



Is India Moving away from Coarse Cereals? Examining Evidence from Trends in Rice, Wheat and Coarse Cereals.

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Abstract

India's agricultural production of cereals since the 1950s mainly comprises of rice, wheat and coarse cereals. Data shows that coarse cereals despite having maximum area under cultivation post independence and a high growth rate of production, have registered a declining trend in the recent decades. With global warming becoming a threat to monsoon-dependent grains like rice and wheat, India needs to start focusing more on coarse cereals. They are not only climate resilient using one-third the amount of water as compared to rice and wheat, but are also nutritionally superior to these grains. Data analysis for top five rice, wheat and coarse cereal producing states show that the decadal growth rates and yield per hectare have been declining for rice and wheat. Detailed inter-state comparisons are done to evaluate various aspects of these foodgrains. Finally, a fixed effects regression model is estimated to analyze the effect of area, annual rainfall, fertilizer consumption and MSP on the productivity of coarse and fine cereals, results show coarse cereals to be less dependent on rainfall and fertilizer use.



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Introduction


India started as an agrarian economy, with more than 47% of the land under cultivation in the last four decades (Land Use Statistics, various years). Since the 1950s the three main cereals produced are rice, wheat, and coarse cereals like jowar (sorghum), ragi (finger millet), bajra (pearl millet), maize, barley, etc. However, while the area under cultivation for rice and wheat continues to grow, area under cultivation for coarse cereals has registered a marked decline. But it was not the case historically.

In the first two decades after independence, area under cultivation was the highest for coarse cereals¹ among the three foodgrains, followed by rice and wheat. Between 1950-1970, almost 43% of the area was under coarse cereal cultivation, 37% under rice and only 14% under wheat (IndiaStat, various years). After 1976 the area under rice cultivation surpassed coarse cereals, and after 2006 the area under wheat cultivation exceeded coarse cereals. There were considerable differences in the growth rate of production as well. In the first decade, right

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after India's independence, the cumulative rate of growth of the three cereals was quite similar at approximately 4%.² With the first wave of Green Revolution in the latter half of the 1960s, the cumulative rate of growth of wheat in the decade 1960-70 shot up to 6.21%, while that of rice and coarse cereals was comparable at close to 2%. The next decade, 1970-80, was fraught with three major droughts in 1970, 1972 and 1979, mainly affecting the states of Rajasthan, Himachal Pradesh, Uttar Pradesh, and Punjab in the three years. These were one of the major producers of rice, wheat and coarse cereals. As a result, the cumulative rate of growth plummeted to 0.03% and 3% for rice and wheat respectively, while it became negative for coarse cereals. 1980s onwards to 2020, the rate of growth stabilized for rice and wheat, with some fluctuations. But it kept declining for coarse cereals. The production of rice has always been the highest since 1950. Coarse cereals have been a close second, but the decline in production started after 1974 and continues till the present period. In general, Mukherjee (2020) finds that between 1950-2018 rate of growth of production of rice and wheat was several times higher than nutria-cereals. The first wave of the Green Revolution also brought with it an increased use of chemical fertilizers for the finer cereals, that helped to boost productivity. As per a report published by the Food and Agriculture Organization of the United Nations (2005), in the year 2003-04, the share of rice and wheat in total fertilizer consumption was 31.8% and 21% respectively, while the share of some coarse cereals like sorghum, maize, pearl millets was much lower at 2.9%, 2.3% and 1.7% respectively.

