

# Agricultural productivity in the Brahmani-Baitarni River Basin of India

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We hope that the results of this study are used to improve the livelihoods of the people of the Brahmani-Baitarni Basin.

## Executive summary

The Brahmani-Baitarni Basin extends over the Indian states of Chhattisgarh, Jharkhand, and Odisha. The total area of the Basin is 51,822 km<sup>2</sup> with a population of 16.7 million, 87% of which is rural. Agriculture plays a critical role in the economy and the livelihoods of the majority of the population of the Basin, and is the major sector for employment. Hence, development of agriculture plays a significant role in food security and improving the livelihoods for the people living within the Basin.

In this study, we analysed spatial and temporal trends of productivity of the major crops grown in the Basin. We also analysed the constraints and identified and modelled the opportunities to increase agricultural productivity.

There are two main cropping seasons in the Basin; Kharif and Rabi. Kharif season is mainly rainfed and Rabi is mainly irrigated. In the upper part of the Basin, crops are grown predominantly in the Kharif season. Cultivation of Rabi crop is less than 10% of the cultivable area. In the lower part of the Basin crops are grown in both Kharif and Rabi seasons. The current cropping intensity is around 160%. Rice is the predominant crop in the Kharif season within the Basin (93% of the cropped area in the upper part and 74% in the lower part). The average yield of Kharif rice is significantly lower in the upper part of the Basin (around 1.5 tonne/ha) and highly variable from year to year without any particular trend. In the lower part of the Basin, the yield is close to the country average with less variation from year to year. The productivities of other crops are similar to that of rice.

Low yield in the upper part of the Basin is primarily due to lack of irrigation. The rainfall in the Basin is low, erratic and with prolonged dry spells within the wet season. Crops suffer from water stress resulting in yield loss which can be mitigated by providing supplementary irrigation. There is limited irrigation infrastructure in the upper part of the Basin, so development of irrigation infrastructure will significantly improve productivity. However, productivity of the crops can also be greatly improved by adopting effective rainwater conservation and management practices, increasing ponding water depth by raising the bund height thus mitigating the in-seasonal drought of winter rice, improved cropping practices, and by using quality seeds and higher inputs.

The key findings from this study are:

1. In general, productivity of crops is low. Productivity is lower in the districts of Jharkhand and Chhattisgarh compared to the districts in Odisha within the Basin.
2. There is no or negligible irrigated crops in Jharkhand and Chhattisgarh; both of which are mono-crop (rice) regions. Rabi cropping in Odisha (within the Basin) is more than 60% of the cultivable area (area of the Basin within Odisha) because of irrigation infrastructure.
3. Irrigation development will increase productivity and improve livelihoods, particularly in the upper part of the Basin in Chhattisgarh and Jharkhand.
4. Local water harvesting and farm level water management may have good potential to improve productivity.
5. Research in agriculture and cropping systems is essential.





# 1 Introduction

## 1.1 Background

The Brahmani-Baitarni Basin comprises two major rivers, Brahmani and Baitarni, and extends over the states of Chhattisgarh, Jharkhand and Odisha (Figure 1.1). The total area of the Basin is 51,822 km<sup>2</sup> with a maximum length and width of 403 km and 193 km<sup>1</sup>. The Brahmani sub-Basin covers 39,033<sup>2</sup> km<sup>2</sup> and the Baitarni sub Basin extends over 12,789 km<sup>2</sup>. The Basin drains into the Bay of Bengal. The state-wise break up of drainage area of the Basin is given in Table 1.1. The Basin covers small parts of the two districts within Chhattisgarh, seven districts partly within Jharkhand, and twelve districts either completely or partly within Odisha (Figure 1.1). The population of the Basin is 16.7 million, of which 87% live in rural areas (Amarasinghe et al. 2004).



**Figure 1.1 Location of the Brahmani-Baitarni River Basin**

<sup>1</sup> <[http://india-wris.nrsc.gov.in/wrpinfo/index.php?title=Brahmani\\_and\\_Baitarni](http://india-wris.nrsc.gov.in/wrpinfo/index.php?title=Brahmani_and_Baitarni)>. NRSC and CWC (2011) reported the total area of the Basin as 50,768 Km<sup>2</sup> in one place (page 64) and 51,822 Km<sup>2</sup> in another place (page 74).

<sup>2</sup> This area is reported in source <sup>1</sup> above. Pollino et al. (2016) reported the area of Brahmani Basin as 34,614 Km<sup>2</sup>.

Agricultural land covers 52% of the total area of the Basin. Agriculture is the primary occupation and predominant economic activity of the people in the Basin. Of the three states covering the Basin, Jharkhand and Odisha constitute about 98% of the Basin area. At the state level, agriculture is the main stay for the 80% of rural population in Jharkhand. Agriculture is the primary employment and income-generating activity. The agricultural economy of the Jharkhand state is characterised by dependence on nature, low investment, low productivity, mono-cropping with rice as the dominant crop, limited irrigation facilities and small and marginal holdings<sup>3</sup>. The agriculture is highly dominated by rainfed agriculture; only 8% of the total cultivated area is irrigated.

**Table 1.1 State-wise breakup of the drainage area of the Basin with the name of the districts covering the Basin**

| State        | Drainage area, km <sup>2</sup> | Percentage of total Basin area | Name of the districts covering the area of the Basin                                                                        |
|--------------|--------------------------------|--------------------------------|-----------------------------------------------------------------------------------------------------------------------------|
| Chhattisgarh | 900                            | 2.5%                           | Jashpur, Surguja                                                                                                            |
| Jharkhand    | 16,505                         | 30.4%                          | Gumla, Khunti, Latehar, Lohardaga, Pashchimi Singhbhum, Ranchi, Simdega                                                     |
| Odisha       | 34,749                         | 67.1%                          | Anugul, Baleshwar, Bhadrak, Cuttack, Debagarh, Dhenkanal, Jajapur, Kendrapara, Kendujhar, Mayurbhanj, Sambalpur, Sundargarh |

Source: <[http://india-wris.nrsc.gov.in/wrpinfo/index.php?title=Brahmani\\_and\\_Baitarni](http://india-wris.nrsc.gov.in/wrpinfo/index.php?title=Brahmani_and_Baitarni)>. According to NRSC and CWC (2011), out of the total area of 50768 Km<sup>2</sup>, 66.82% (33,923 Km<sup>2</sup>) lies in Odisha State, 30.49% (15,479 Km<sup>2</sup>) is in Jharkhand State and 2.69% (1,367 Km<sup>2</sup>) is in Chhattisgarh State.

Agriculture plays a critical role in the economy and livelihood of the majority of the population of Odisha. The share of Gross State Domestic Product (GSDP) from agriculture (including animal husbandry) during 2009–10 was 17.84%. The sector provides employment to 70% of the total workforce (Government of Odisha, 2011). Thus development in agriculture holds the key to food security and socioeconomic development of the states representing the Basin.

The primary aim of this study was to understand the state of agriculture in the Basin. Specifically, the objectives were:

- to analyse the types of crops cultivated and their distribution in the Basin districts;
- to analyse the spatial and temporal trends in the productivity of the major crops grown in the Basin agricultural districts; and
- to analyse the constraints to improving crop productivity and opportunities to increasing productivity.

## 1.2 Scope and limitations of the study

The analyses described in this report rely on secondary data of the Basin districts (covering fully or partly) as well as the other districts of the states, available from public online sources listed in Table 1.2. The spatial resolution of the available data is the administrative districts<sup>4</sup> of the states. The data are the average for the districts since 2000. For Jharkhand, the available data covers the period 2002–2008 and 2010–11. For Odisha, data is only available since 2006–07.

<sup>3</sup> <[http://www.jharkhand.gov.in/web/guest/agriculture\\_about\\_the\\_dept](http://www.jharkhand.gov.in/web/guest/agriculture_about_the_dept)>

<sup>4</sup> In the Statistical Yearbook of Odisha ([http://agriodisha.nic.in/Http\\_public/statistics.aspx](http://agriodisha.nic.in/Http_public/statistics.aspx)), there is a district called Phulbani which is not available in the national database. Checking reveals that Phulbani is the same as Kandhamal. The district might have been renamed as Phulbani.

**Table 1.2 Source of available statistical data**

| Type of data                                                                                                       | Source                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|--------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| State-wise area, production and productivity of rice during 2006/07 to 2010/11                                     | Directorate of Rice Development, Government of India, Ministry of Agriculture, 250 – A, Patliputra Colony, Patna-800 013 (Bihar)<br>< <a href="http%3A%2F%2Fdrd.dacnet.nic.in%2FDownloads%2FStatewise-APY-of-Rice-2006-07-to-2010-11.pdf&amp;usg=AFQjCNGShnpMu5Jzf1x5D3-3kdu2CfSzwg&amp;sig2=JjicFQ8-Bmaw_AZj5pTnfg&amp;bvm=bv.106379543,d.cGc">http%3A%2F%2Fdrd.dacnet.nic.in%2FDownloads%2FStatewise-APY-of-Rice-2006-07-to-2010-11.pdf&amp;usg=AFQjCNGShnpMu5Jzf1x5D3-3kdu2CfSzwg&amp;sig2=JjicFQ8-Bmaw_AZj5pTnfg&amp;bvm=bv.106379543,d.cGc</a> > |
| District-wise crop production statistics                                                                           | National Database of district-wise crop production statistics for selected states, crops and given range of years, SDDS-DES, Ministry of Agriculture, Govt. of India, AGRID-NIC, Ministry of Communications and Information Technology, Government of India, < <a href="http://apy.dacnet.nic.in/crop_fryr_toyr.aspx">http://apy.dacnet.nic.in/crop_fryr_toyr.aspx</a> > (downloaded on 15 April 2016)                                                                                                                                                |
| Agricultural statistics of Odisha, long-term area, production, and productivity of rice, wheat and maize of Odisha | Statistical Yearbook of Odisha Agricultural Statistics, published every year by the Directorate of Agriculture and Food Production, Government of Odisha, Bhubaneswar, Available online from 2006-07 to 2012-13 at <a href="http://agriodisha.nic.in/Http_public/statistics.aspx">http://agriodisha.nic.in/Http_public/statistics.aspx</a>                                                                                                                                                                                                            |

## 2 Crops and cropping intensity

### 2.1 Cropping season and crops

There are two main cropping seasons; Kharif and Rabi (Chauhan and Shrivastava 2007, Panigrahi et al. 2007, Government of Odisha 2014). Kharif season (June to December) is rainfed and Rabi (December to May) is mainly irrigated as the rainfall at that time is very low. Where three crops seasons prevail, crops grown during July to October are known as autumn or monsoon crop; during November to February are known as winter crops and during March to June are known as summer crops (Nayak 2006, Cornish et al. 2015a, 2015b). NRSC and CWC (2011) defined crop growing season as Kharif only crop during 4 months (July to October), Rabi only crop during 4 months (November to February) and Zaid only crop during 4 months (February to May<sup>5</sup>). So Zaid is closer to the summer season described by Nayak (2006) and Cornish et al. (2015a, 2015b). Pollino et al. (2016) used the seasons defined by NRSC and CWC (2011) in the river system modelling.

The Odisha national database has data (area, production and yield) for four types of rice – autumn rice, Kharif rice, summer rice, and winter rice. The total area and production of rice grown in the Basin per year is the sum of all four types of rice. However, only 2005/06 has data for all four types. In other years (2006/07 onwards) the total area is the sum of autumn, winter and summer rice as there is no Kharif area (or it is not recorded as separate area). The Statistical Yearbook of Odisha records only two types of rice - Kharif and Rabi. The total area of rice is the same in both these sources (national database and the Statistical Yearbook) – Kharif is the sum of autumn and winter rice<sup>6</sup> and Rabi or irrigated rice is the same as summer rice.

So for Jharkhand, both autumn and winter rice are rainfed Kharif rice. Based on the cultivated area it seems autumn rice is the Kharif rice grown during April to July and winter rice is the Kharif rice grown during June to November. There is no record of irrigated or summer rice. This is also true for Chhattisgarh. The crops grown in the districts of the Basin are listed in Table 2.1.

---

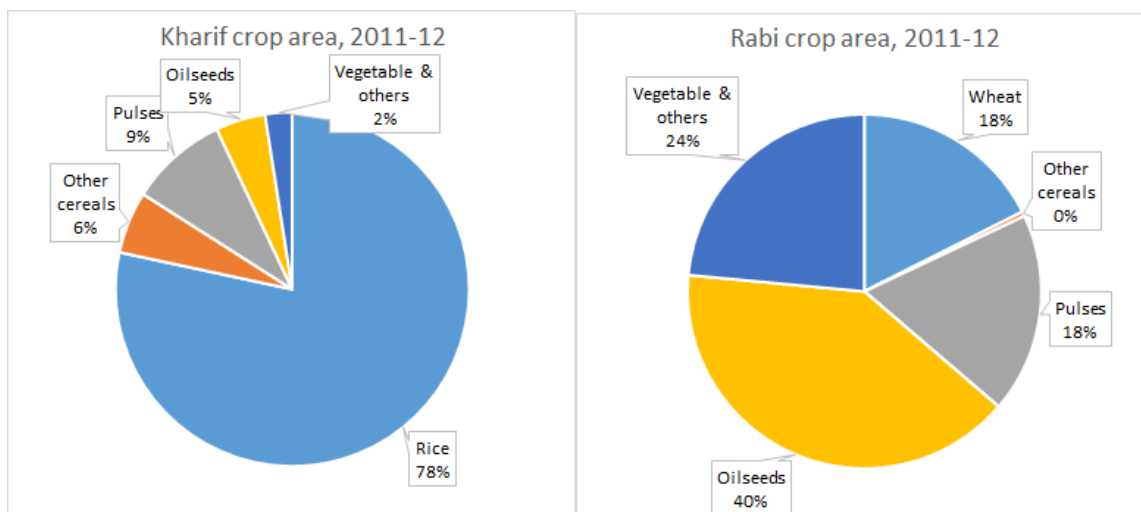
<sup>5</sup> In the NRSC and CWC (2011) report, this is reported as February to May. As February is common month with Rabi season, we wonder whether it should have been March to June. There is no mention of June in the season defined in the report.

<sup>6</sup> Nayak (2006) and Cornish et al. (2015a, 2015b) described winter crops that are grown in November to February. But for rice it seems they are named in the database based on their time of harvest. The monsoon or main Kharif rice is harvested in October/November so they are termed as winter rice. Autumn rice harvested earlier in autumn season, so they are termed as autumn rice.

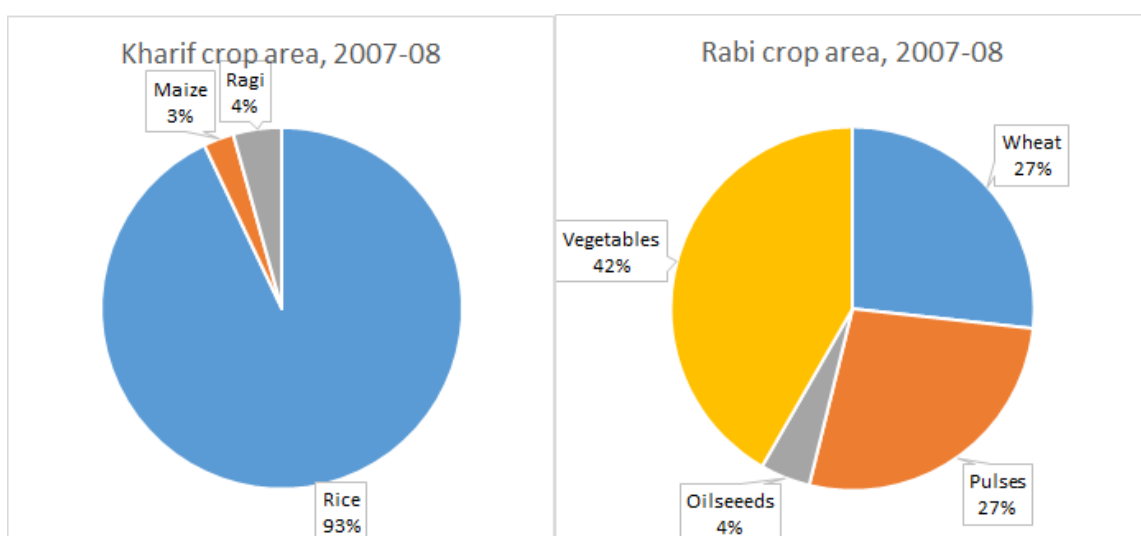
**Table 2.1 Crops grown in the Basin districts**

| State        | Crops grown                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Chhattisgarh | <p><b>Kharif crops</b></p> <ul style="list-style-type: none"> <li>• Rice – Kharif rice</li> <li>• Other cereals – Maize, small millets, jowar, ragi</li> <li>• Pulses - arhar (tur), urad, moong, horsegram, other kharif pulses</li> <li>• Oilseeds - groundnut, sesamum, niger seed, sunflower, soybean</li> <li>• Fibre – sannhamp, mesta</li> </ul> <p><b>Rabi crops</b></p> <ul style="list-style-type: none"> <li>• Cereal – wheat, Barley</li> <li>• Pulses – Gram, masoor, kesari, peas and bean, other rabi pulses</li> <li>• Oilseeds - rapeseed, linseed</li> </ul> <p><b>Crops grown year round</b></p> <ul style="list-style-type: none"> <li>• Vegetables – potato, sweet potato, onion</li> <li>• Spices and condiments – dry chillies, dry ginger, turmeric, coriander, garlic</li> <li>• Others – sugarcane, tobacco, banana</li> </ul>                                                                                                                                                                                              |
| • Jharkhand  | <p><b>Kharif crops</b></p> <ul style="list-style-type: none"> <li>• Rice – Autumn rice, winter rice</li> <li>• Other cereals – Maize, ragi</li> </ul> <p><b>Rabi crops</b></p> <ul style="list-style-type: none"> <li>• Cereal – wheat</li> <li>• Pulses – Gram, arhar (tur), masoor</li> <li>• Oilseeds – rapeseed</li> <li>• Vegetables – potato, onion</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| • Odisha     | <p><b>Kharif crops</b></p> <ul style="list-style-type: none"> <li>• Rice – Autumn rice, winter rice</li> <li>• Other cereals – Jowar, Bajra, maize, ragi, small millets</li> <li>• Pulses – arhar (tur), urad, moong, horsegram, other Kharif pulses</li> <li>• Oil seeds – groundnut, sesamum, castor seed, niger seed, sunflower</li> <li>• Fibre – cotton, jute, mesta,</li> <li>• Spices – dry ginger</li> <li>• Vegetables</li> </ul> <p><b>Rabi crops</b></p> <ul style="list-style-type: none"> <li>• Cereal – wheat, maize, ragi</li> <li>• Pulses – Gram, urad, moong, masoor, horsegram, other Rabi pulses</li> <li>• Oilseeds – groundnut, sesamum, rapeseed, mustard, linseed, castor seed, safflower, niger seed, sunflower</li> <li>• Vegetables - potato</li> </ul> <p><b>Crops grown year round</b></p> <ul style="list-style-type: none"> <li>• Fibre – Sannhamp</li> <li>• Spices - dry chillies, turmeric, coriander, garlic, onion</li> <li>• Vegetables - potato, sweet potato</li> <li>• Others - sugarcane, tobacco</li> </ul> |

