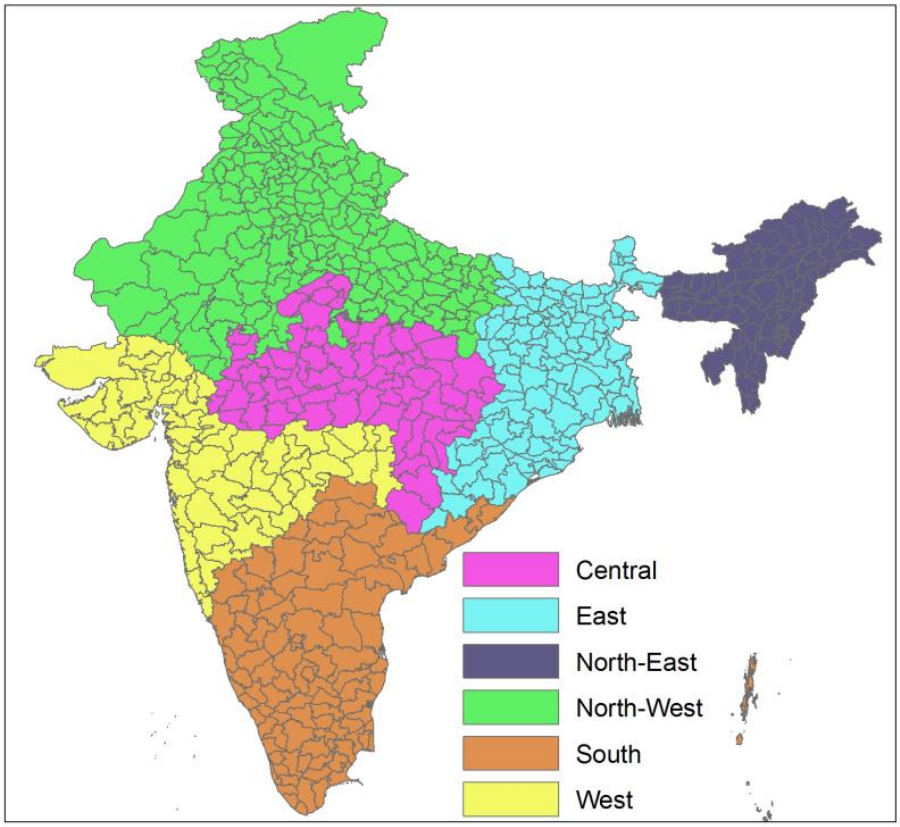



**Fig. 4** The six grouped geographical divisions used to report the crop advisory and calendar data.

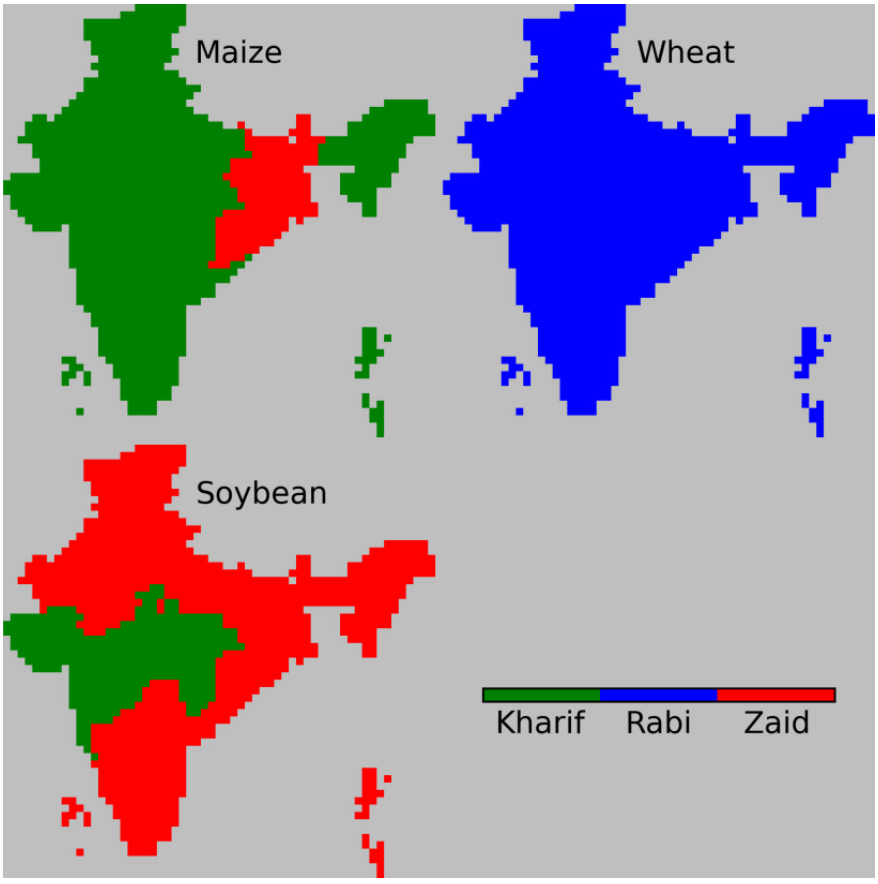



**Fig. 5** Spatial distribution of crop seasonality for three crops.

# 3 Methods used for data fusion

## 3.1 Harmonizing remote sensing based and survey based data for net area sown

For each district, the spatial distribution of cropland used in different seasons (Kharif, Rabi and Zaid), of double-triple cropping, plantation and orchards, and fallow land were available from the NRSC (remote sensing based) at high spatial resolution and for each year in period 2004 – 2012. However, the remote sensing