But the question is why should a decline in the production or area under cultivation of coarse cereals be a matter of worry? With global warming and the effect of climate change becoming a real threat to agriculture, especially to the crops that are dependent on monsoons or high level of irrigation, it is important for India to reevaluate the cropping system. Rice and wheat have the highest water footprint. Between 2005-2014, production of rice and wheat required the maximum amount of water (Kayatz *et al.*, 2019). The percentage of gross irrigated area to the total cropped area has been among the highest for states that are top producers of rice, and this includes Punjab, Uttar Pradesh, West Bengal, Andhra Pradesh, etc. (Land Use

Statistics, various years). Davis *et al.* (2019) finds that erratic climate conditions that include increasing temperatures, changing monsoon, and more frequent climate extremes have a greater negative impact on rice yield. For some of the top producers of coarse cereals, like Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, etc., the percentage of gross irrigated area to the total cropped area has been well below the all-India average. Coarse cereals need one-third the amount of water needed by rice and wheat and their yield is unaffected by rise in the levels of carbon dioxide, unlike rice and wheat (Srividhya *et al.*, 2022). They can easily grow in semi-arid and dry regions of the country and are also called "dryland crops" as they can be grown in areas with 50-100 cm rainfall (APEDA, Ministry of Commerce and Industry, Government of India). They also need less amount of fertilizers and pesticides, and leave a lower carbon footprint than the finer cereals. This makes coarse cereals more resilient to changing climatic conditions and unpredictable monsoons. In fact, an article published in The New York Times on September 6, 1974 when India was in the midst of a drought, mentioned that fertilizer shortages and a lack of fuel for irrigation pumps threatened to destroy rice and wheat crops. However, the effect on the coarse cereals was less as their water requirement was much lower than rice and wheat. With growing population and the dependence of rural India on agriculture, it's imperative that the government looks for crops that have high yield and are more immune to changing climatic conditions. As per Kumar and Sidana (2019), climate change will lower the rice and wheat yield by 8.10% and 6.51% respectively by 2080, and therefore India needs to start exploring options. Saxena *et al.* (2018) find that India along with China, parts of Africa and South America, and USA will face adverse effects of soil degradation, climate change and water scarcity. Hence, to mitigate the effects of global warming and ensure food security, it is the need of the hour to diversify to alternative climate resilient crops like millets, that will reduce the stress on natural resources.

What makes coarse cereals a viable alternative is that besides the ability to withstand changing environmental conditions, they have tremendous health benefits as well. Most of these cereals like millets, etc. are nutritionally superior to rice and wheat as they have a higher content of protein,

vitamins and minerals like iron that helps to reduce anaemia. Fu *et al.* (2020) refer to these cereals as functional foods with nutritional and pharmacological properties and give a detailed explanation of their health benefits, like the ability to fight chronic diseases like tumor, inflammation and cardiovascular diseases. Banerjee and Maitra (2020) emphasize on the importance of small millets as they are a rich source of carbohydrates, dietary fibres, fats, proteins, vitamins essential minerals, etc. But in spite of its numerous health benefits (Rao *et al.*, 2018; Davis *et al.*, 2019, Eliazar Nelson *et al.*, 2019; Mukherjee, 2020), coarse cereals have disappeared from the modern diet. In fact, Murdia *et al.* (2016), taking the example of maize, rightly point out that it is the third most important foodgrain for the Indian population, and is a rich source of fiber, antioxidants, etc. But it is still majorly used for poultry and animal feed, and not for human consumption.

Data shows that although traditionally Indian agriculture had a significant share of coarse cereals, overtime there was a move towards finer cereals. Other than the Green Revolution, agricultural policies that have largely focused on maximizing production of foodgrains, have paid little attention to other important aspects like nutrition, crop diversity, etc. (Davis *et al.*, 2019). Government policies related to minimum support price (MSP) or distribution of foodgrains through the public distribution system, have also focused on finer cereals like rice and wheat. They have enjoyed much higher MSP, that has caused farmers to allocate higher acreage to these cereals due to lower price risk (Aditya *et al.*, 2017). Over the years, strong farmer lobbies with considerable political influence have emerged, especially in Punjab and Haryana. They have used their influence to set high MSPs for rice and wheat. Literature also shows that households have shifted away from coarse cereals due to availability of subsidized rice and wheat through the public distribution system, while no such step has been taken for nutrient rich cereals (Khera, 2011, Desai and Vanneman, 2014).