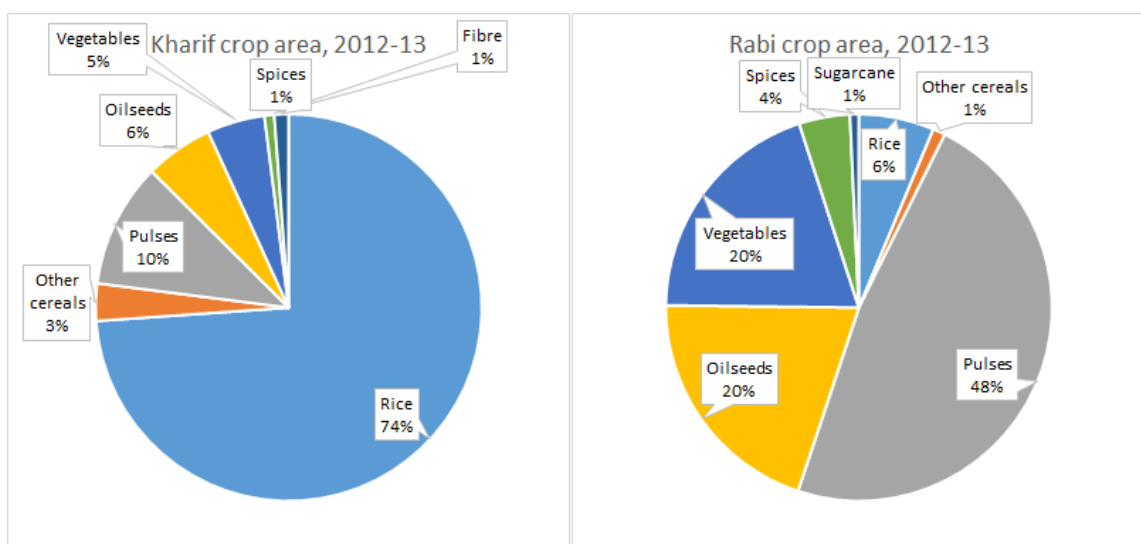
Rice is the predominant crop in the Basin in the Kharif season (Figure 2.1). The largest area (93%) is in the upper part of the Basin in the districts of Jharkhand and Chhattisgarh, and the smallest area is in the districts of Odisha (74%). Some other crops such as maize, small millets, pulses, and oilseeds are also grown in that season. Wheat, pulses and oilseeds are the dominant crops in the Rabi season in the districts representing the Basin. Summer or irrigated rice is grown only in Odisha (6%).



(a) Chhattisgarh



(b) Jharkhand



(c) Odisha

**Figure 2.1 Crops cultivated (%) in the districts of the Basin in Kharif and Rabi seasons for the last year of the available data**

The distribution of annual total crop area is given in Table 2.2. Rice dominates the total annual cultivated area in Jharkhand (87.7%) followed by Chhattisgarh (76.8%) and Odisha (53.2%).

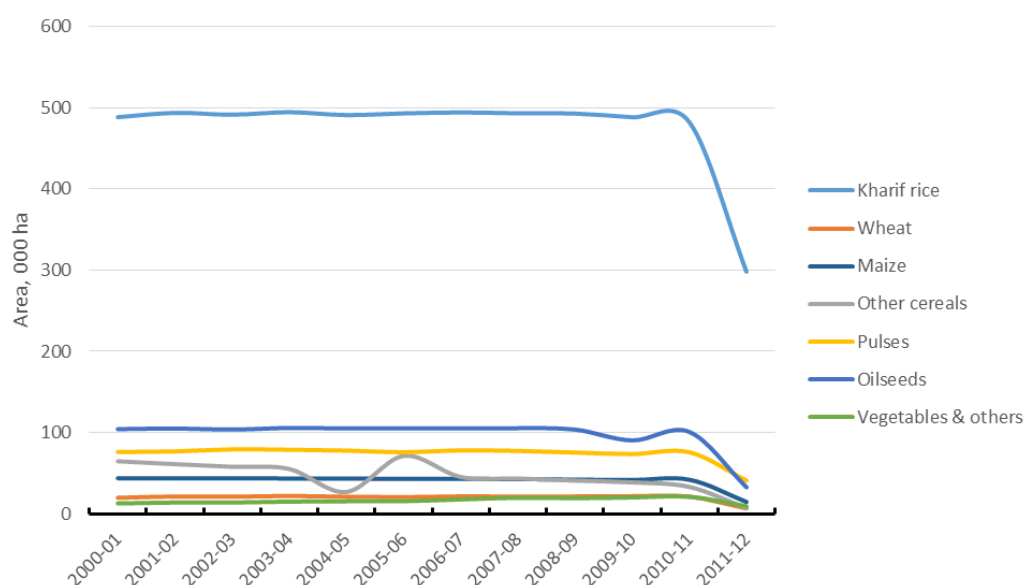
**Table 2.2 Annual cultivated area of different crops in the Basin districts**

| Crop               | Area, 000 ha |           |        | Area as % of total |           |        |
|--------------------|--------------|-----------|--------|--------------------|-----------|--------|
|                    | Chhattisgarh | Jharkhand | Odisha | Chhattisgarh       | Jharkhand | Odisha |
| Rice               | 298.1        | 523.5     | 1784.0 | 76.8%              | 87.7%     | 53.2%  |
| Wheat              | 6.7          | 9.0       | 0.9    | 1.7%               | 1.5%      | 0.0%   |
| Other cereals      | 0.2          | 39.8      | 82.4   | 0.0%               | 6.7%      | 2.5%   |
| Pulses             | 41.1         | 9.1       | 732.8  | 10.6%              | 1.5%      | 21.9%  |
| Oilseeds           | 32.7         | 1.5       | 338.7  | 8.4%               | 0.3%      | 10.1%  |
| Vegetable & others | 9.4          | 14.0      | 414.1  | 2.4%               | 2.3%      | 12.3%  |
| Total              | 388.2        | 596.9     | 3352.9 | 100%               | 100%      | 100%   |

## 2.2 Trend in cultivated area

This section reports the results of an analysis of cropping areas and crop types.

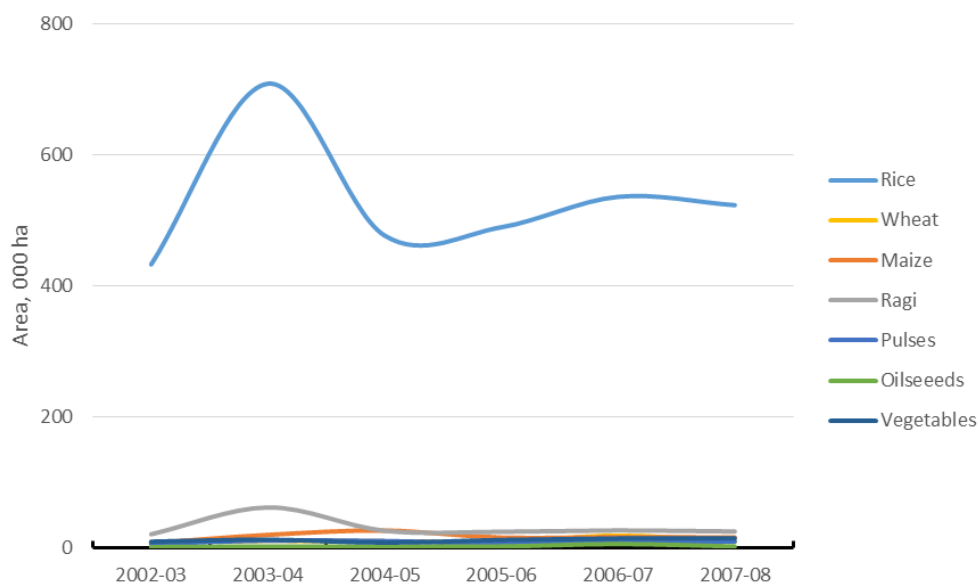
There is almost no change in cultivated area of the crops in the Basin districts of Chhattisgarh during the period of 2000–2011 (Figure 2.2). There was a sharp drop in the cultivated area of all crops in 2011–12 which could be related to rainfall patterns (late arrival and/or prolonged dry spells in the monsoon season) as the area is the rainfed mono crop region. The late arrival of rainfall would mean that farmers might not prepare the land in time to sow or transplant seeds. A long period of no rainfall (prolonged dry spell) within the growing season of the crops could result in a reduced harvest of crops across large areas. There could be other factors (e.g. natural disaster, severe insect/pest attacks) which might have caused serious damage to the crops, reducing the harvesting area.



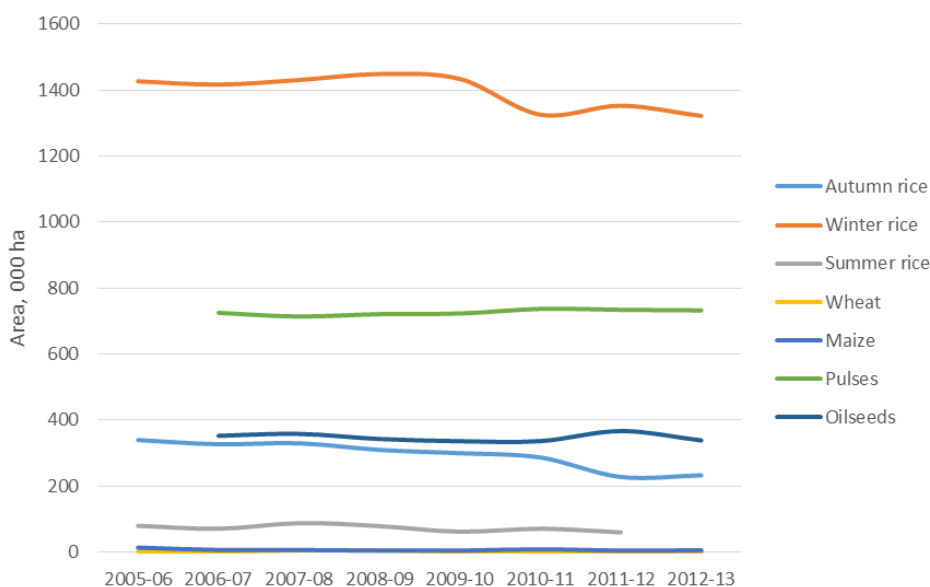
**Figure 2.2 Trend in cultivated area of different crops in the Basin districts of Chhattisgarh over the period 2000/01 to 2011/12**

The cultivated area of crops in the Basin districts of Jharkhand is constant across the years analysed, with Kharif rice being the exception (Figure 2.3). The cultivated area of rice peaked at over 700,000 ha in 2003/04 followed by a sharp drop in the following year. The area then gradually settled around 520,000 ha.

The trend in cultivated area in the Basin districts of Odisha between 2005 and 2013 is similar to that of Chhattisgarh and Jharkhand (Figure 2.4). The area of winter rice has gradually decreased from the peak of around 1.5 million ha in 2008/09 to 1.32 million ha in 2012/13. Autumn rice has also exhibited a downward trend. There is very little change in areas for the other crops over the same period.



**Figure 2.3** Trend in cultivated area of different crops in the Basin districts of Jharkhand



**Figure 2.4** Trend in cultivated area of different crops in the Basin districts of Odisha

## 2.3 Cropping intensity

Cropping intensity, usually expressed as percentage, is the ratio of 'total cropped area' in a year to 'net cropped area or physical area' of that year. As net cropped area was not available for the districts of Chhattisgarh and Jharkhand, cropping intensity for the districts of these states was estimated using Kharif cropped area as the 'net cropped area'. District-wise cropping intensity is available in the Statistical Yearbook for Odisha. Trends in cropping intensity are given in Figure 2.5. A Basin level map of cropping intensity for the latest data available for all the districts is shown in Figure 2.6.



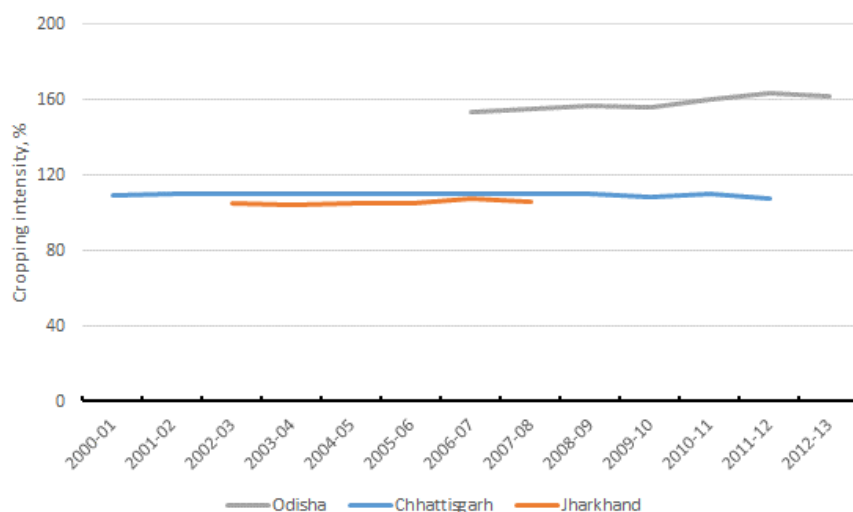


Figure 2.5 Trends in cropping intensity for the districts representing the Basin

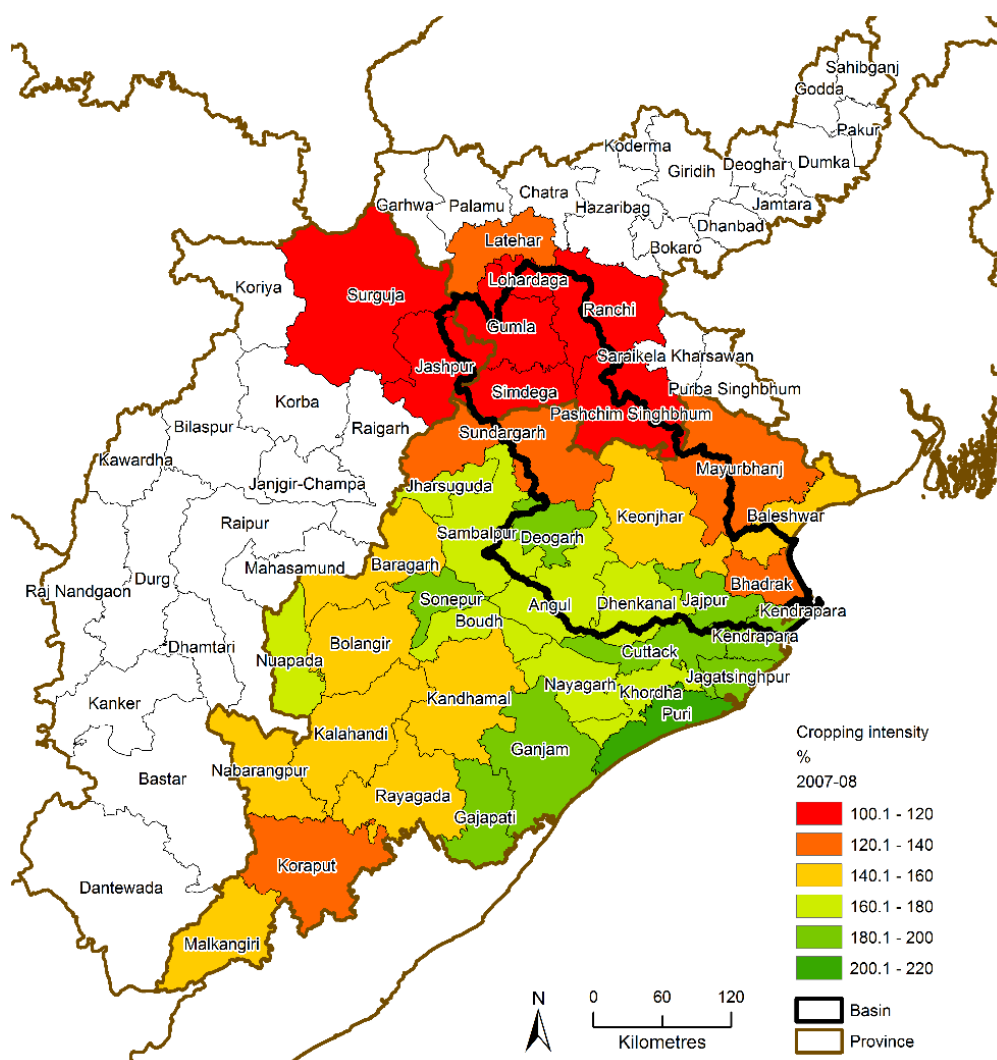


Figure 2.6 Cropping intensity at the district level at the Basin for 2007-08

Cropping intensity is much higher in the lower part of the Basin (Figure 2.5 and Figure 2.6). There is no change in cropping intensity in the upper parts of the Basin in Chhattisgarh (~110%) and Jharkhand (~105%) within the period data are available. This indicates that cultivation of Rabi crops is very limited in the states of Jharkhand and Chhattisgarh, with <10% of the total area cultivated in the Kharif season. In Odisha, this is higher with greater than 50% of the total area cultivated in the Kharif season.