data did not distinguish specific crops. The NIC land use statistics distinguished specific crops but the spatial resolution of the statistics was low (district level). To make use of the advantages of both data types and to obtain a product with high spatial and categorical detail, the data needed to be combined. As a first step, consistency of total net area sown and total net irrigated area between the NRSC data and the NIC census data needed to be ensured for each district. The comparison between the original data is shown in Fig. 6 and 7.

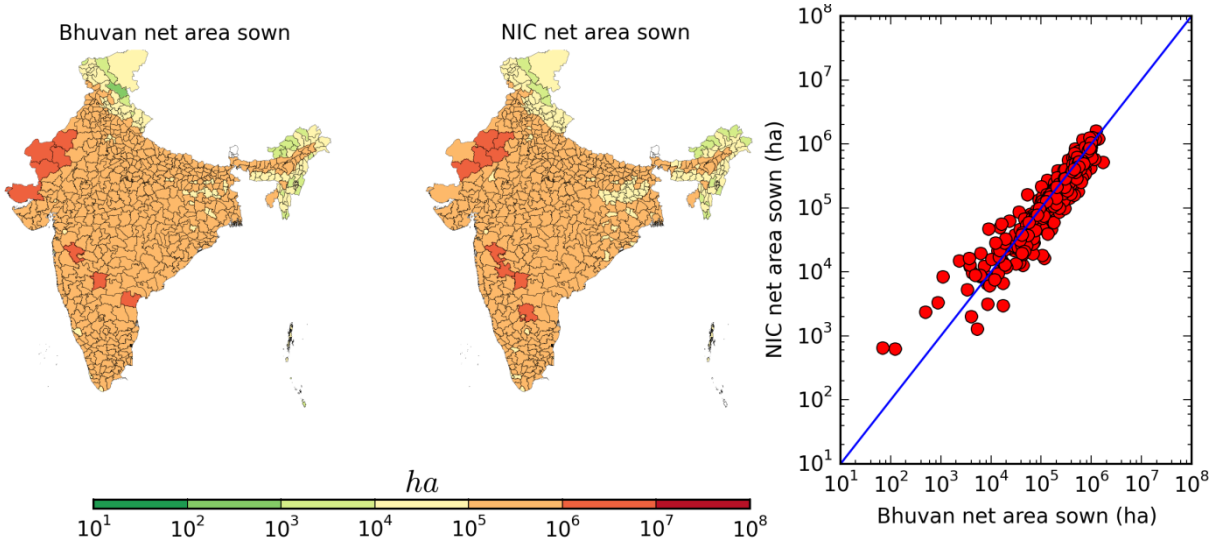



Fig. 6 Total net area sown in 2005 reported by the NRSC LULC data and the NIC land use statistics.