What is clear is that certain policies at the state level also need to be amended to reflect the growing importance of coarse cereals in reducing agriculture's share in greenhouse gas emissions, lowering water dependence, mitigate the health problems

arising out of micronutrient intake deficiencies (Rao *et al.*, 2018), ensure climate resilient food supply in India, etc. In order to create greater awareness about the importance of coarse cereals in general and millets in particular, commendable steps taken by the Government of India led to the United Nations declaring 2023 as the International Year of Millets. India's laudable efforts were supported by more than 70 nations. This will not only help in achieving greater food security in the light of climatic constraints, but will also help to boost research and development investment and promote sustainable agricultural practices.

The focus of this paper is to compare rice, wheat and coarse cereals using numerous aspects like area under cultivation, total production, and yield per hectare, and the changes that have been observed overtime. Detailed inter-state comparison is done for states that are the top producers of coarse cereals, with a special reference to the states that feature in the top five list of all the three cereals. Finally, a fixed effects regression model is estimated to evaluate the effect of factors like area, annual rainfall, fertilizer consumption and minimum support price (MSP) on productivity of coarse cereals and fine cereals like rice and wheat. Results show rice and wheat together to be more dependent on fertilizer use and monsoon.

Materials and Methods

The paper uses data from the Handbook of Statistics on Indian Economy, and Handbook of Statistics on Indian States, both published by Reserve Bank of India, to analyse trends in various aspects of fine cereals like rice and wheat and coarse cereals, and the factors affecting the productivity thereof. The general analysis focuses on the sample period 1950-2020 to get capture the trend and changing pattern in cultivation. The state level analysis is done for a sample period of 1990-2020 due to data constraints.

The last section presents a panel data fixed effects model to evaluate the impact of various factors on the productivity of coarse cereals and finer cereals. The model controls for time invariant effects that differ across states but remains constant overtime. Yield per hectare measured in kg per hectare, that is used to capture crop productivity, is the dependent

variable. The sample period is from 1990 to 2020. The fixed effects regression model is estimated as follows.

$$\ln(\text{Yield per hectare}_{i,t}) = \alpha_i + \delta_t + \beta_1 \ln(X_{i,t}) + \varepsilon_{i,t}$$

Where $X_{i,t}$ refers to the set of independent variables. It includes *area under cultivation* in thousand hectares, *annual rainfall in millimeters*, *consumption of fertilizer N+P+K* in kg per hectare, and *minimum support price* in rupees per quintal. All the variable are in natural logarithms.

Results and Discussion

This section is divided into three sub sections, viz., (i) Trends in production and area under cultivation for rice, wheat and coarse cereals, (ii) Analysing trends in the top five states producing coarse cereals, and (iii) Results from the fixed effects model.

Trends in Production and Area Under Cultivation for Rice, Wheat and Coarse Cereals

The top five producers of rice are West Bengal, Uttar Pradesh, Punjab, Andhra Pradesh, and Tamil Nadu, with a share of more than 55% in the overall rice production in India. The major wheat producing states are Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, and Rajasthan, with Uttar Pradesh

producing more than 30% of the total wheat in the country mainly as it was one of the initial states to enjoy the benefits of the Green Revolution. The top five coarse cereal producing states are Rajasthan, Karnataka, Maharashtra, Madhya Pradesh and Uttar Pradesh, with these states producing more than 60% of the total coarse cereals in the country.

Overall, data on agricultural production on foodgrains from the Handbook of Statistics on Indian States, shows that from 1950 to 2021, production of rice has been the highest. Interestingly, coarse cereals were the second largest foodgrains to be produced till 1974-75, with the difference in production between the two grains being quite negligible till 1954-55. Post 1954-55, this difference kept on widening, not just between rice and coarse cereals, but also between wheat and coarse cereals. With the Green Revolution that commenced in the latter half of 1960s, production of wheat saw an unprecedented increase and it soon surpassed the production of coarse cereals, as shown in Figure 1 below. Rice and wheat have been moving parallelly with each other, with almost a constant difference in production. A similar conclusion was drawn by Pingali *et al.* (2017) that Green Revolution, due to its favoring of finer cereals, caused crowding out of coarse cereals from the areas where they were historically grown.