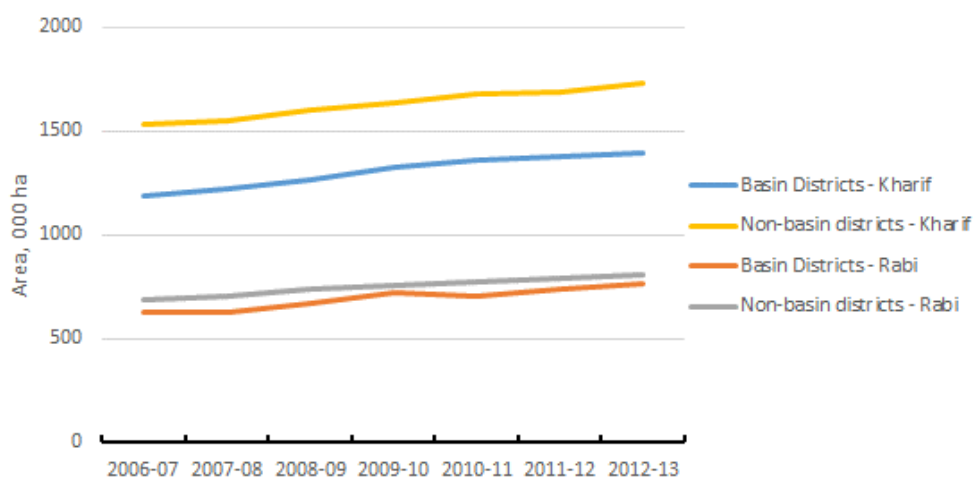
The current cropping intensity in Jharkhand for the whole state is reported as 116%<sup>7</sup>. State agriculture profile (DACD website)<sup>8</sup> of the Government of Jharkhand reported 12.73% of land as irrigated. It seems in recent years, crops are being grown in Rabi season in some areas using irrigation.

During the project team's visit to the field areas of Jharkhand in March 2015, irrigated wheat, onion and other vegetables were found in small patches of land where stored water is used for irrigation (Figure 2.7). It is likely that crops are currently being cultivated in the Rabi or summer season using irrigation resulting in an increase in cropping intensity as reported by DACD.



**Figure 2.7 Wheat and onion grown in Topra within the district of Ranchi of Jharkhand in the Rabi season using stored water for irrigation (photo taken on 23 March 2015)**

There is a steady increase in cropping intensity in the areas of the Basin in Odisha. Intensity has increased gradually from 153% in 2006-07 to 162% in 2012-13. The highest intensity within this period was 164% in 2011-12. The increase in intensity is mainly because of the expansion of the potential irrigation area in both the Kharif and Rabi season (Figure 2.8). The expansion is higher in the districts outside the Basin and current cropping intensity is also higher (e.g. above 200% in Puri district) in the districts outside the Basin (Figure 2.9).



**Figure 2.8 Trend in potential irrigation area created in Odisha**

<sup>7</sup> <<http://agri.jharkhand.gov.in/?ulink=dept/stateprofile.asp>>, accessed January 2016

<sup>8</sup> Department of Agriculture and Cane Development (DACD), <<http://agri.jharkhand.gov.in/?ulink=dept/stateprofile.asp>>

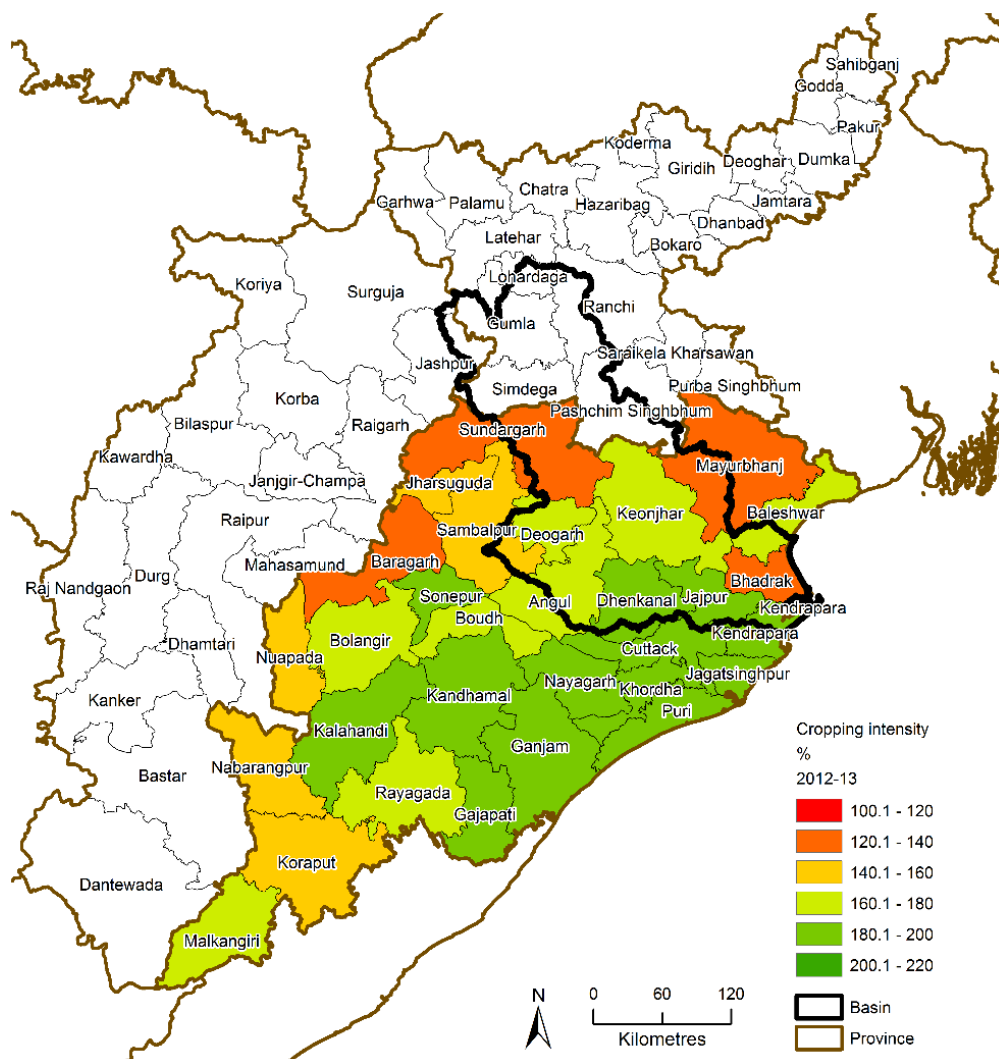


Figure 2.9 Cropping intensity in the districts of Odisha in 2012–13

## 3 Crop yield and production

### 3.1 Yield and production of rice at the State level

Odisha and Chhattisgarh were among the top five states of India in terms of cultivated area in 2010–11 (Figure 3.1). The cultivated areas in these two states were 9.9 and 8.6% of the total cultivated area of the country respectively. The cultivated area in Jharkhand was 1.7% of the total area. There was no growth in cultivated areas over the last 5 years (Figure 3.2); rather the total area has declined sharply in Jharkhand (from 1.6 million ha (Mha) in 2006–07 to 0.7 Mha in 2010–11) and slightly in Odisha (4.5 Mha to 4.2 Mha). The cultivated area in Chhattisgarh was stable over this period.

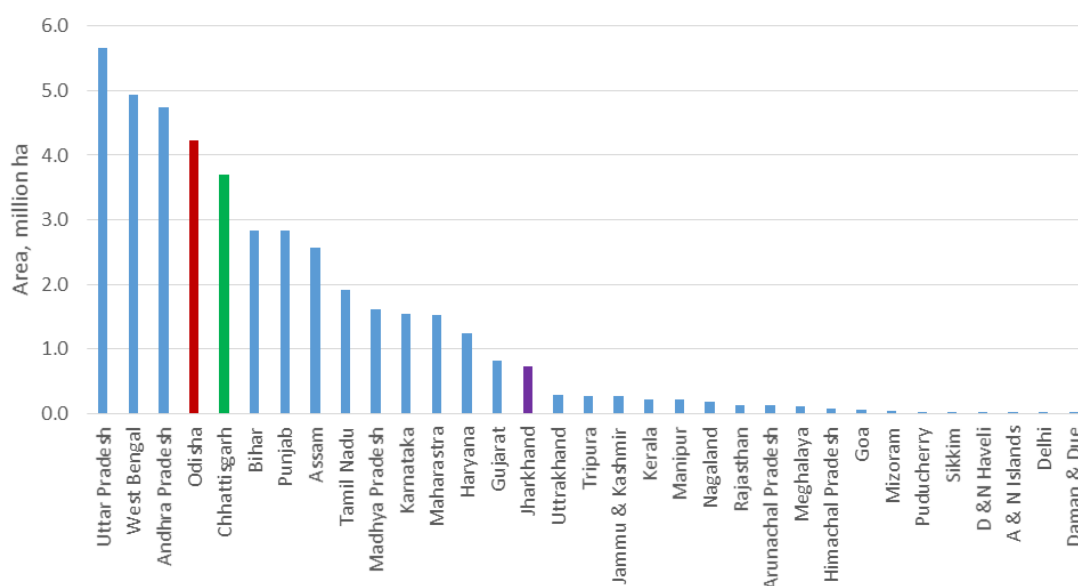


Figure 3.1 Cultivated area of rice in the states of India for 2010–11. The Basin states are highlighted

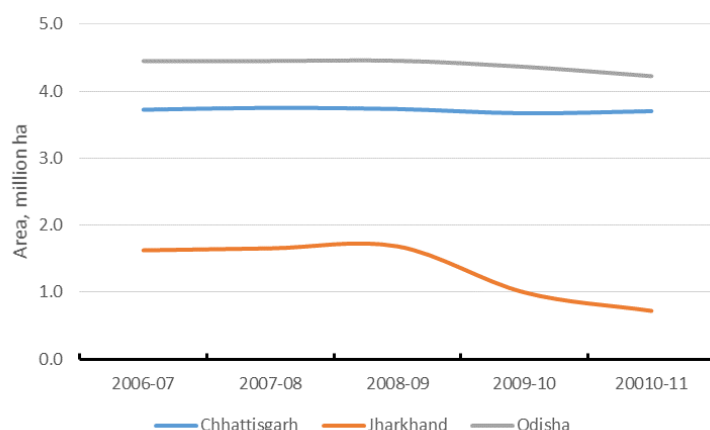
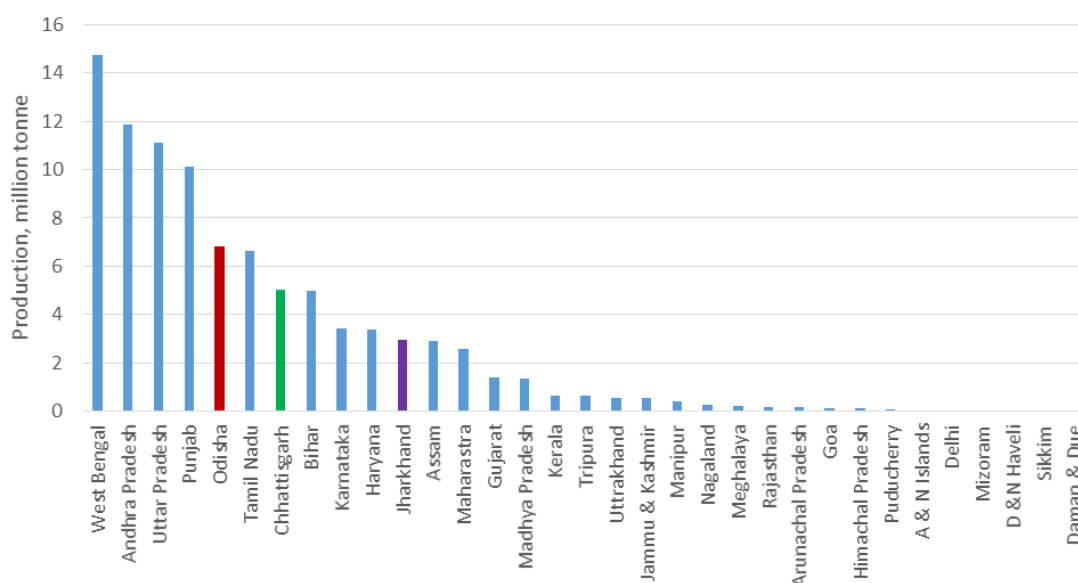


Figure 3.2 Trend in total cultivated area of rice in Chhattisgarh, Jharkhand, and Odisha

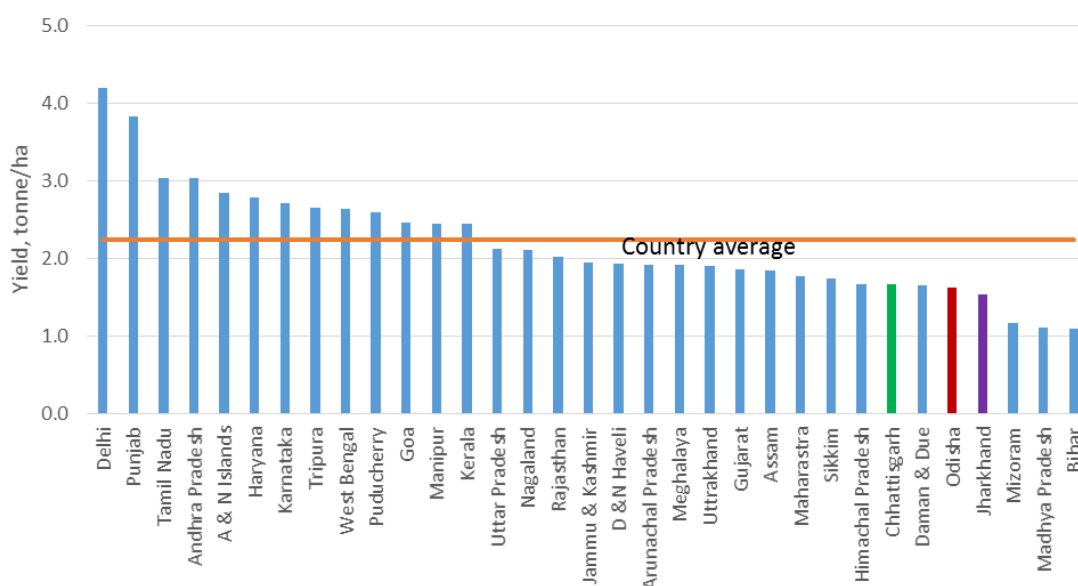
Chhattisgarh and Odisha produced 6.16 and 6.83 Million tonnes (MT) of rice in 2010–11, representing 6.4% and 7.1% of total production of India respectively (Figure 3.3). The production in Jharkhand was 1.1 MT (1.2%). The Basin districts of Chhattisgarh, Jharkhand, and Odisha covered 11.0% (2011–12), 43.7% (2007–

08), and 41.0% (2011–12) of the total rice area and produced 9.6%, 40.6%, and 49.2% of the total rice production of the states.



**Figure 3.3 Production of rice in the states of India for 2010–11. The Basin states are highlighted**

While in terms of cultivated area, the three Basin states are among the highest, in terms of average yield they are among the lowest (Figure 3.4) and significantly below the country average.



**Figure 3.4 Average yield of rice in the states of India for 2010–11**

The average yield in 2010–11 was 1.663, 1.541 and 1.616 tonne/ha respectively in Chhattisgarh, Jharkhand and Odisha compared to the country average of 2.24 tonne/ha. There are two main reasons:

1. The average yield of rice is the average of Kharif (rainfed) and summer/Rabi (irrigated) rice. In general, the yield of Rabi/irrigated rice is higher than Kharif rice (Figure 3.5 and Figure 3.6). So the average yield is higher in the states having higher irrigated rice area. There was no irrigated or summer rice in the states of Chhattisgarh and Jharkhand in 2010–11 (Figure 3.7). In Odisha, irrigated rice was only 7.45% of the Kharif rice area compared to the country average of 12.7%.

2. The yield of Kharif rice is also lower compared to the other states (Figure 3.5). The average yield of Kharif rice was 21.6, 27.3 and 28.5% lower respectively for Chhattisgarh, Jharkhand and Odisha in 2010–2011 compared to the country average yield of 2.12 tonne/ha.