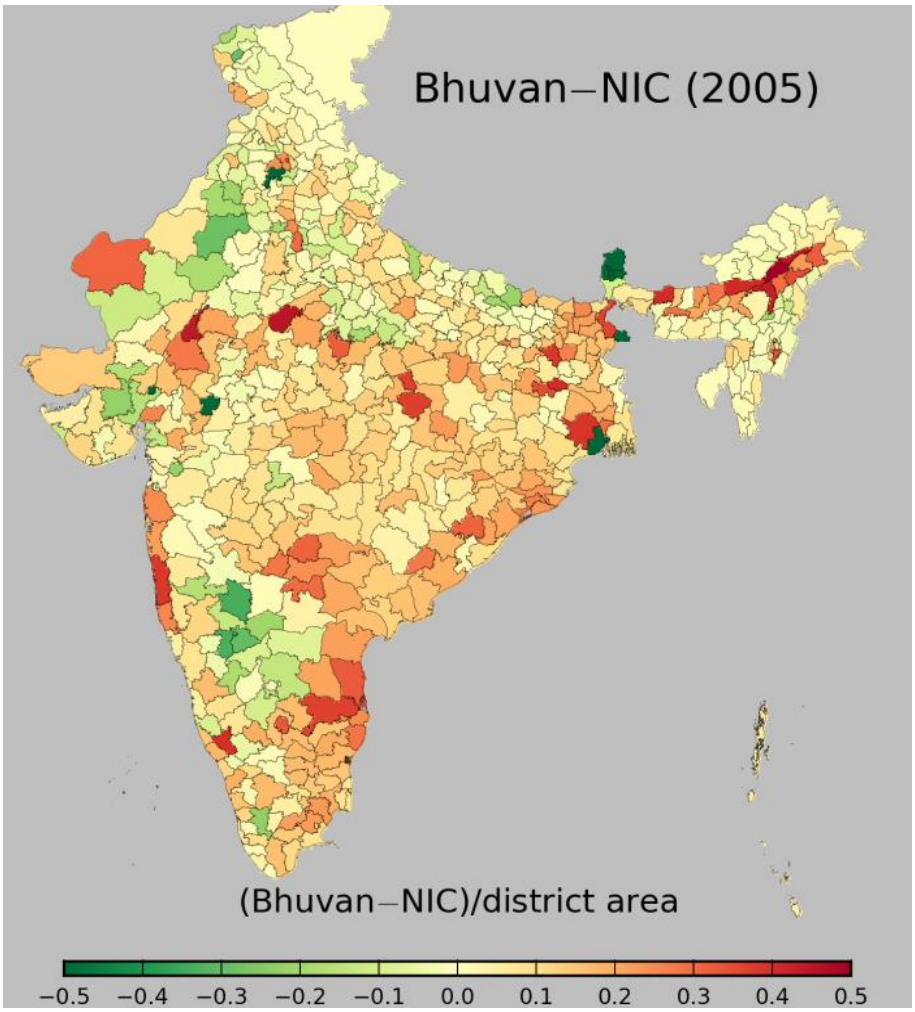



**Fig. 7** Discrepancy between remote sensing based net area sown (Bhuvan) and sample survey based net area sown (NIC) for year 2005.

Because the data originate from independent sources and were developed with different methods, the differences shown in Fig. 6 and Fig. 7 were expected. To harmonize the data from the two sources, we first used the double-triple cropping area reported by the remote sensing data to reduce the differences. When there was a smaller net area sown according to the NRSC data than according to the NIC census data, we treated the pixels of double-triple cropping as a double cropping. Otherwise, we treated them as the triple cropping. Then we searched for the year in the NRSC data that was fitting best to the NIC census data by selecting the closest net sown area across years from 2004 to 2011 (Fig. 8).