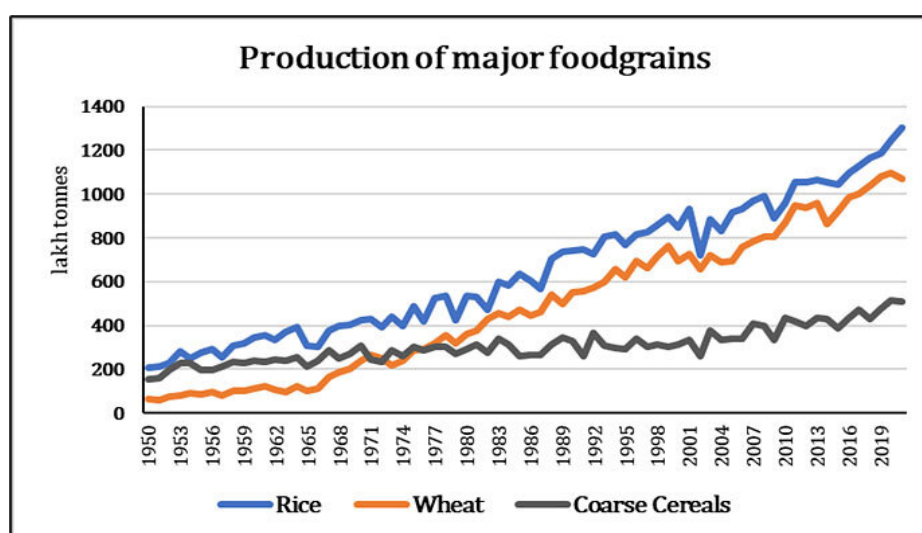


Fig. 1: Production of major foodgrains in India (lakh tonnes)
Source: Handbook of Statistics on Indian States, RBI

But what seems to be true from the figure is that coarse cereals did form an important part of the dietary composition in the early days. The high production and high rate of growth of coarse cereals in the earlier decades could be because right after independence India was still trying to find its foothold in agriculture and was struggling to meet the food requirements of its people. Coarse cereals have been considered as inferior crops, compared with rice and wheat. Traditionally they have been grown in parts of India that are relatively dry, and have resource constraint, and have been considered to be staple food of people from lower income groups.

But then with increasingly erratic rainfall and long summer season with dry spells, water dependent

cereals like rice and wheat will be difficult to maintain. Mukherjee (2020) finds a nexus between agricultural growth and unsustainable use of groundwater resources and energy in Indian agriculture in the cultivation of water-intensive finer cereals. Data procured from the Land Use Statistics shows that for the top five rice growing states, almost 99% of the total area under rice cultivation was irrigated between 2009-2018 for Andhra Pradesh and Punjab, more than 90% for Tamil Nadu and more than 80% for Uttar Pradesh, and more than 50% for West Bengal. The percentage of area under irrigation gets lesser for wheat and coarse cereals. Figure 2 below compares the area under irrigation for some years for states that are among the top five producers of more than one foodgrain.