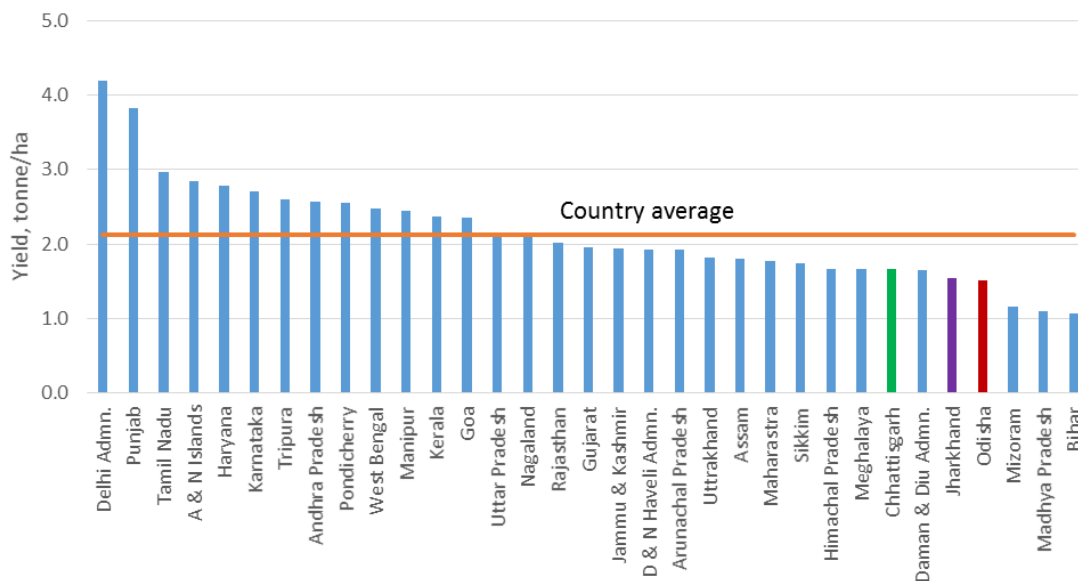


Figure 3.5 Average yield of Kharif/rainfed rice in the states of India for 2010-11

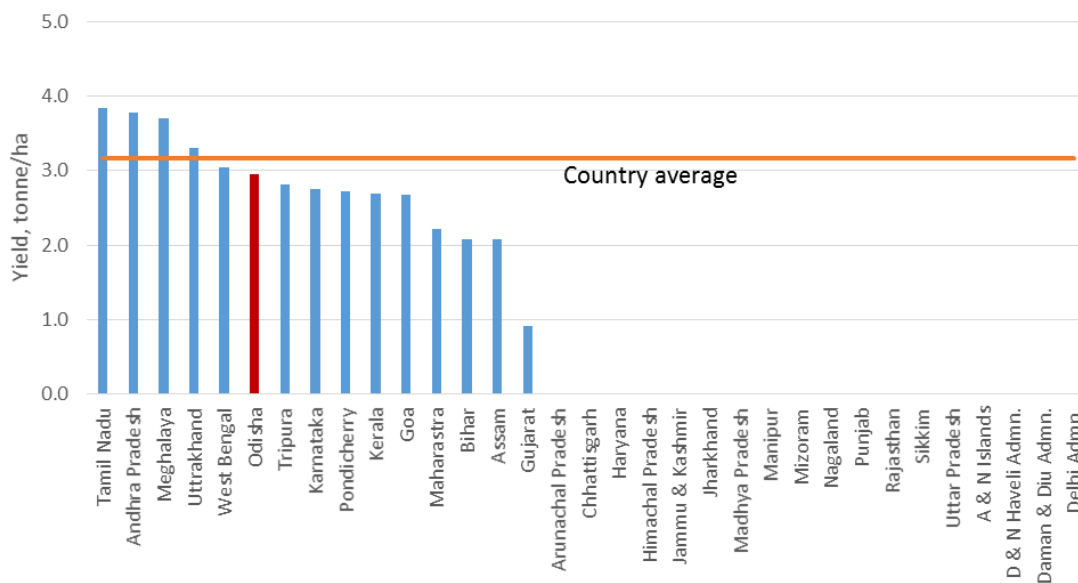
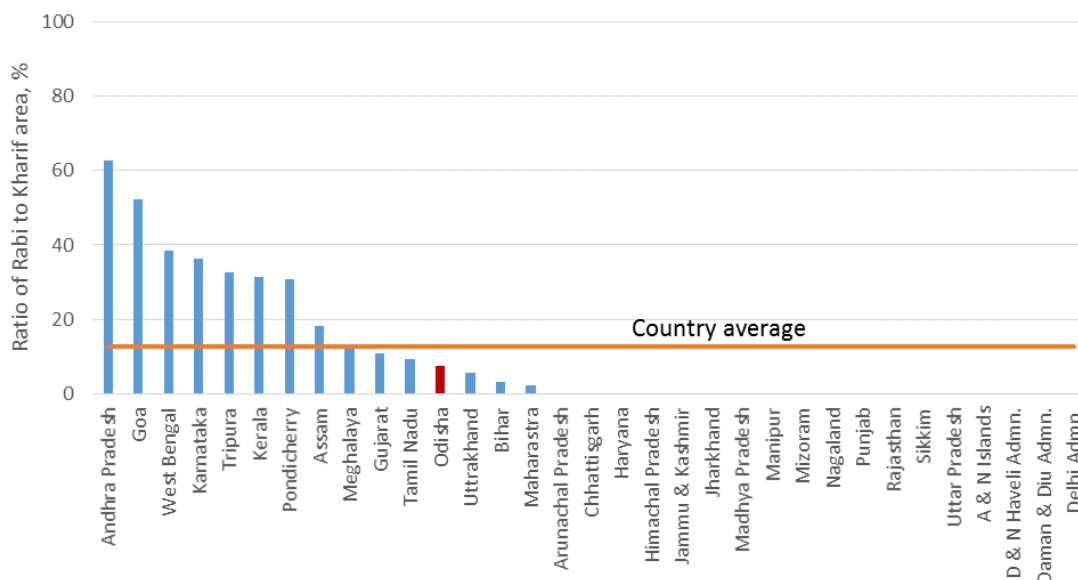
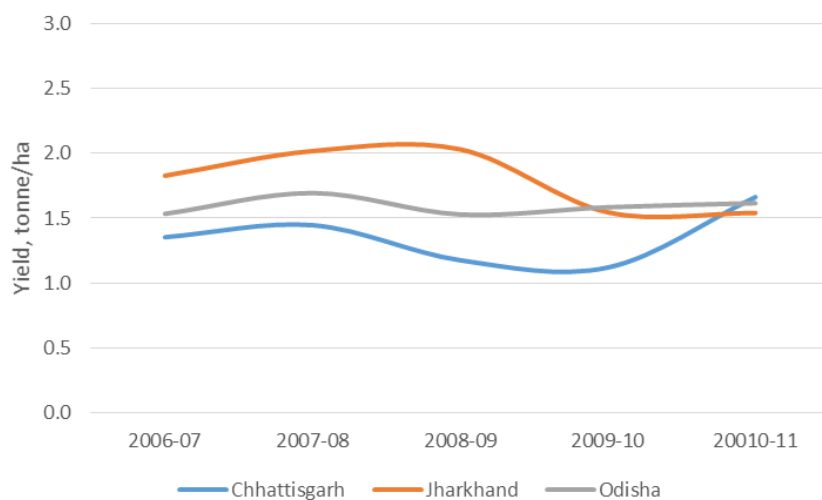


Figure 3.6 Average yield of Rabi/irrigated rice in the states of India for 2010–11

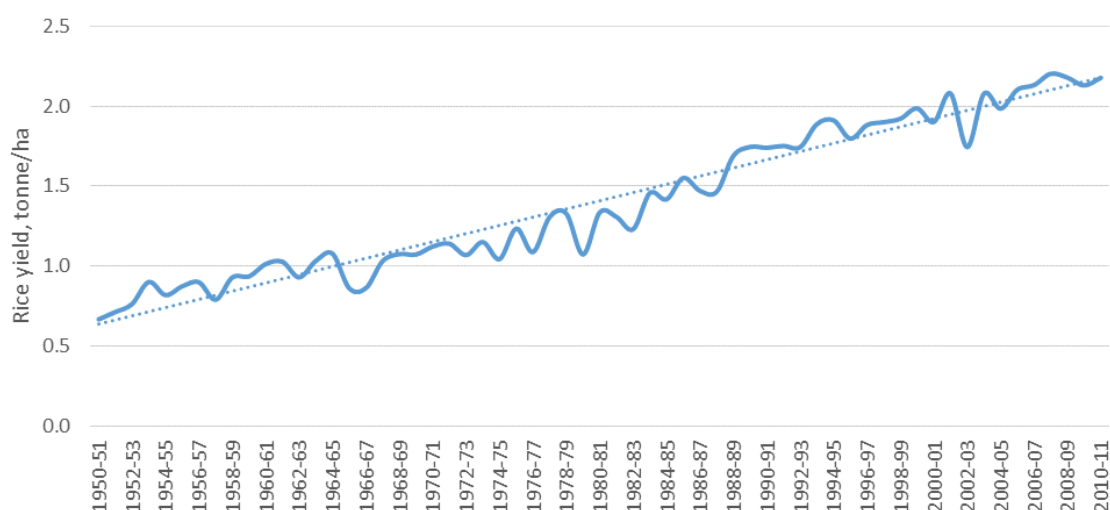


**Figure 3.7 Ratio of Rabi/summer rice area to the Kharif rice area in 2010–11**

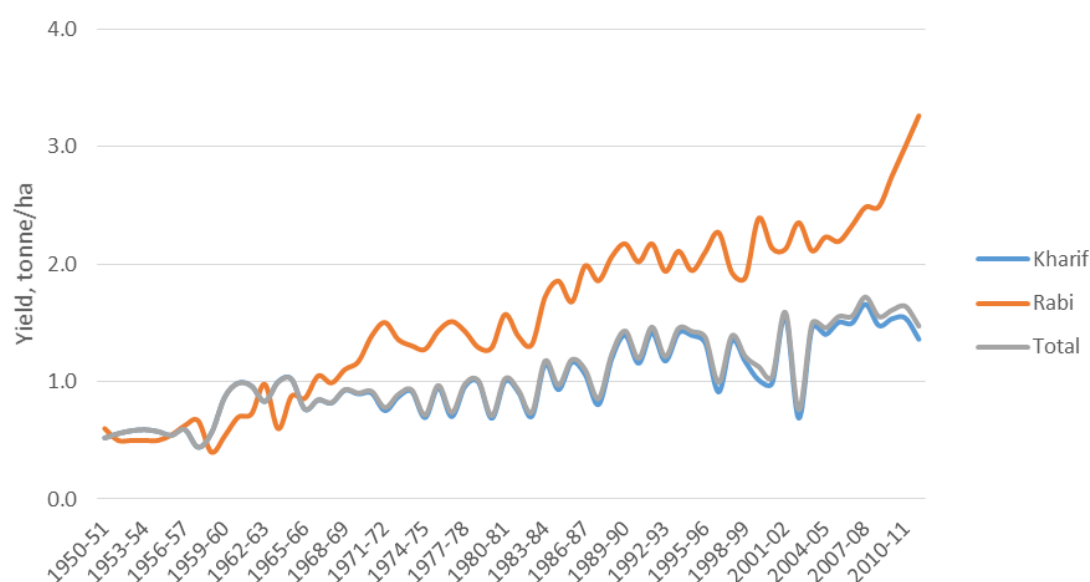
There is no particular trend in average yield of rice in the three states (Figure 3.8) during the period of 2006–07 to 2010–11 though there was steady growth in average yield at the country level (Figure 3.9). It should be noted here that the trend in state-level yield is for a very short period compared to the long-term trend available at the country level. However, long-term available data of yield of rice in Odisha shows the growth in yield (Figure 3.10) is slower compared to that at the country level. The trend in yield of Kharif rice is identical to that of total rice as shown in Figure 3.10. The growth in irrigated/Rabi rice is much higher in recent years.



**Figure 3.8 Trend in average yield of rice in the Basin states**



**Figure 3.9 Trend in average rice yield in India**



**Figure 3.10 Trend in average rice yield in Odisha**

## 3.2 Yield and production of rice at the district level

Rainfed winter rice covers about 83% and 73% of the total rice area and produces 85% and 79% of the total rice production in the Basin districts of Jharkhand and Odisha respectively (Table 3.1). Spatial variation of the yield of winter rice (for Chhattisgarh Kharif rice as no separate winter rice data are available) at the district level for 2007–08 is shown in Figure 3.11. This is the latest year for which the data for all three states are available. There is significant variation in yield among the districts. The spatial coefficients of variation (CV) in the average yield of the districts were 24%, 25%, and 18% respectively in Chhattisgarh, Jharkhand, and Odisha in 2007–08. The spatial CV varies from year to year. For Chhattisgarh, it varied from 10.1% to 37.6% during 2000 to 2012, for Jharkhand 25.0% to 55.0% during 2002 to 2008, and for Odisha 17.3% to 38.0% during 2005 to 2013.

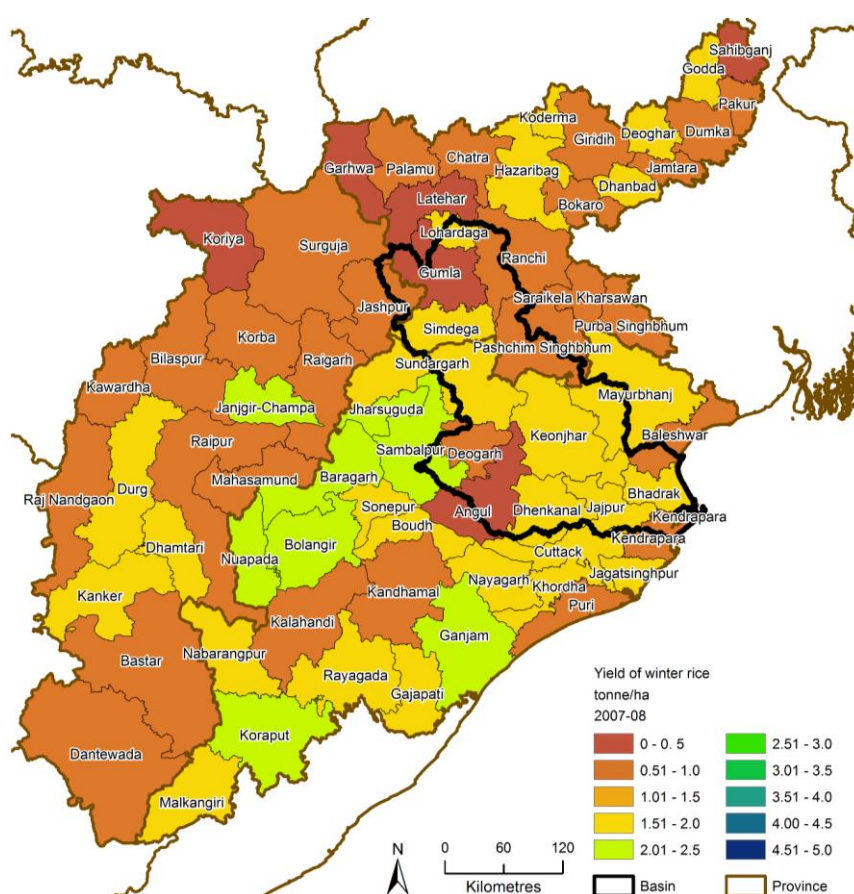


**Table 3.1 Contribution of different rice to the total within the Basin districts**

| Crop        | Area as % of total |                | Production as % of total |                |
|-------------|--------------------|----------------|--------------------------|----------------|
|             | Jharkhand 2007-08  | Odisha 2011-12 | Jharkhand 2007-08        | Odisha 2011-12 |
| Autumn rice | 26.7               | 13.9           | 21.2                     | 8.4            |
| Winter rice | 73.3               | 82.4           | 78.8                     | 85.2           |
| Summer rice |                    | 3.7            |                          | 6.4            |

Note: For the Basin districts of Chhattisgarh, according to the available data, 100% are Kharif rice

In general, the yield of winter rice is higher in the lower part of the Basin in the districts of Odisha compared to the upper part of the Basin in the districts of Chhattisgarh and Jharkhand. Among the districts of the states, the yield in the Basin districts of Chhattisgarh was lower (1.486 and 1.398 tonne/ha) compared to the average yield of the state (1.67 tonne/ha) in 2011-12. For Jharkhand, the average yield was higher than the state average (1.29 tonne/ha) in some Basin districts (e.g. Simdega, Lohardaga) while lower in some others (Gumla, Latehar) as shown in Figure 3.11. This is also true for Odisha: the average yield is higher than the state average (2.4 tonne/ha in 2012-13) in the districts of Bolangir, Sambalpur, Cuttack, Deogarh, Dhenkanal, and Sundargarh (Figure 3.12). The lowest yields are in the districts of Balasore followed by Keonjhar and Mayurbhanj. Comparing the two figures (Figure 3.11 and Figure 3.12), one can see the significant increase in yield in the districts of Odisha. There is no consistent temporal trend in yields within the Basin districts (Figure 3.13 to Figure 3.15). In the districts of Odisha though the yield in 2012-13 was significantly higher compared to the previous year.