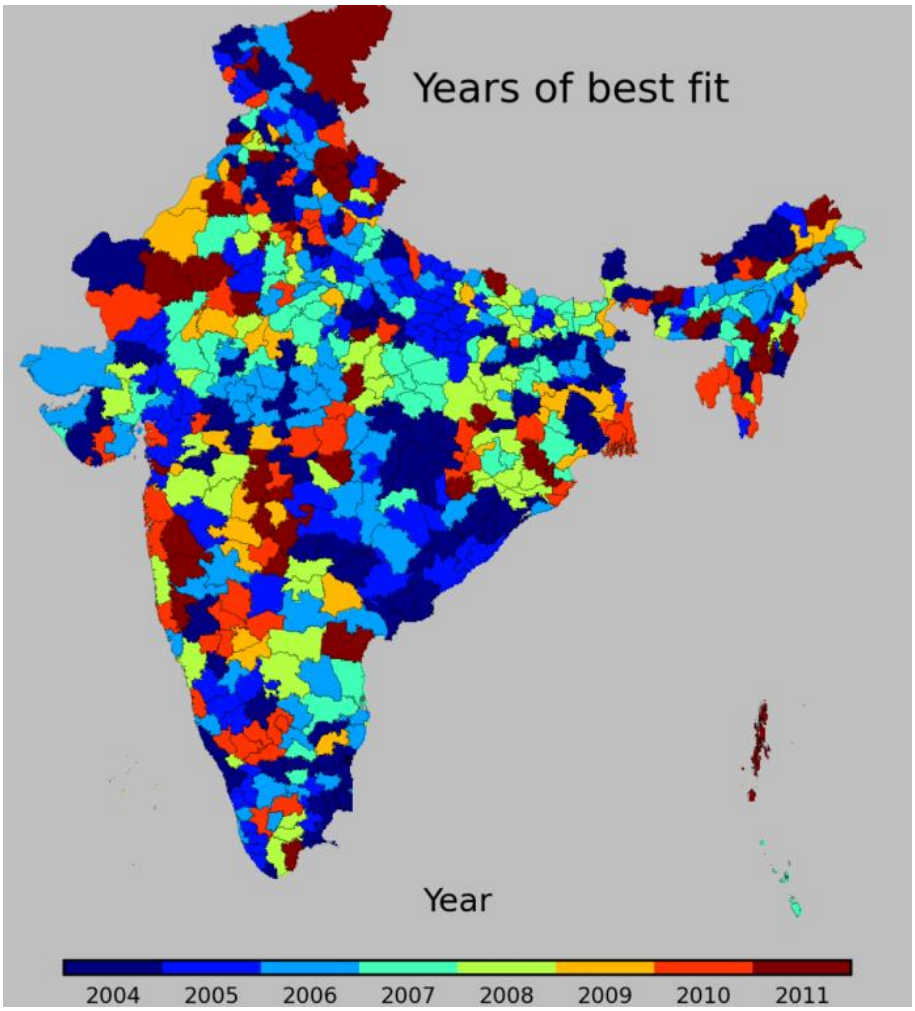



**Fig. 8** The years of best of fit of net sown area between Bhuvan remote sensing data (2004 – 2011) and NIC land use statistics for year 2005.

The NRSC data from the year with the best fit to the NIC data for year 2005 was then selected. This procedure reduced the differences between the two data sets considerably (Fig. 9).