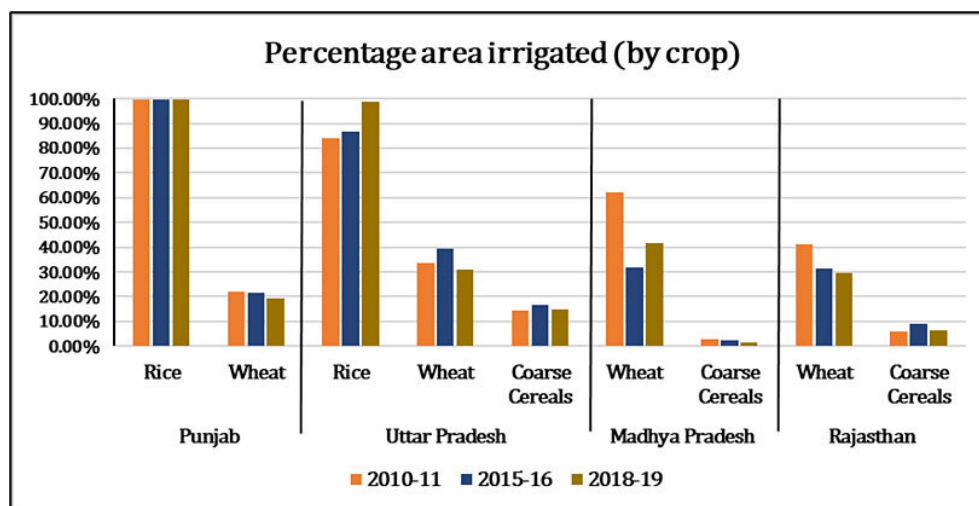


Fig. 2: Percentage area irrigated by crop for select years
Source: Author's own calculations

Punjab, a top producer of both rice and wheat, has almost 100% of the area under rice cultivation being irrigated, as compared to 20% or less for wheat. Similarly for Uttar Pradesh, there is an immense gap between the irrigated area under rice, wheat and coarse cereal cultivation. More than 30% of the area under wheat cultivation is irrigated, while a little more than 14% of the area under coarse cereal cultivation is under irrigation. For Madhya Pradesh, the irrigated area under coarse cereals is almost negligible as against wheat. Approximately 30% of the area under wheat cultivation in Rajasthan is irrigated, in comparison to 6% to 7% under coarse cereals.

This further highlights the significant dependence of rice and wheat on water, and the need of the hour to invest in climate resilient cereals with known nutritional benefits. Davis *et al.* (2018) estimates the reduction in water demand in the irrigated areas of India by replacing rice areas with alternative cereals like maize, finger millet, pearl millet, or sorghum.

Overtime, the finer cereals may have started to feel the effects of climate change. As Figure 3 shows below, a general data analysis of decadal growth rates of rice, wheat and coarse cereals shows that

although the growth rates of production of rice was the highest in the decade 1951-61, it has been lower than wheat and coarse cereals in all

the remaining decades till 2011-2021, after which it was negligibly higher than wheat.

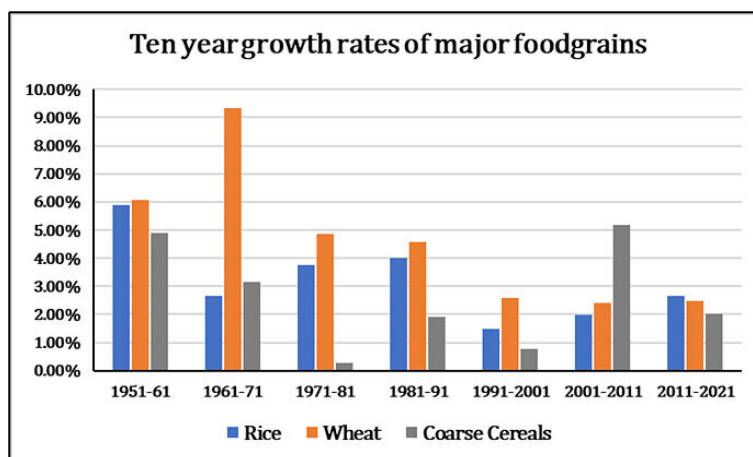


Fig. 3: Ten year growth rates of major foodgrains in India (percentage)
Source: Author’s own calculations

Since the first wave of the Green Revolution was confined to wheat and its positive effects were only felt in the top wheat producing states of India between late 1960s to 1970s, the rate of growth of wheat production escalated in this decade, after

which it declined considerably. Rate of growth of coarse cereals also declined from its high levels in the first decade, mainly due to a shift in the consumption habits of the population as per capita incomes increased.