**Figure 3.11 Spatial variation in yield of winter rice among the districts of three states**

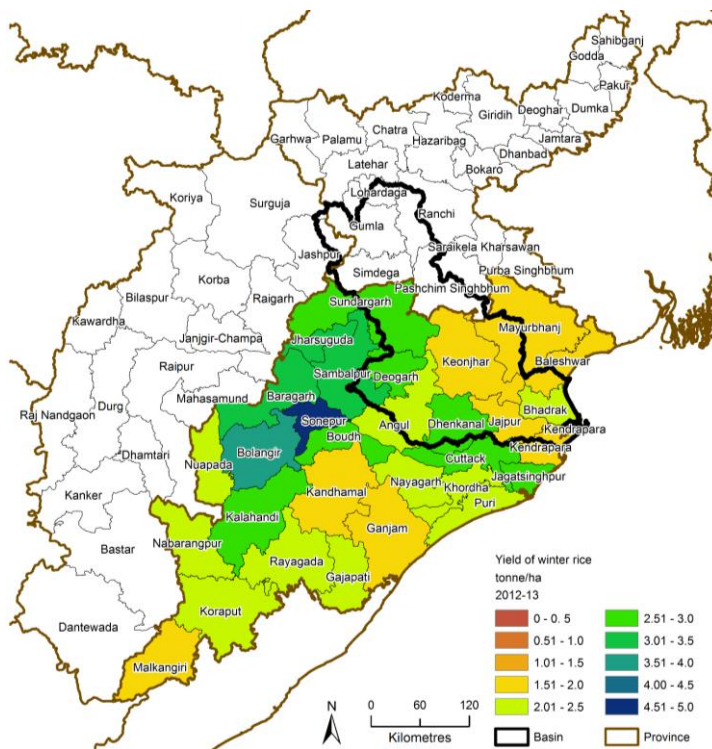


Figure 3.12 Spatial variation in the yield of winter rice in 2012-13 (replace this figure with 2011-12 map as the data of Chhattisgarh are also available for that year)

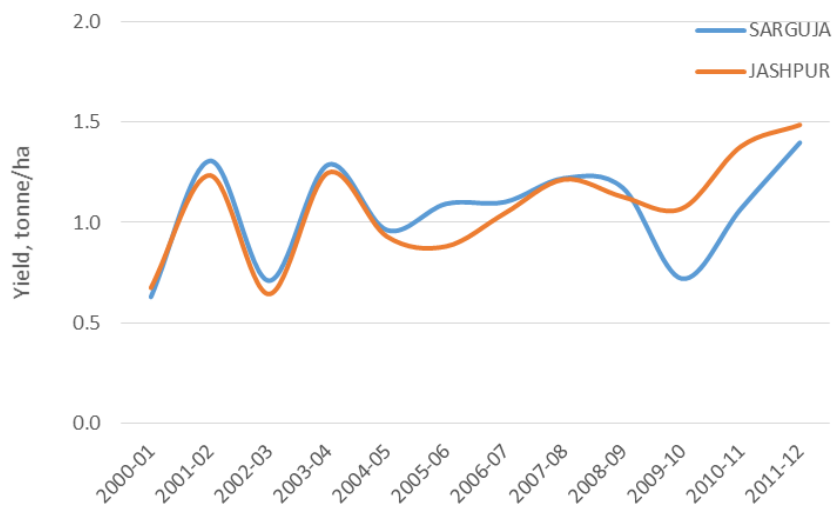


Figure 3.13 Trend in yield of Kharif rice in the Basin districts of Chhattisgarh

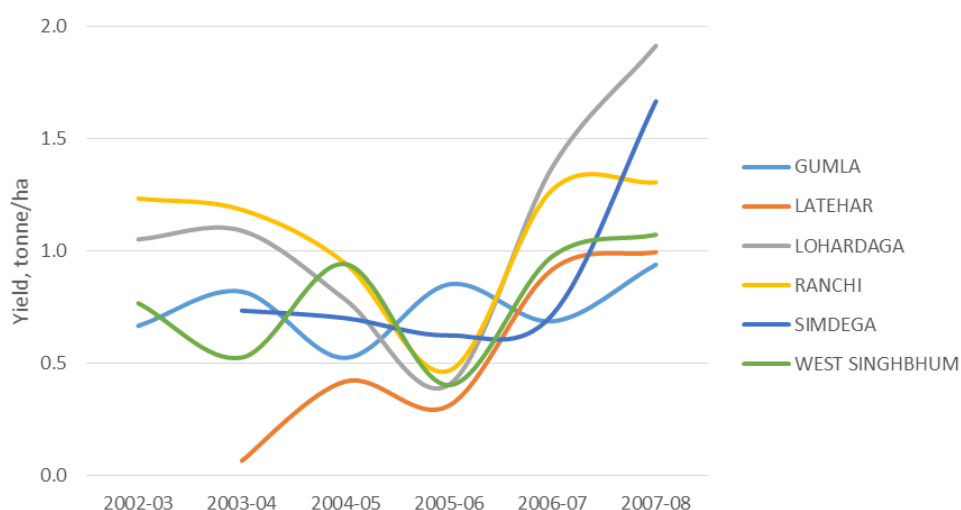


Figure 3.14 Trend in yield of winter rice in the Basin districts of Jharkhand

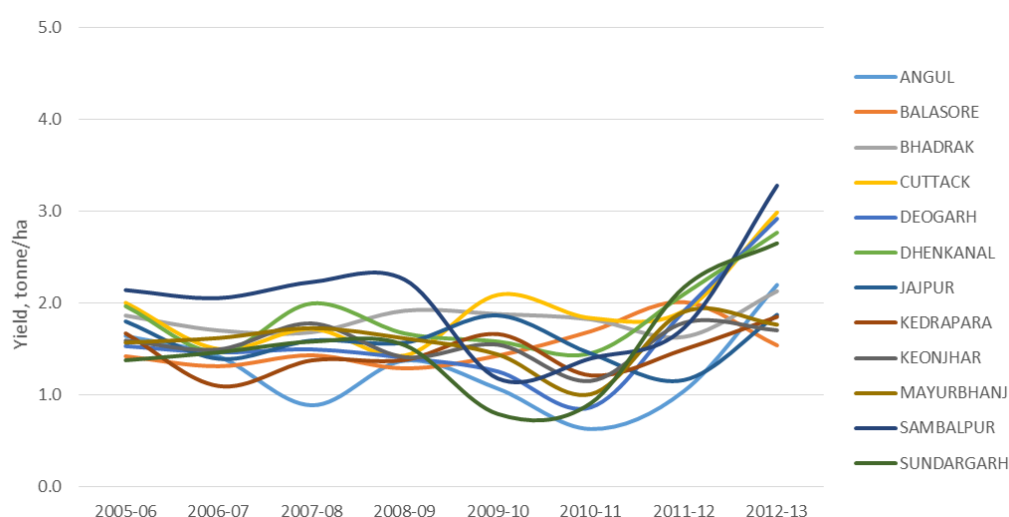


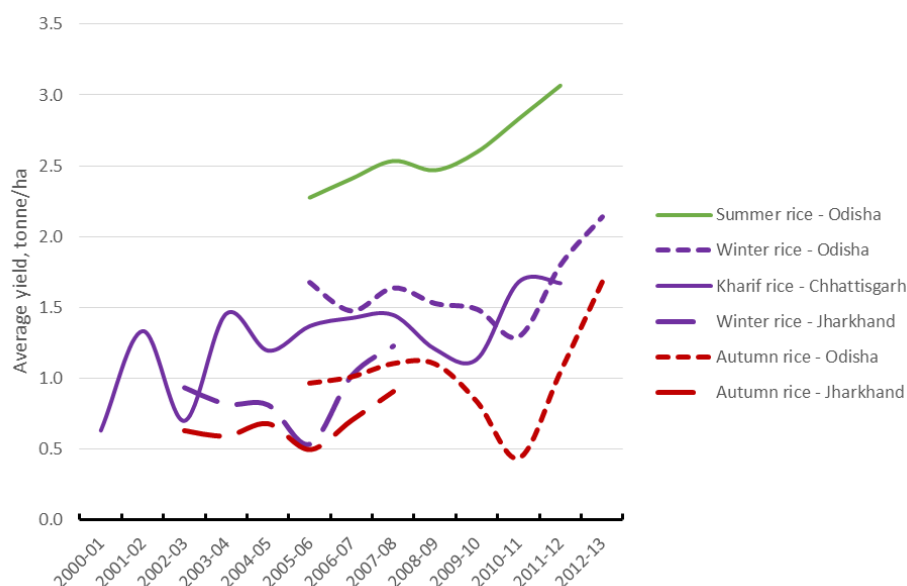
Figure 3.15 Trend in yield of winter rice in the Basin districts of Odisha

Data for autumn rice were available for Jharkhand and Odisha. More than three-quarters of autumn rice of the state of Jharkhand are grown within the Basin districts (Table 3.2). In Odisha this is about 42% of the state, equivalent to that of winter rice. The spatial variation in the average yield of the districts is similar to that of winter rice (the CV was 37.2% in 2007-08 in Jharkhand, and 29.8% in 2012-13 in Odisha). The temporal trend of the average yield for the districts are similar to that of winter rice. However, the average yield is, in general, lower than the winter rice (Figure 3.16).

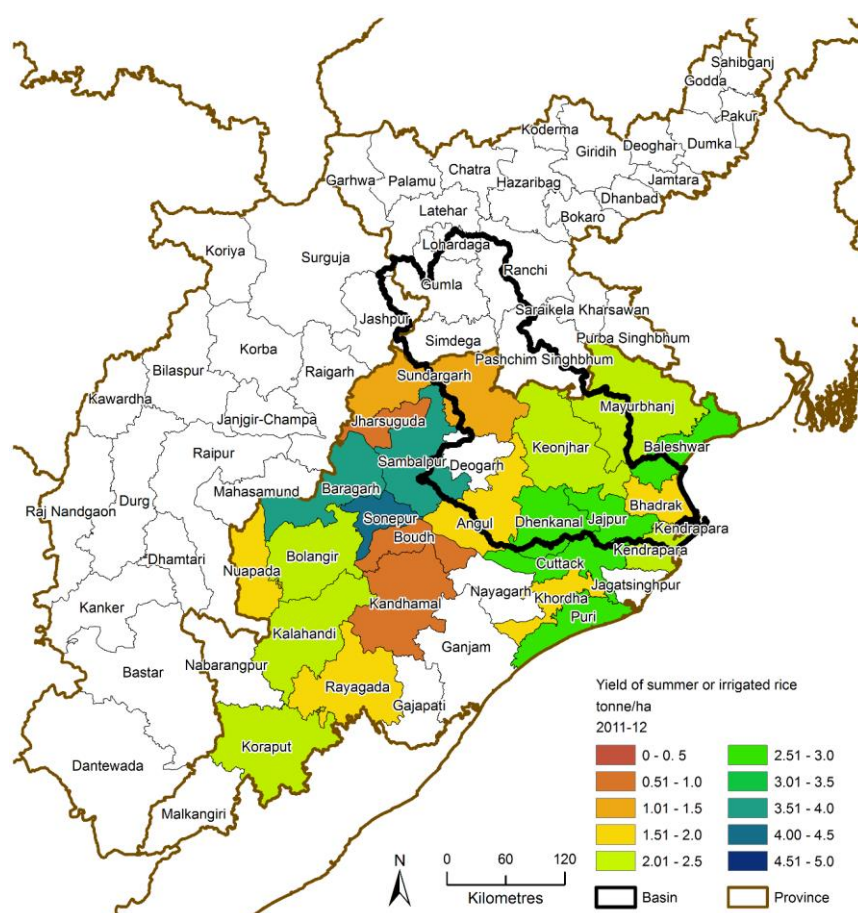
Table 3.2 Contribution of area and production of the Basin districts to the total of the states

| Crop              | Area as % of total of the state |                      |                    | Production as % of total the state |                      |                   |
|-------------------|---------------------------------|----------------------|--------------------|------------------------------------|----------------------|-------------------|
|                   | Chhattisgarh<br>2011-12         | Jharkhand<br>2007-08 | Odisha<br>2012-13* | Chhattisgarh<br>2011-12            | Jharkhand<br>2007-08 | Odisha<br>2012-13 |
| Autumn rice       |                                 | 76.3                 | 41.5               |                                    | 77.5                 | 40.4              |
| Winter rice       | 11.0                            | 37.8                 | 41.5               | 9.6                                | 36.0                 | 36.9              |
| Summer rice       |                                 |                      | 25.4               |                                    |                      | 24.4              |
| <b>Rice total</b> | <b>11.0</b>                     | <b>43.7</b>          | <b>41.0</b>        | <b>9.6</b>                         | <b>40.6</b>          | <b>49.2</b>       |
| Wheat             | 11.4                            | 11.9                 | 83.9               | 11.2                               | 12.5                 | 84.3              |
| Maize             | 24.2                            | 20.1                 | 6.3                | 21.2                               | 19.2                 | 3.8               |

\*Data for summer and total rice for Odisha are for 2011-12



**Figure 3.16 Average yield of autumn, winter and summer rice in the Basin districts of the states**



**Figure 3.17 Spatial variation in the yield of irrigated summer rice for 2011-12 in Odisha**

Rabi or summer rice is cultivated only in the districts of Odisha. Basin districts covered 25% of the total Rabi rice area of the state and produced 24% of the total irrigated rice production in 2011-12 (Table 3.2). Spatial variation in yield for 2011-12 is shown in Figure 3.17. The CV in the average yield of the districts is 37%. The average yield of the Basin districts has gradually increased over the years from 2.28 tonne/ha in 2005-06 to 3.07 tonne/ha in 2011-12 (Figure 3.16). However, there is fluctuation in yield at the districts levels over this period with a general increasing trend (Figure 3.18).

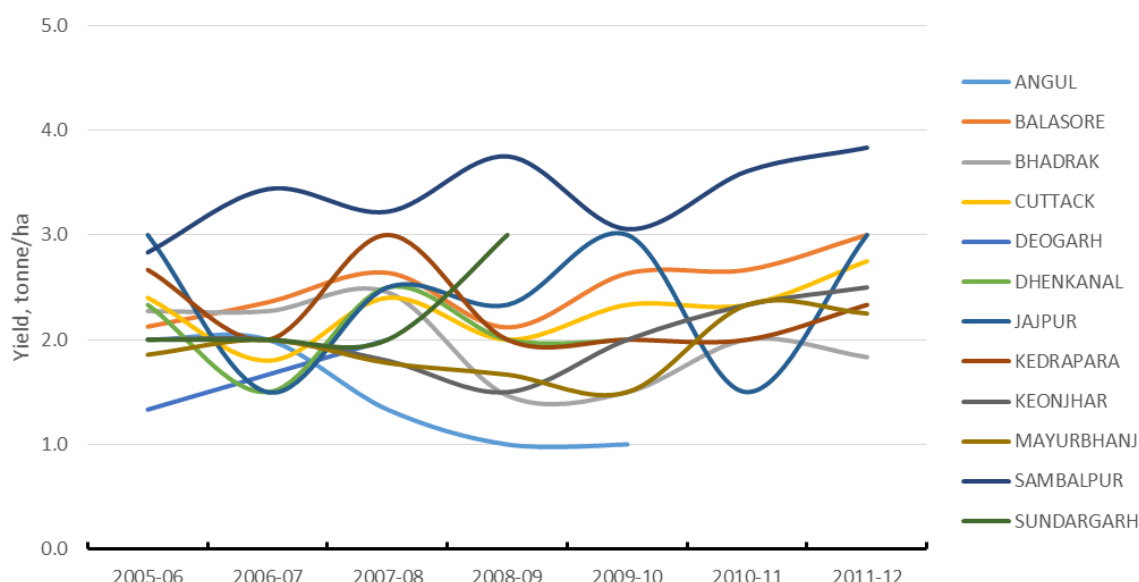


Figure 3.18 Trend in yield of summer/Rabi rice in the Basin districts of Odisha

### 3.3 Yield and production of non-rice crops

Many crops other than rice, such as wheat, maize, pulses, oilseeds, and vegetables, are grown in the Basin (Table 2.1). The trends in average yield of these crops for the Basin districts of the three states are shown in Figure 3.19 through to Figure 3.21. The yield of maize varies significantly from year to year in the Basin districts of Chhattisgarh while the yield of other crops remained almost steady over the same period (Figure 3.19). In Jharkhand, yield varies from year to year for all crops (Figure 3.20) with no increasing or decreasing trends. In Odisha there is significant increase in average yield of wheat and maize, particularly over the last few years (Figure 3.21). The yield of pulses and oil seeds have also gone up gradually over the years.

The average yields of wheat and maize for all India in 2012 were 3.18 and 2.56 tonne/ha respectively<sup>9</sup>. The yields of wheat and maize in the Basin districts of the states are much lower than the country average (in Chhattisgarh the respective yields are 1.31 and 2.27 tonne/ha, in Odisha 1.64 and 1.22 tonne/ha), but in some years (e.g. 2010–11), the yield of maize in the districts of Chhattisgarh (Figure 3.19) was higher than the country average. The average yields of wheat and maize in the districts of Jharkhand were 1.54 and 1.17 tonne/ha respectively in 2007–08 compared to the country average of 2.80 and 2.41 tonne/ha. The contribution of wheat and maize of the Basin districts to the total of the states is given in Table 3.2.

The mix of crops within pulses, oilseeds and vegetables varies from state to state and districts to districts. So it is difficult to compare the yield of these crops across the state or districts. Gram is the predominant crop among the pulses in the districts of all three states. The state average yields of gram in 2007–08 in Chhattisgarh, Jharkhand and Odisha were 0.874, 0.66 and 0.659 tonne/ha compared to the country average of 0.762 tonne/ha (Government of Odisha 2010).

Similar to rice, there is spatial variation in the average yield of these crops at the district level. For example, the variation in average yield of wheat for all the districts of the three states for 2010–11 is presented in Figure 3.22. Figure 3.23 shows the variation in the average yield of gram for the districts of Jharkhand for 2007–08.

<sup>9</sup> <[www.faostat.fao.org](http://www.faostat.fao.org)>

So, in general, productivity of almost all crops are significantly lower in the Basin compared to the country average. The productivity is, in general, higher in the lower part of the Basin in Odisha compared to the upper part of the Basin in Chhattisgarh and Jharkhand.