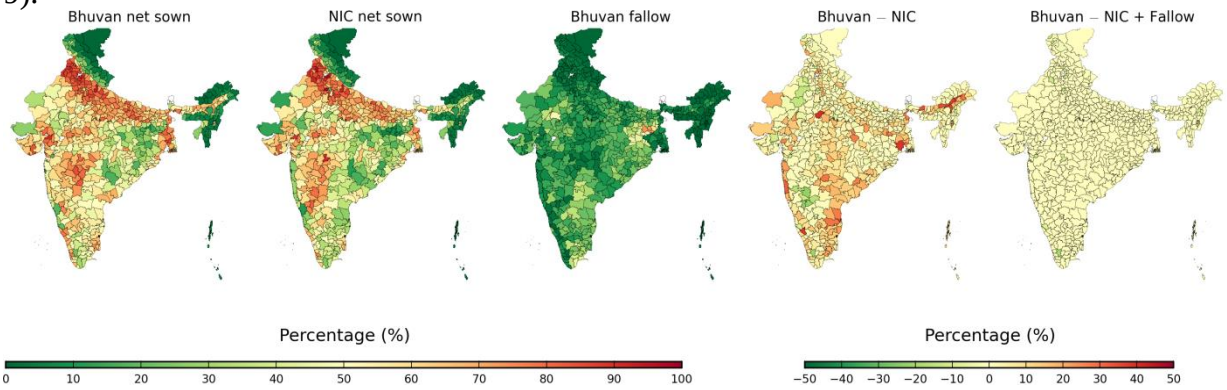



**Fig. 9** Comparison of the fraction of net area sown between remote sensing based data (Bhuvan) and land use statistics (NIC) after selecting the Bhuvan data in the year of best fit (Bhuvan net sown), the Bhuvan fallow area after the adjustment of the fallow area (Bhuvan fallow), the difference between Bhuvan and NIC after selecting the best year of fit (Bhuvan – NIC), and the difference between Bhuvan and NIC after adjusting the Bhuvan net area sown by using the fallow land use type (Bhuvan – NIC + Fallow).

After this step, only small differences remained in some counties. To further improve the consistency, we used the fallow land use type as a buffer to level out the discrepancies

between net area sown in the Bhuvan and NIC data by converting either fallow land to cropped area or wise versa. When there was no pixel with fallow land available, we also used other pixels in the surrounding of cropped pixels to buffer these difference. At the end, we matched the two sources of data with an acceptable accuracy and differences in the net area sown less than 500 ha for each district (Bhuvan – NIC + Fallow in Fig. 9).

## 3.2 Mapping of irrigated and rainfed crop areas

Based on the harmonized net area sown, total and irrigated cropping areas reported by NIC for specific crops were assigned to the Bhuvan crop area, accordingly. First, the total cropping area for each season (Kharif, Rabi and Zaid) was computed for the harmonized Bhuvan data set for each district. The Bhuvan double-triple cropping area was first considered as double cropping area and evenly assigned to three seasons. In each district and season, the cropping area of each crop from NIC was compared with the total seasonal crop area form the NIC data. If the total Bhuvan cropping area in a season was smaller than the cropping area according to the NIC data, we assumed that the double-triple cropping area is triple cropping and assign them to all three seasons. Then the ratio of irrigated and total cropping area to the agricultural area in each season and district was computed. Finally, the resultant ratio was multiplied by the seasonal Bhuvan land use in each district for each crop. The products of the two ratio resulted in the final products.

# 4 Final products

## 4.1 Description of the products

The final products have two spatial resolutions (500 m and 0.5°) and are provided in the three raster formats ASCII grid, ERDAS IMAGINE and NetCDF (Table 2). The ERDAS IMAGINE image file (.img) format is a binary format that contains the spatial reference information and can be directly read by GIS software (e.g. ArcGIS). The ESRI ASCII grid format (.asc) is a text format. The first six lines indicate the geo-reference of the grid, followed by the data itself. The spatial reference can be find in Table .The NetCDF format contains all the meta-data internally.

**Table 2** Characteristics of the final products of irrigated/cropping areas at two spatial resolutions.

| | | |
|---|---|---|
| Resolution | 500 m | 0.5° |
| Unit | Fraction of pixel area or 25 hectare | Hectare |
| Coordinate system | Projected | Geographic |
| Spatial references | WGS_1984_UTM_Zone_44N | WGS1984 |
| Format | ERDAS IMAGINE, ESRI ASCII grid and NetCDF | ERDAS IMAGINE, ESRI ASCII grid and NetCDF |

## 4.2 Examples of final products for three crops

We show examples of the final products for three crops, i.e. rice, maize and wheat in Figs 10, 11 and 12. The maps show spatial distributions of irrigated area, cropping area, and ratio of irrigated area to cropping area. The resolution for the maps is 500 metre and the area for each pixel is 25 ha.