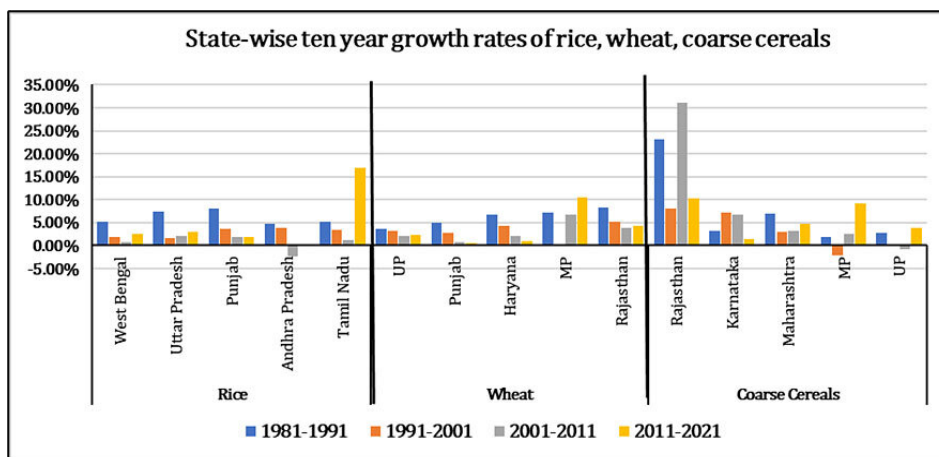


Fig. 4: Ten-year average growth rates in major states producing rice, wheat and coarse cereals (percentage) Source: Author’s own calculations

A state level analysis of major rice and wheat producing states paints a similar picture, as shown in Figure 4 below. The ten-year growth rates in the production of rice and wheat have been declining as compared to the decade 1980-1990. Coastal

Andhra Pradesh recorded negative growth rates in the decade 2001-2011, and became negligibly positive in the next decade. Since 1950, annual rainfall in the state has been between the intervals 900 mm to 1400 mm, with occasional slumps

and surge. But there has been a marked decline between 2001 to 2011, and after a brief rise in 2010 again there has been a consistent decline in the annual rainfall in coastal Andhra Pradesh. Similarly for Punjab the interval within which annual rainfall lay was approximately 400 mm to 800 mm between 1951 to 1996, after which it went below 400 mm to approximately 600 mm. Tamil Nadu is the only exception, because of the method of System of Rice Intensification or SRI adopted by the state on a large scale (Pandian *et al.*, 2014) that has helped to increase the yield of rice. Similarly, overtime the rate of growth of wheat has also been declining due to a rise in heat conditions brought about by global warming. Other factors that are common to all foodgrains is a shift away from agriculture towards other non-agricultural activities, especially among the younger population.

Coare cereals aslo show a lot of fluctuations, with the maximum fluctuation being in Rajasthan. Madhya Pradesh shows a substantial rise in the decadal growth rate in 2011-2021, while Maharashtra shows a marginal increase after 1981-1991.

One of the factors that affects the trends in production is trends in area under production of these foodgrains. Data from the Handbook of Statistics on Indian Economy, published by the Reserve Bank of India, shows that the area under cultivation for coarse cereals was the highest from 1950 to 1983 (Figure 5 below). But a decline had already set in during the 1980s. Meanwhile, the area under cultivation for rice and wheat continued to rise consistently, with rice and wheat overtaking coarse cereals in 1984 and 2008 respectively. The decline in the area under cultivation for coarse cereals became more rapid around the second half of the 1970s, the same time when production of this cereal declined and went below wheat. A similar conclusion was drawn by Pingali *et al.* (2017) that Green Revolution, due to its favoring of finer cereals, caused crowding out of coarse cereals from the areas where they were historically grown. Other studies (Aditya *et al.*, 2017, Roy, 2017, Eliazer Nelson *et al.*, 2019) also find that a significant amount of area under coarse cereal crop has been replaced by finer cereals like rice and wheat.