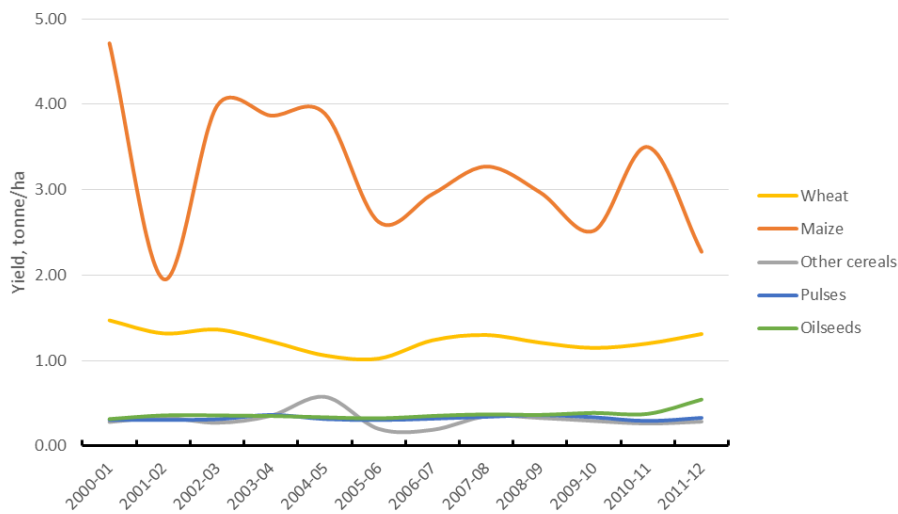


Figure 3.19 Average yield of different non-rice crops in the Basin districts of Chhattisgarh

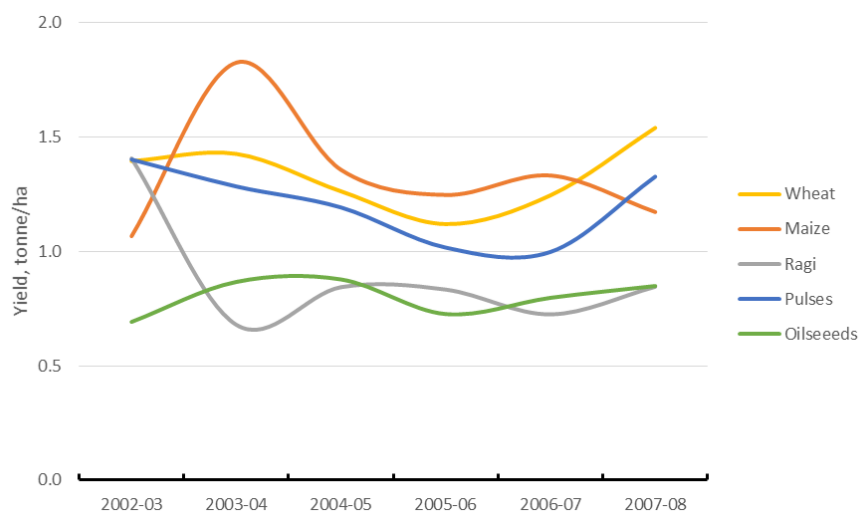


Figure 3.20 Average yield of different non-rice crops in the Basin districts of Jharkhand

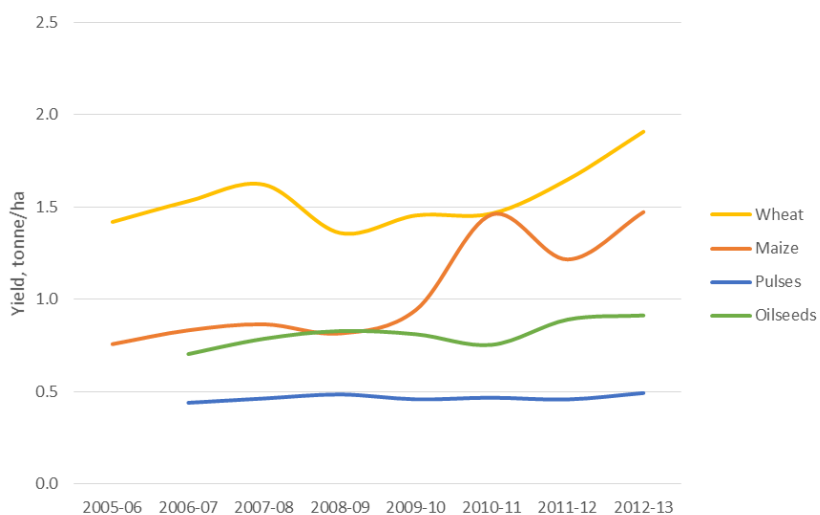


Figure 3.21 Average yield of different non-rice crops in the Basin districts of Odisha



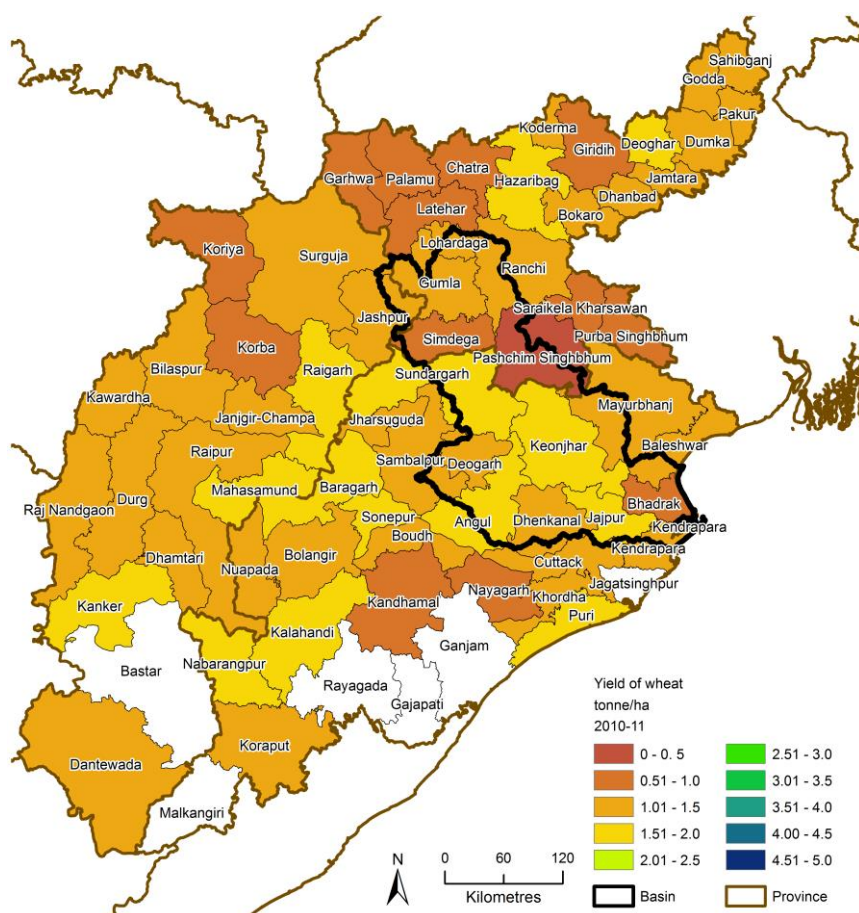


Figure 3.22 Spatial variation in the average yield of wheat for 2010-11

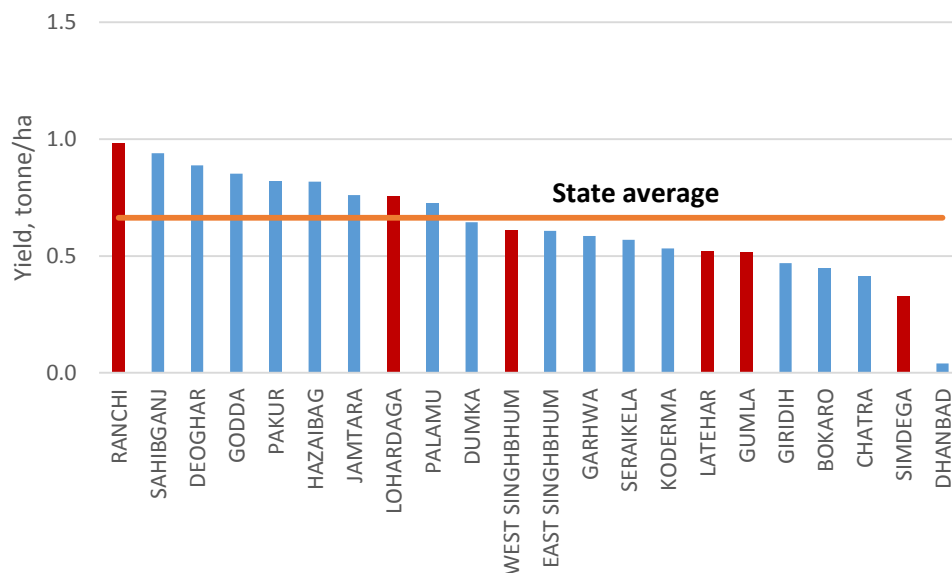


Figure 3.23 Average yield of gram at the districts of Jharkhand for 2007-08 (Basin districts are highlighted red)

## 4 Constraint and opportunities for productivity

In sections 2 and 3, we have presented a snapshot of the current state of agriculture and its productivity in the Basin. As we have found, the Basin is highly dominated by rainfed rice cultivation in the monsoon season, the yield of which is very low and highly variable from year to year. This is more prominent in the upper part of the Basin. In the Rabi/summer season, there is very little cultivation of crops in the upper part of the Basin, resulting in very low cropping intensity. The yield of non-rice crops is also low and highly variable. Although the average yields are higher in the lower part of the Basin than in the upper part of the Basin, these are still lower compared to the country average.

In this Chapter, we discuss the constraints and opportunities to improved productivity for the crops in the Basin.

### 4.1 Constraints

#### 4.1.1 Variation in rainfall

As outlined, the Basin's agriculture is dominated by rainfed cultivation. In the upper part of the Basin within the state of Jharkhand there is minimal irrigation. Consequently, agricultural productivity is highly dependent on rainfall<sup>10</sup>. Typically, the temporal and spatial distribution of rainfall and its unpredictability from year to year affects rice yields (Panigrahi et al. 2007). Even with the high concentrations of rainfall during the monsoon/rainy season (June–September), rainfed rice in most of the years suffers from in-season drought and consequent loss of yield (Panigrahi et al. 2007, Pandey et al. 2006).

Rainfall data for the stations within the Basin are available for 2000 to 2012<sup>11</sup>. Annual rainfall for three stations, Chhendipada, Keonjhar, and Nuagaon, are shown in Figure 4.1. Chhendipada represents the lower part of the Brahmani Basin or western part of the lower Brahmani-Baitarni Basin, Keonjhar represents the eastern part of the lower Basin, and Nuagaon represents the upper part of the Basin in Jharkhand (see Figure 1.1). As shown in the Figure 4.1, the annual rainfall is highly variable from year to year. For an average year (at 50% probability of exceedance), the annual expected rainfall for these three stations is within the range of 1200–1300 mm (Figure 4.2).

More than 80% (for Nuagaon 91%) of the annual rainfall falls within four months (June–September) of the year (Figure 4.3). Agricultural production is naturally variable given this unstable and somewhat erratic rainfall. Thus a primary reason for the variation in yields is the variation in rainfall during the cropping season.

Monsoon rainfall in the upper part of the Basin is more concentrated within the months of June to September (91%). Compared to the other two stations which are located within the Basin areas of Odisha, pre-monsoon (May) and post-monsoon (October) rainfall is very low. Even the rainfall on the onset of the monsoon season (June) is low compared to the other two stations. This will significantly impact the yield of winter/Kharif rice. Moreover, due to low rainfall in June, farmers may be unable to prepare fields for transplanting seedlings at the right time. During our field visit to, and discussion with the farmers in, a village in the districts of Ranchi (Jharkhand), farmers expressed the belief that the duration of the rainy

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<sup>10</sup> <[http://www.jharkhand.gov.in/web/guest/agriculture\\_about\\_the\\_dept](http://www.jharkhand.gov.in/web/guest/agriculture_about_the_dept)>

<sup>11</sup> Data obtained from the Central Water Commission



season is decreasing, which is affecting the yield of rice and cultivation of other crops. They also mentioned in-seasonal drought in the rainy season which kills crops.

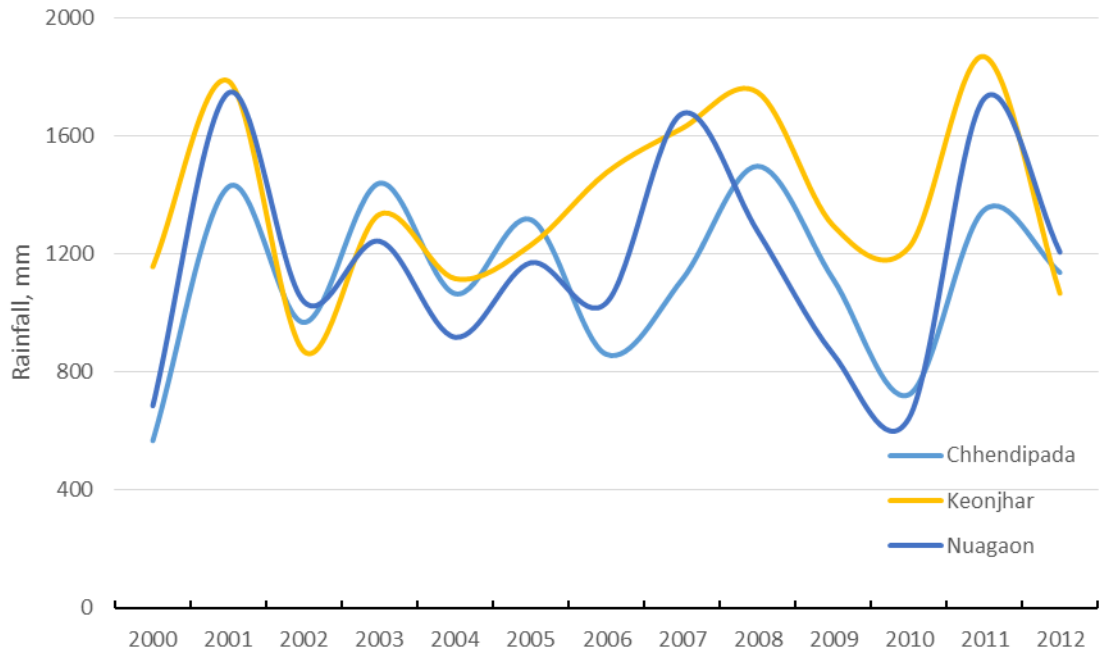


Figure 4.1 Annual rainfall at the three selected rainfall stations within the Basin

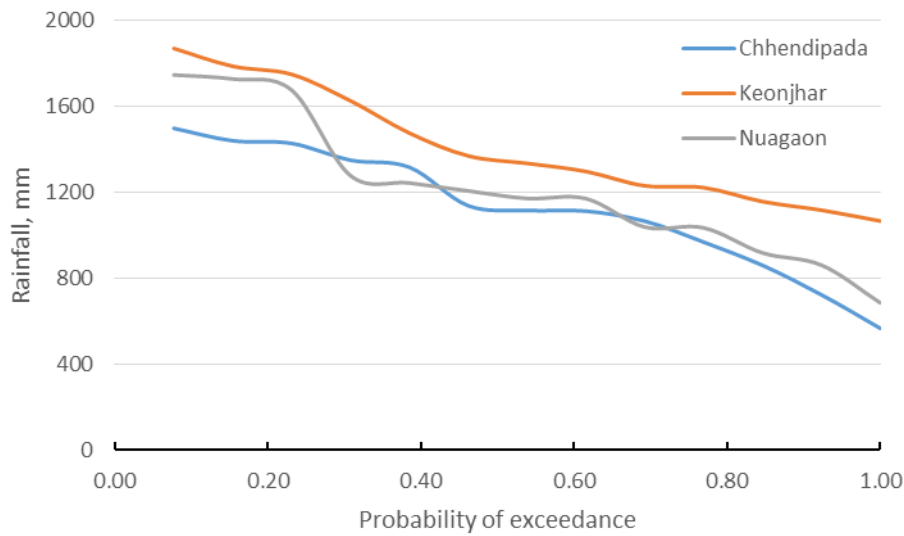


Figure 4.2 Probability of exceedance of the annual rainfall at the three selected rainfall stations (2000-2012)