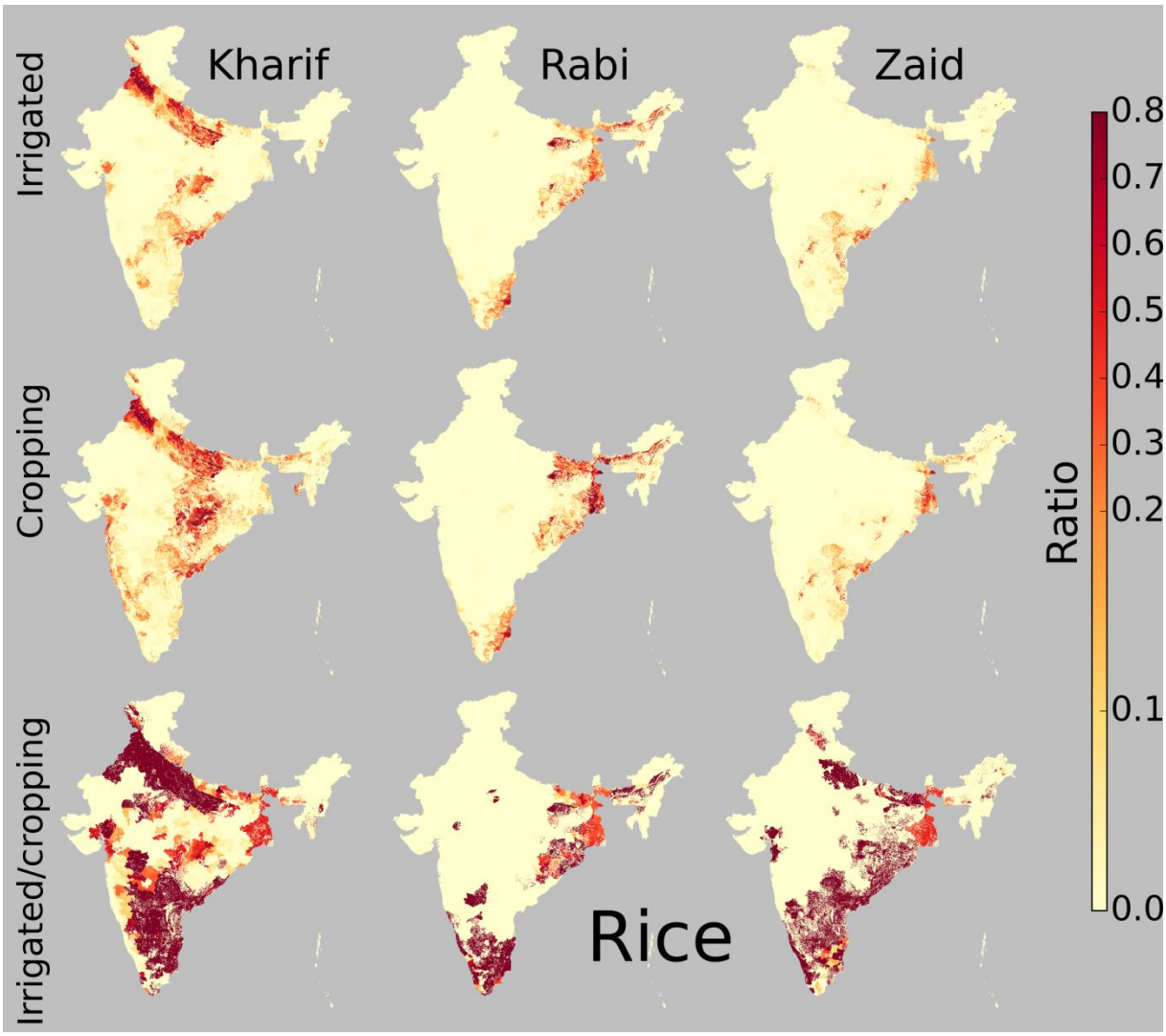



**Fig.** 10 The spatial distribution of irrigated area, cropping area, and ratio of irrigated area to cropping area for rice in three growing seasons (Kharif, Rabi and Zaid) in India. The spatial resolutoin is 500 metre. The value for irrigated and croping area is the area fraction to the pixel area of 25 ha.