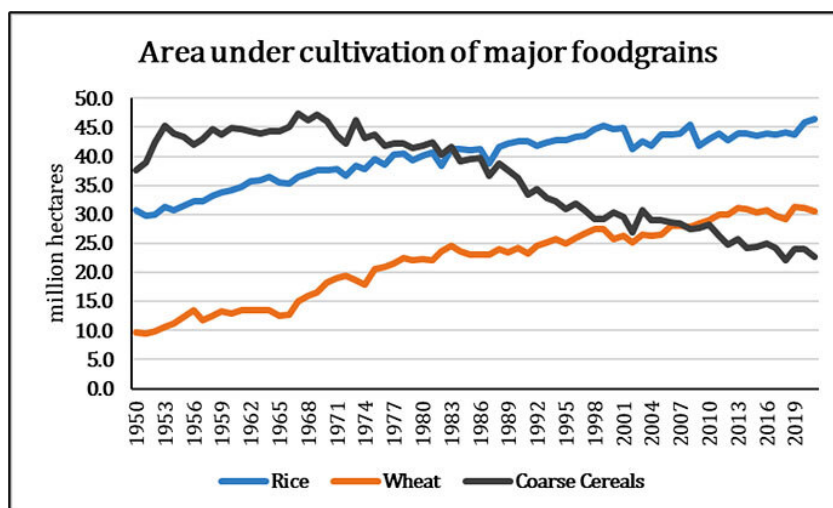


Fig. 5: Trends in area under production of rice, wheat and coarse cereals (million hectares)
Source: Handbook of Statistics on Indian Economy, RBI (various years)

What is interesting to note is that between 1950 till the latter half of 1970s, even though area under cultivation was higher for coarse cereals, the total production was more for rice. This implies that the productivity in rice production was higher

compared to coarse cereals. Decadal growth rates of yield per hectare, which reflects the productivity, shows that in the first decade after independence, yield per hectare was the highest for rice and almost equal for wheat and coarse cereals. It rose greatly

for wheat in the next decade, which was due to the first wave of the Green Revolution. In fact, even during the years that production of wheat remained below coarse cereals, the rate of growth of production was higher for wheat for most years. However, after the 1990s, productivity improved for

coarse cereals and it remained consistently greater than both rice and wheat. Roy (2017) also finds that the decline in area under cultivation did not translate into a steep decline in production of coarse cereals due to growth registered in yield rate due to adoption of the new seed technology.

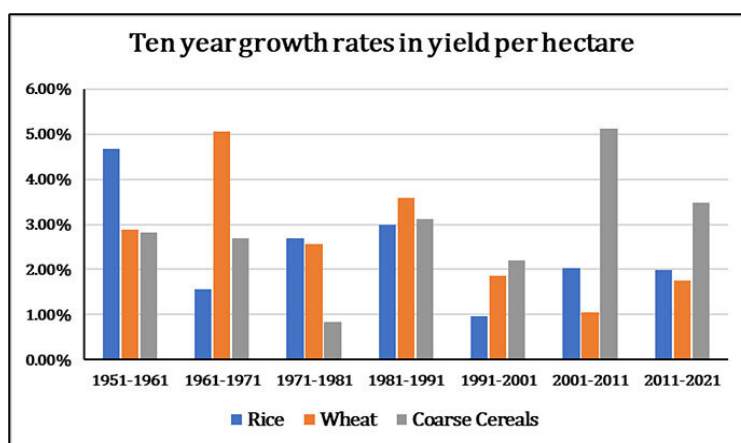


Fig. 6: Ten year growth rates in yield per hectare of major foodgrains in India (percentage)
Source: Author's own calculations

The change in the pattern of productivity could reflect the effects of climate change, given that coarse cereals are more climate resilient than the other finer cereals, with much less water requirement. They can easily grow in semi-arid and dry regions of the country.