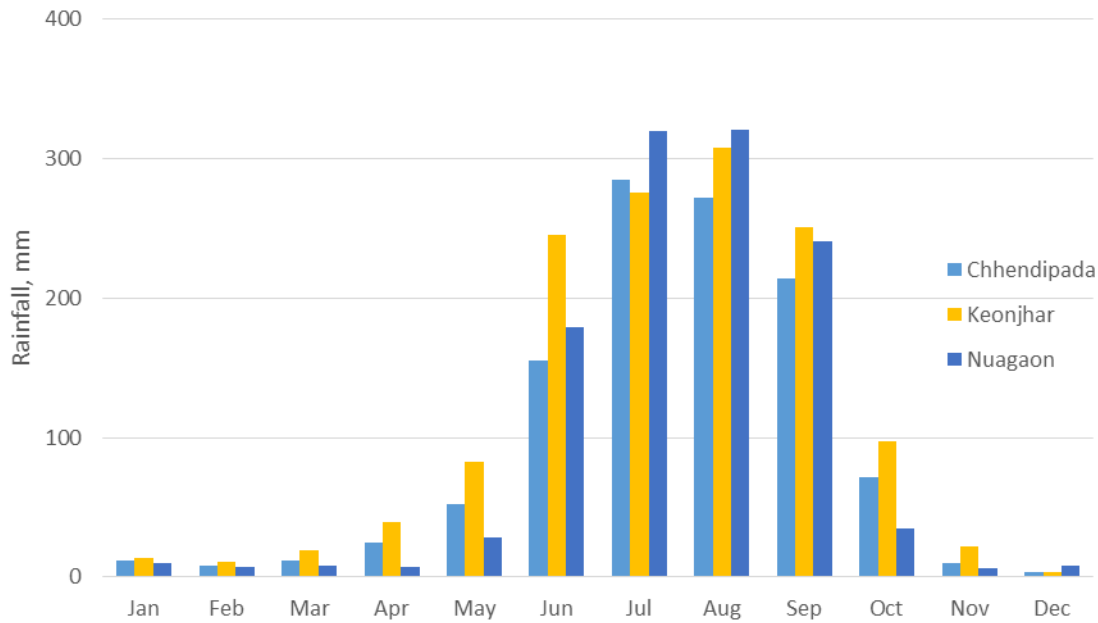


Figure 4.3 Monthly average rainfall at the three selected rainfall stations

#### 4.1.2 Analysis of variation in rainfall on rice yields

To understand the impact of rainfall on rice yield, we have simulated the water balance in a typical rice field in the upper part of the Basin considering the rainfall and evapotranspiration (ET) of the Nuagaon station. The daily water balance, expressed in terms of depletion at the end of the day is (Allen et al. 1998):

$$D_{r,i} = D_{r,i-1} - (P - RO)_i - I_i - CR_i + ET_{c,i} + DP_i \quad (4.1)$$

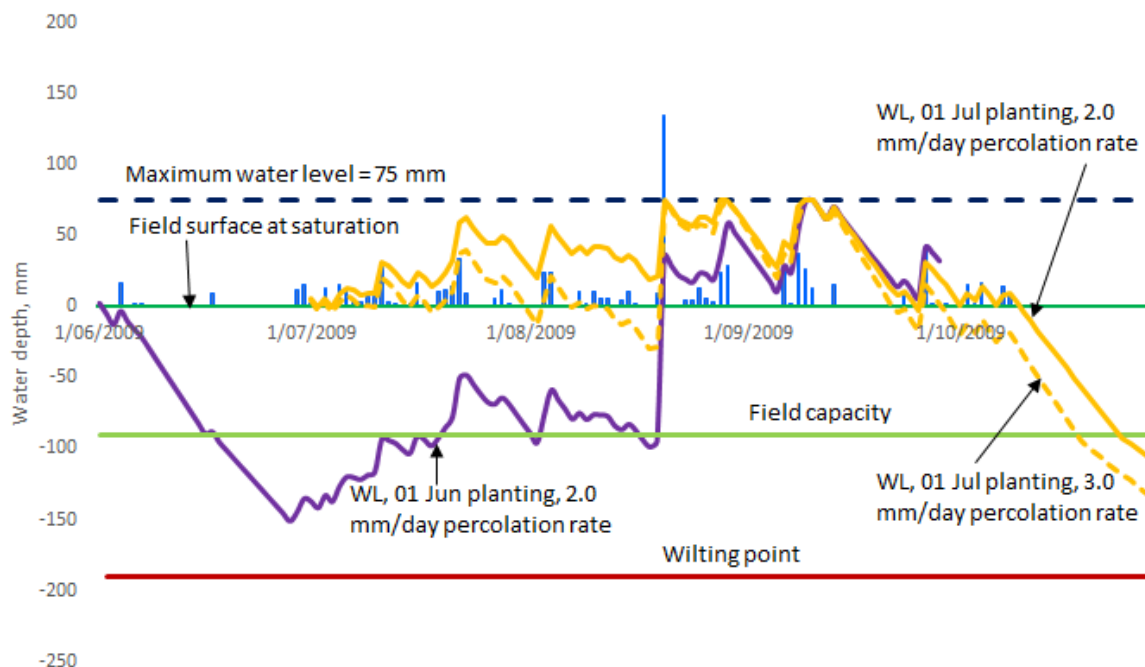
where,

- $D_{r,i}$  ponding water level at the end of the day  $i$  (mm),
- $D_{r,i-1}$  ponding water level at the end of the previous day,  $i - 1$  (mm),
- $P_i$  precipitation on day  $i$  (mm),
- $RO_i$  runoff from the soil surface on day  $i$  (mm),
- $I_i$  net irrigation depth or requirements on day  $i$  (mm),
- $CR_i$  capillary rise (for non-rice crops, for rice usually there is no capillary rise) from the groundwater table on day  $i$  (mm),
- $ET_{c,i}$  crop evapotranspiration on day  $i$  (mm),
- $DP_i$  water loss out of the root zone by deep percolation on day  $i$  (mm).

The cropping period (transplanting to harvest) is considered as 120 days and the percolation rate is 2.00 mm/day. The bund height of the field is considered as 75 mm (Cornish et al. 2015a). The data considered here are similar to the field data collected by Cornish et al. (2015a) in West Singhbhum (State of Jharkhand).

Figure 4.4 shows the daily water surface profiles for two transplanting dates of rice: 1 June (purple line) and 1 July (solid yellow line) in 2009. These timeframes represent two possible decisions by farmers. If the farmers transplant in June, there will be no standing water at the initial period (purple line is below the green saturation line). For some period in late June, water level in the field goes below the field capacity due to no rainfall during the last half of June. This is likely to have a significant impact on yield. Rainfall events in July increase the water levels in the field but the water level remains below saturation level and

very near to the field capacity until close to the end of August. While this may not have direct impact on the plant growth, due to lack of standing water, there could be a lot of weed growth in the field affecting the overall development of the crop and ultimately affecting yield (particularly if weeds are unmanaged). If the farmers delay the rice transplant until the beginning of July, the crop will suffer water stress (yellow line is going below the field capacity) due to low rainfall in October. Despite this, the impact on yield for the July planting could be much lower than the June planting.



**Figure 4.4** Water balance of a rice field, assuming rice is rainfed only (Nuagaon). The blue bar shows the daily rainfall and the purple line shows water depth in the field for transplanting on 1 June and the solid yellow shows the water depth in the field for transplanting on 1 July; both with percolation rate of 2.0 mm/day. Dotted yellow line shows the water depth in the field for transplanting on 1 July with 3.0 mm/day percolation rate.

A farmer's decision of transplanting time is characterised by uncertainty and risk. Planting early in the season after a good rainfall may be followed by a long period of little rainfall (Figure 4.4), whilst planting later in the season has also some risk, such there may not be enough rainfall for the crop at the end.

In the simulation used here, the percolation rate is considered at 2mm/day which is low. Soils are not uniform from field to field and there is high variation in soil parameters. In many fields the percolation rate could be much higher. In a field where the percolation rate is higher, let's say 3.0 mm/day (as considered by Cornish et al. 2015a), the water level will fall below saturation during the middle of the season (broken yellow line in Figure 4.4) and for a longer duration at the end stage of the crop even for 1 July transplanting. The impact of this could be higher on yield compared to the yield for plots at 2mm/day percolation rate.

Comparatively higher rainfall in May, June and October in the lower part of the Basin (Chhendipada and Keonjhar) could be one of the reasons for higher yield of winter rice in the districts of Odisha. Moreover, this could also help growing Rabi crops following the harvest of winter rice using the residual soil moisture.

Variability in rainfall is a key risk for production and is the principal source of fluctuations in global food production, particularly in semi-arid tropical countries of the developing world (Aggarwal et al. 2010, Balaghi et al. 2010). In-seasonal water stress or drought due to high variability in rainfall (prolonged non-rainfall period) is considered to be one of the primary factors of low yield of rainfed rice in south and southeast Asia (Mainuddin et al. 2015, Mainuddin et al. 2013, Pandey et al. 2012, Mainuddin et al. 2011, Roy et al. 2009, Aggarwal et al. 2008, Jensen et al. 1993, Islam and Mondal 1992). Due to the risk of crop

losses from in-seasonal water stress or drought, farmers often choose not to cultivate high yielding varieties, and limit the use of fertilizer, pesticides, and herbicides thus affecting crop yields even further.

### 4.1.3 Lack of irrigation facilities

Supplementary irrigation is recognized as the key to prevent in-seasonal drought and to increase the productivity of rainfed crops. This is particularly practised for rice in many Asian countries (Mainuddin et al. 2015, Mainuddin et al. 2013, Mainuddin et al. 2011, Arora 2006, Jensen et al., 1993, Mondal et al. 1992, Pandey et al. 2006, Panigrahi et al. 2007). For the summer/Rabi season, irrigation is essential to successfully grow crops. To provide an estimate of the requirement of irrigation water and its variation with the different planting and sowing date of the crops, we have estimated irrigation requirements of the major crops grown in the Basin using the data of the three rainfall stations described in 4.1.1.

Here, we used a soil water balance (SWB) simulation model similar to the FAO (Food and Agricultural Organization) crop coefficient-based CROPWAT 8.0 model<sup>12</sup>. The model gives identical results under the same conditions. The basis of the crop coefficient approach is described in Allen et al. (1998) and Doorenbos and Kassam (1979). The net irrigation requirements of the crops are calculated using the field water balances in terms of depth of water as described by Equation 4.1<sup>13</sup>. We used point rainfall data of the stations and the evapotranspiration (ET) data taken from the surfaces used in rainfall-runoff modelling (Pollino et al. 2016) (estimation of reference evapotranspiration, ETo, was not possible due to unavailability of climatic data). The detailed description of the model can be found in Mainuddin et al. (2014, 2015).

The range of date of transplanting and sowing, and crop duration are taken from the Statistical Yearbook of Odisha (Table 4.1). The crop coefficient of the different growth stages and the length of growth stages (Table 4.1) are taken from Nayak (2006) and from the FAO Irrigation and Drainage Paper 56 (Allen et al. 1998). We have used five different planting or sowing dates 15 days apart for the crops considered. Gram and mustard are considered as the representative crops for pulses and oilseeds respectively.

**Table 4.1 Crop parameters used in the soil water balance simulation model**

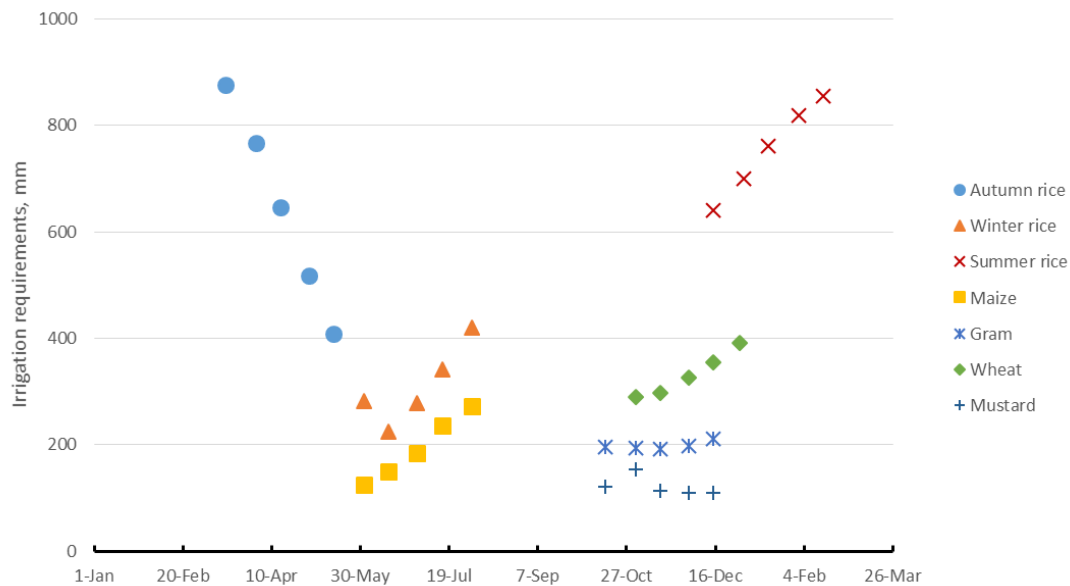
| Crop        | Initial planting/sowing date | Crop duration (days) | Crop coefficient |            |      |
|-------------|------------------------------|----------------------|------------------|------------|------|
|             |                              |                      | Initial stage    | Mid-season | End  |
| Autumn rice | 15 Mar                       | 120                  | 1.15             | 1.19       | 1.02 |
| Winter rice | 01 Jun                       | 120                  | 1.15             | 1.19       | 1.02 |
| Summer rice | 15 Dec                       | 100                  | 1.15             | 1.19       | 1.02 |
| Maize       | 01 Jun                       | 125                  | 0.40             | 1.20       | 0.60 |
| Wheat       | 01 Nov                       | 120                  | 0.40             | 1.15       | 0.40 |
| Gram        | 15 Oct                       | 100                  | 0.40             | 1.00       | 0.35 |
| Mustard     | 15 Oct                       | 60                   | 0.35             | 1.05       | 0.25 |

For rice, the maximum ponding water depth and seepage and percolation rate are considered as 100 mm and 2.0 mm/day, respectively. For the non-rice crops, standard soil parameters for clay loam soil are used.

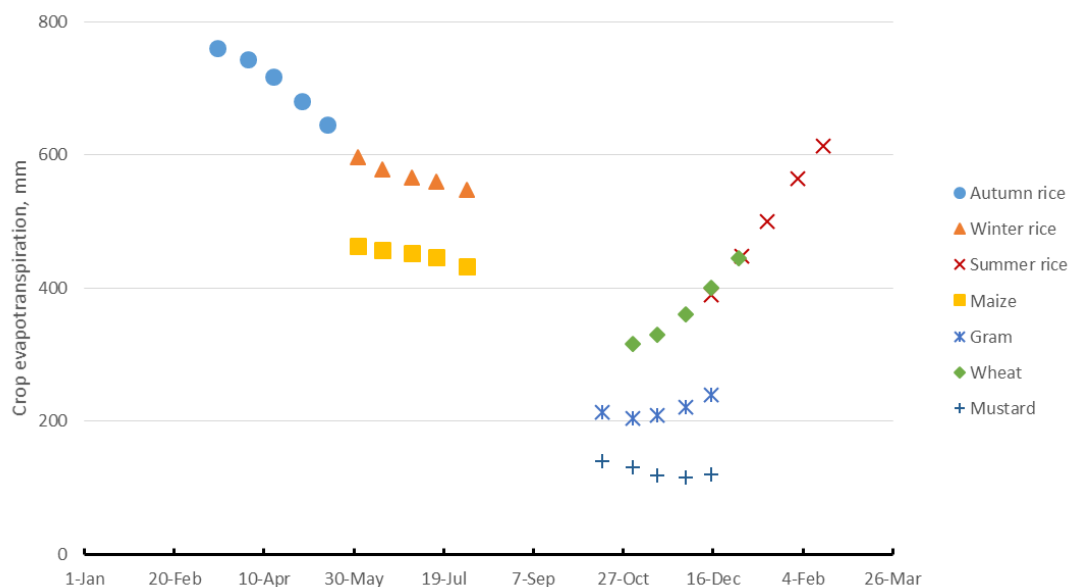
<sup>12</sup> <[http://www.fao.org/nr/water/infores\\_databases\\_cropwat.html](http://www.fao.org/nr/water/infores_databases_cropwat.html)>

<sup>13</sup> The model described in Section 4.1.2 and in this section are based on the same water balance equation. The SWB model described in this Section to estimate irrigation requirements of different crops can consider any number of crops (both rice and non-rice) and can provide range of outputs for a range of irrigation management conditions. The one used in Section 4.1.2 is developed using the same principle to simulate the water balance in the rice field only.

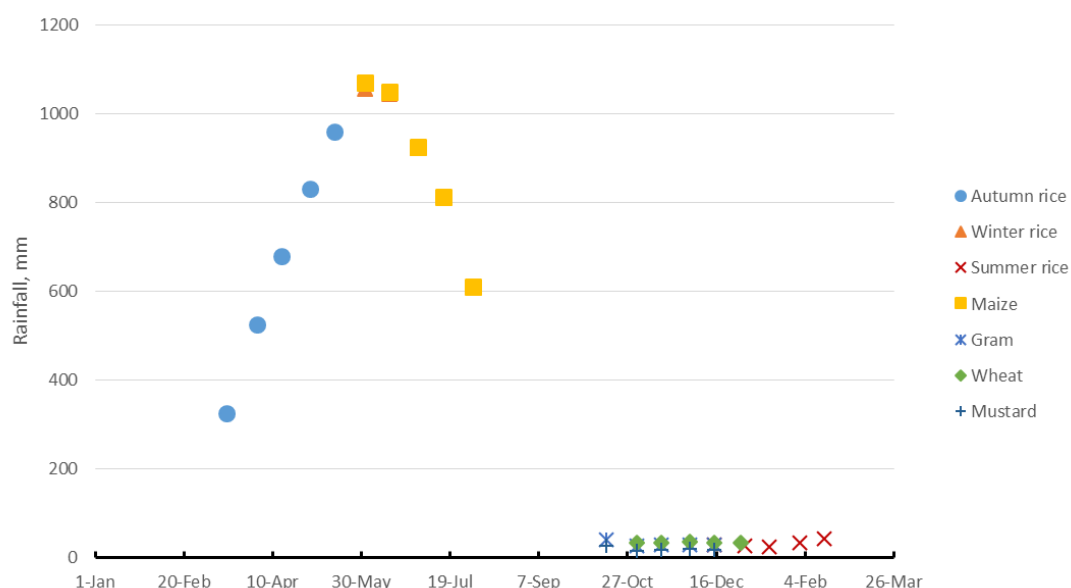
The seasonal irrigation requirements of the selected crops at different planting and sowing dates are given in Figure 4.5 for the station of Nuagaon. Irrigation requirements of autumn rice decreases (from 876 mm to 409 mm) sharply with later transplanting dates, due to lower ET (Figure 4.6) and higher rainfall (Figure 4.7). The delay in decisions for transplanting may have a knock on affect, impacting the timely transplanting of main Kharif or winter rice.