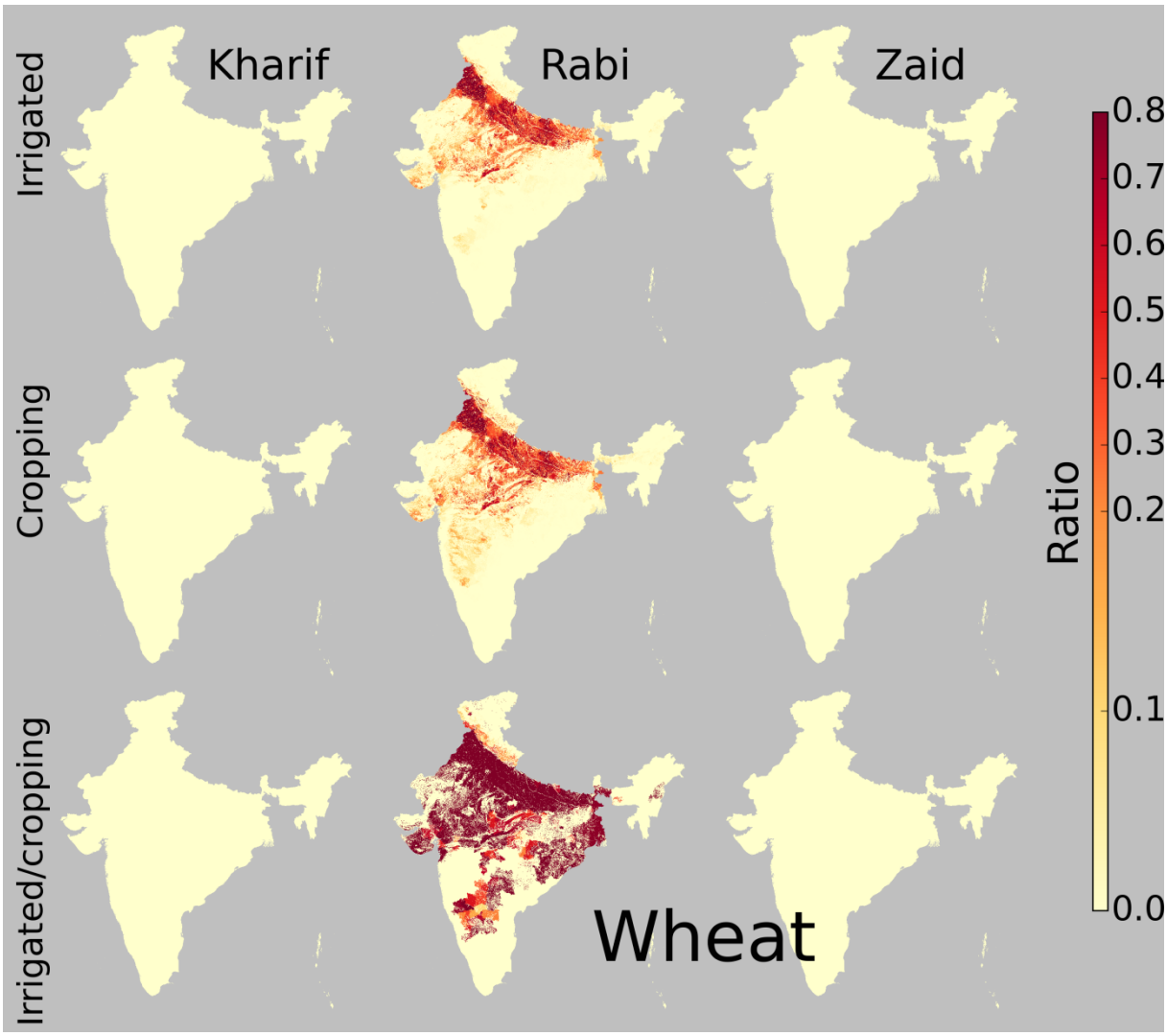



**Fig.** 11 The spatial distribution of irrigated area, cropping area, and ratio of irrigated area to cropping area for wheat in three growing seasons (Kharif, Rabi and Zaid) in India. The spatial resolutoin is 500 metre. The value for irrigated and croping area is the area fraction to the pixel area of 25 ha.