**Figure 4.5 Irrigation requirements of different crops in the upper part of the Basin at different planting and sowing dates**



**Figure 4.6 Crop evapotranspiration of different crops in the upper part of the Basin at different planting and sowing dates**



**Figure 4.7 Rainfall during the cropping period of different crops in the upper part of the Basin at different planting and sowing dates**

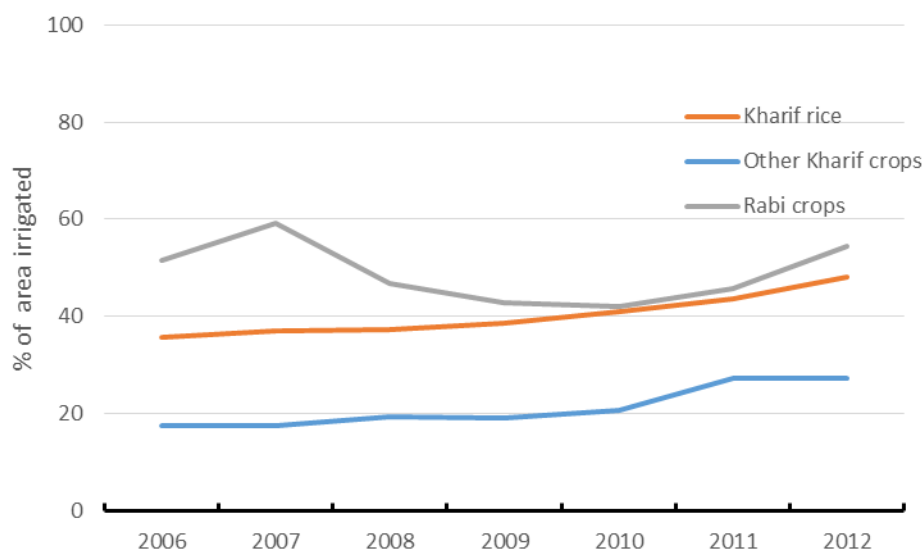
The irrigation requirements of winter rice (225 mm) are the lowest if they are planted in the first half of June, because of the maximum rainfall available during the cropping period (Figure 4.7). Though ET decreases with later crop planting, the rainfall decreases further, resulting in increased supplementary irrigation water. A later (at and post the second half of June) transplanting of rice will not only increase the irrigation requirements of rice, but will also increase the irrigation requirements of the following Rabi season crops as there will be very low residual soil moisture (Figure 4.4). This is also true for Kharif maize.

Irrigation requirements of wheat and summer rice (Figure 4.5) increases with the shifting of planting/sowing date forward from the initial planting/sowing due to increase in crop evapotranspiration (Figure 4.6). However, there is not much variation in the irrigation requirements due to different planting dates of the gram and mustard representing pulses and oilseeds (Figure 4.5). However, it would be good to sow them as soon as possible after the harvest of winter rice to utilize the residual soil moisture in the field and the availability of some rainfall in November.

The variation in irrigation requirements, crop evapotranspiration, and rainfall during the growing period for different planting/sowing dates are similar for the other two sites (Chhendipada and Keonjhar). However, the amount varies slightly. For example, the supplementary irrigation requirement of winter rice varies from 269 to 446 mm in Chhendipada, 209 to 361 mm in Keonjhar, and 225 to 420 mm in Nuagaon.

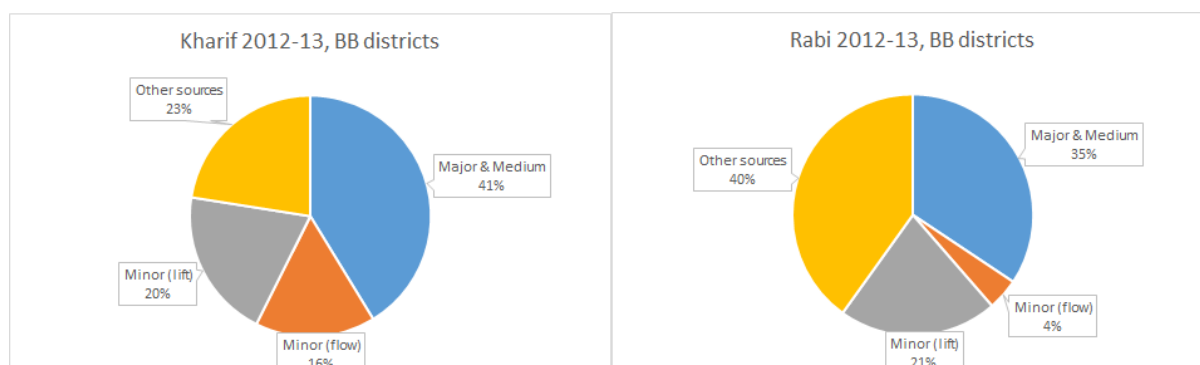
Supplementary irrigation in the Kharif season, particularly for rice, and irrigation for all crops in the Rabi season is the key to improving agricultural productivity in the Basin. While other factors (such as good crop varieties, quality seeds, application of fertilizer and pesticides, inter-cultural management, etc.) are also important for improving productivity, the success and efficiency of these inputs are dependent on the quantity, quality and timely availability of water (Panigrahi et al. 2007).

Available data (as discussed in Section 2) for the districts of Chhattisgarh and Jharkhand (upper part of the Basin) show no areas of irrigation. However, some Rabi crops are grown by applying irrigation water as shown in Figure 2.7. In the lower part of the Basin, irrigation is provided to the crops both in the Kharif and Rabi season (Figure 4.8). The cultivated area under irrigation is increasing for both the Kharif and Rabi seasons. This could be the primary reason for increases in yield and less variability in the yield of crops in the districts of Odisha.



**Figure 4.8 Percentage of cultivated area irrigated in the districts of Odisha**

The sources of irrigation for the Basin districts of Odisha for 2012-13 are shown in Figure 4.9, where most of the water is from surface water sources. It is unclear what 'other sources' means in the data. There is no data on whether groundwater is used for irrigation or whether they are included in the other sources. However, it seems groundwater is being used for irrigation in the lower part of the Basin (Schmid et al. 2016). Schmid et al. (2016) reported declining trend of groundwater level due to pumping in some areas in the lower part of the Basin (Dhenkanal, Jajapur, Mayurbhanj districts).



**Figure 4.9 Source of irrigation in the Basin districts of Odisha for Kharif and Rabi season of 2012-13**

#### 4.1.4 Cultivation of local rice varieties and low input use

Due to significant risk of yield loss due to water stress, it is common that farmers grow local rice varieties instead of high-yielding varieties (HYV) as local varieties are comparatively more tolerant to water stress than the HYV rice. Yields of local varieties are lower than the yield of HYV, however, growing local varieties ensures some yield at the end as varieties are adapted to local environments. This may not be the case with the HYV. In addition, there may be low use of fertilizer, pesticides, and cultural management as additional investment may not be profitable for the farmers with marginal increment (if any) with yield. Type of soil and fertility condition (such as organic matters in the soil) is also a determining condition for good yield.

#### 4.1.5 Lack of knowledge on modern technologies

There is a lack of knowledge of modern agricultural technologies in the region of Jharkhand. Available evidence suggests that farmers are not aware of the Department of Agriculture and its activities. Based on information provided by the farmers of the area we have visited, farmers have no knowledge of agricultural

extension by any government departments. It is important that farmers are aware of the recent technology for increasing agricultural productivity, access to good seeds and other inputs (such as fertilizer, pesticides, etc.), and access to good production technologies, so that they can learn and apply to improve productivity.

## 4.2 Opportunities for improving agriculture productivity

### 4.2.1 Irrigation development

From the discussion above it is clear that agricultural productivity is not uniform across the Basin. There is a clear divide between the upper part (areas of the Basin within Chhattisgarh and Jharkhand) and the lower part of the Basin area within the state of Odisha. The upper part of the Basin is predominantly a mono crop region; crops are grown mostly in rainfed conditions during the Kharif season. Due to lack of irrigation facilities, there is almost no cultivation of crops in the Rabi season – even if they are cultivated, their productivity is very low.

In addition, rainfall in the upper part of the Basin is comparatively lower than the lower part of the Basin and the rainfall season is shorter (as shown in Figure 4.1 and Figure 4.3). This has additional impact on the rainfed cultivation. Consequently, agricultural productivity is very low and highly uncertain in the upper part of the Basin.

The productivity in the lower part of the Basin is higher than the upper part of the Basin. The main reasons for this is the availability of irrigation. However, they are still much below the average of the country. There is still ample scope for increasing productivity by increasing the area under irrigation. The irrigation facilities have been increasing in recent years and there is a corresponding upwards productivity trend.

Groundwater is being used in the lower part of the Basin (please see the report of Schmid et al. 2016 produced as part of this project). There is not much information available on groundwater in the upper part of the Basin. Whether there is potential to use groundwater sustainably for irrigation in the upper part of the Basin is unknown.

### 4.2.2 Rainwater harvesting through on-farm reservoir

Irrigation developments based on large investments in surface water infrastructure are costly and long-term processes. The undulating topography in the upper part of the Basin could also be a significant constraint to large-scale irrigation development. In those places, the fate of the millions of rainfed farms can be greatly improved by adopting the effective rainwater conservation and management practices (Pandey et al. 2006, Panigrahi et al. 2007). Construction of the reservoir at one corner of the field to harvest the runoff generated from the diked rice fields may play a crucial role in alleviating drought in the rainfed systems. The harvested runoff in the reservoir can provide supplemental irrigation for rice during the monsoon season and irrigation for the Rabi crops in winter. In addition, the stored water in the reservoir can be used for fish cultivation (Pandey et al. 2006).

Numerous studies on eastern India (Pandey 1991, Panigrahi et al. 2001, Srivastava 2001, Pandey et al. 2006, Panigrahi et al. 2007, Roy et al. 2009) are available in the literature on the optimum size, technical feasibility, and economic profitability of on-farm reservoirs. All these studies show that rainwater harvesting in the reservoir has great potential to improve productivity in the rainfed farming system in eastern India. They are technically feasible and economically profitable. During our visit to a village in the Ranchi districts of Jharkhand, we have found irrigated rice and other crops are under cultivation using the stored water in wells and ponds (Figure 4.10).

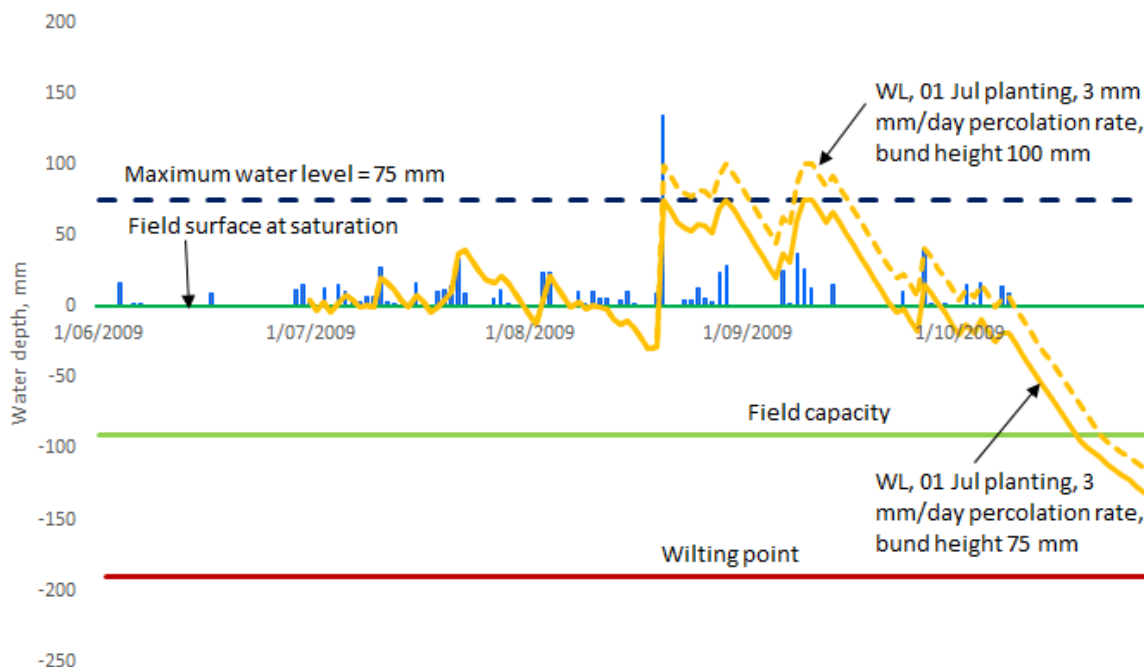




**Figure 4.10 Crop cultivation in the Rabi season using harvested rain water in wells and ponds (photo taken on 23 March 2015 in Topra within the district of Ranchi of Jharkhand)**

In addition to water harvesting in wells and ponds, it is also possible to increase water availability in the rice field by increasing ponding water depth thus mitigating the in-seasonal drought of winter rice, the predominant crop in the Basin. In the water balance simulation of the rice field shown in Figure 4.4, maximum ponding water depth was considered as 75 mm. If we increase this to 100 mm, additional water will be retained in the field which will keep the standing water in the field for an additional 18 days during the most important mid-season or panicle initiation stage of the crop (Figure 4.11). The rice yield in this case is expected to be much less affected than that with the maximum ponding water depth of 75 mm.

Rainwater harvesting while improving the productivity of the crop locally will also reduce the runoff to the rivers which may have adverse impacts (hydrological, environmental, etc.) on the downstream part of the Basin.



**Figure 4.11 Water balance in a rice field with higher (100 mm) ponding water level (dotted yellow line). Solid yellow line shows the water level in the field with 75 mm ponding water level.**

### **4.2.3 Improving research, education, and extension of appropriate production technologies**

The productivity of the crops can be improved by a number of technological, socio-economic and institutional factors even in water limited environments (Jha and Singh 2012, Adhya et al. 2008).

Technological interventions include:

- adoption of suitable and improved varieties such as aerobic and short duration varieties as shown promising by Cornish et al. (2015b),
- use of high quality seeds,
- appropriate level of fertilizer and pesticides use,
- better agronomic and intercultural management,
- use of SRI (System of Root Intensification) techniques and promotion of conservation agriculture, resource conservation tillage and direct seeding, and
- changing cropping options and testing and promotion of alternative cropping systems (demonstrated by Cornish et al. 2015b).

Due to lack of awareness, poverty coupled with justifiable apprehension on crop success is attributable to low use of fertilizers, inputs including quality seeds in rainfed eastern states (Adhya et al. 2008). The majority of the farmers are extremely poor having limited resources, and have limited capacity to invest in improved technologies and inputs (quality seeds, fertilizer, pesticides, herbicides, etc.). In addition, poor infrastructure, non-availability of inputs including credit facilities at the proper time, poor extension, and lack of coordination between agriculture and allied departments (such as department related to irrigation, water resources, cooperative, etc.) are major institutional constraints which should be removed for productivity improvement.

## 5 Key findings

Agriculture plays a critical role in the economy and livelihood of the majority of the population of the Brahmani-Baitarni Basin and is the major sector for employment. Development of agriculture holds the key to food security and improved livelihood for the people living within the Basin.

The primary aim of this report is to provide a snapshot of the current state of agriculture in the Basin. The key outcome expected is to identify the areas of intervention for further investment for research and development to improve the productivity of agriculture thus improving the livelihood of the people.

While this study is based on limited secondary data, the following conclusions can be drawn:

1. Rice is the predominant crop in the Basin in the Kharif season. The highest (93% of total area) is in the upper part of the Basin in the districts of Jharkhand and the lowest is in the districts of Odisha (74%). Wheat, pulses and oilseeds are the dominant crops in the Rabi season in the districts representing the Basin. Summer or irrigated rice is grown only in Odisha (6%).
2. Rice dominates the total annual cultivated area in Jharkhand (87.7%) followed by Chhattisgarh (76.8%) and Odisha (53.2%). Rainfed winter rice area varies from year to year. The area of other crops is constant over the years.
3. Cropping intensity is constant over the years (less than 110%) in the upper part of the Basin, as there is very little cultivation in the Rabi season. The upper Basin is mono-crop (rainfed) area. Cropping intensity is slowly increasing in the lower part of the Basin in Odisha (162% in 2012-13).
4. Odisha (10% of the total area) and Chhattisgarh (8.6%) were among the top five states of India in terms of cultivated area of rice in 2010-11. But in terms of average yield they are among the lowest. The average yield of rice in 2010-11 was 1.663, 1.541, and 1.616 tonne/ha respectively in Chhattisgarh, Jharkhand, and Odisha compared to the country average of 2.24 tonne/ha.
5. Yield of Kharif / winter rice varies significantly from year to year in the upper part of the Basin in Chhattisgarh and Jharkhand with no trend. In the lower part of the Basin, yield varies from year to year but there is an increasing trend. Currently, only Odisha has irrigated summer/Rabi rice cultivation. The yield is close to average and rising.
6. The districts of the states (Chhattisgarh, Jharkhand, and Odisha) covering the Basin produce 11, 44, and 41% of the total rice production of the states, respectively.
7. Yield of other crops also varies from year to year with no particular increasing or decreasing trends.
8. There is no or negligible irrigated crop cultivation in the upper part of the Basin. A total of 47% of the Kharif rice and 17% of the other Kharif crops are irrigated in the lower part of the Basin in Odisha. 54% of the crop area is irrigated in the Rabi season. Irrigated area is increasing gradually in Odisha.
9. In general, yield of crops is higher and less variable (from year to year) in the lower part of the Basin compared to the upper part of the Basin.
10. High variation in rainfall amount and distribution is the main reason for low yield and high variation in yield of crops grown in the Kharif season. Supplementary irrigation in the Kharif season is required to increase the yield or productivity of the crops.
11. Development of irrigation facilities and local water management are the key to improving the productivity of the crops in the Basin. Technological, socio-economic and institutional interventions have also good potential to improve the productivity.

The key findings from this study are:

1. In general, productivity of crops is low. Productivity is lower in the districts of Jharkhand and Chhattisgarh compared to the districts in Odisha within the Basin.
2. There is no or negligible irrigated crops in Jharkhand and Chhattisgarh; both of which are mono-crop (rice) regions. Rabi cropping in Odisha (within the Basin) is more than 60% of total cultivable area because of irrigation facilities.
3. Irrigation development can play a significant role in increasing productivity and improved livelihoods, particularly in the upper part of the Basin in Chhattisgarh and Jharkhand.
4. Local water harvesting and farm level water management may have good potential to improve productivity.
5. Research in agriculture and cropping systems is essential.

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