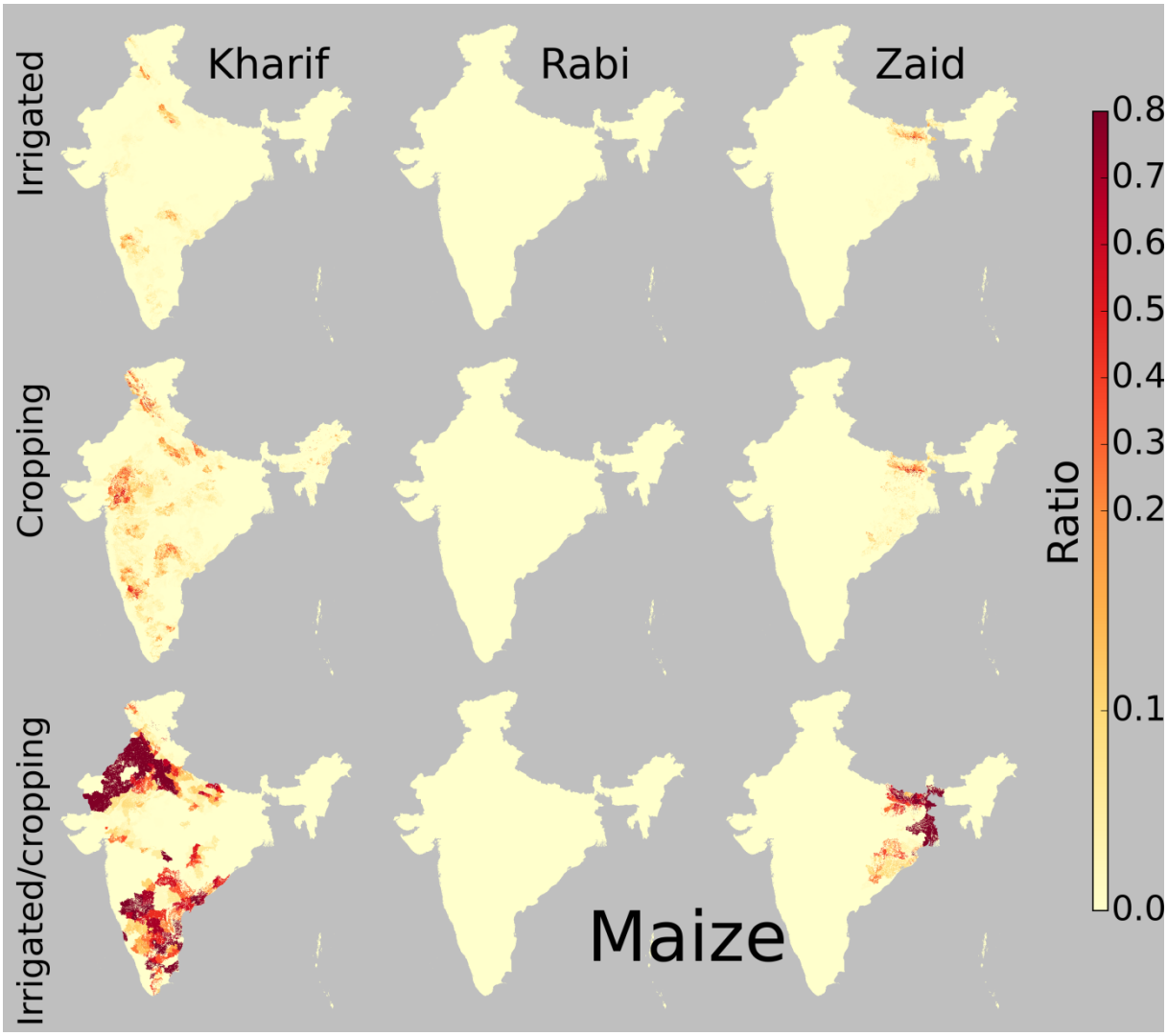



Fig. 12 The spatial distribution of irrigated area, cropping area, and ratio of irrigated area to cropping area for maize in three growing seasons (Kharif, Rabi and Zaid) in India. The spatial resolutoin is 500 metre. The value for irrigated and croping area is the area fraction to the pixel area of 25 ha.

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