Another reason why the government should take steps in promoting both cultivation and consumption of these cereals is that out of the three, coarse cereals are the only ones to be called "super grain" because they are a rich source of macronutrients and micronutrients along with calcium, iron, zinc, potassium, protein, etc. They are a richer source of antioxidants than finer cereals (Kaur *et al.*, 2014). Using data on proximate composition of coarse cereals and fine cereals published in the Status Paper on Coarse Cereals, Government of India (2014), it is found that rice has 35% less protein than jowar, 41% less protein than bajra, 7% less protein than ragi, 41% less protein than maize. Similarly, it has 63%, 74%, 78%, and 60% less mineral matter than jowar, bajra, ragi, and maize respectively. The calcium content of rice is almost 97% less than ragi, and more than 75% less than bajra and maize.

To take an example, Indian women in particular suffer from iron deficiency. One serious repercussion of this deficiency is anaemia. One of the possible causes is that overtime there has been a change in the dietary pattern that has led to a shift away from consumption of coarse cereals. DeFries *et al.* (2018) take data from 800,000 households in India between the period 1983-2011 to assess the health impact of decreased consumption of coarse cereals due to greater production of rice and wheat. The study finds increased instances of anaemia among women and children due to iron deficiency, and suggests increased consumption of coarse cereals could reduce anemia prevalence in Indian women. This paper compares the prevalence of anaemia among women in the top five states producing rice, wheat and coarse cereals. It is found that the percentage of anaemic women is less than the overall average for India in states producing coarse cereals, as compared to states producing rice or wheat, as shown in Figure 7 below.

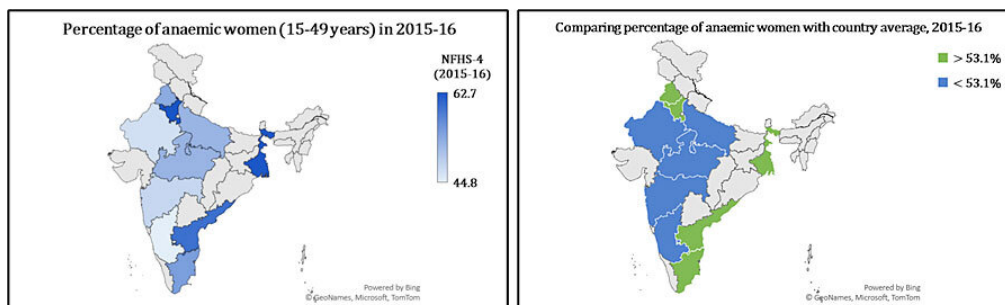


Fig. 7: Percentage of anaemic women in states producing rice, wheat and coarse cereals, 2015-16
Source: National Family Health Survey, India

As per the data from National Family Health Survey-4 (NFHS) conducted in 2015-16, 53.1% of women in India are anaemic. In the states of Karnataka, Madhya Pradesh, Maharashtra, and Rajasthan, the percentage of anaemic women is below the national average. These states are the top five producers of coarse cereals, and the general food composition of the population will reflect the same. The top rice producers like Andhra Pradesh, Punjab, Tamil Nadu, West Bengal show high cases on anaemia among women. A similar trend was observed as per the NFHS-5 (2019-20) round as well, with coarse cereal producing states showing lower than the national average. Other studies in the literature (Eliazar Nelson *et al.*, 2019, Pradhan *et al.*, 2019) also find a rise in instances of anaemia due to a decline in the consumption of these cereals. Pradhan *et al.* (2019) conducts a village level study in the Boipariguda block of Koraput district in Odisha for 2015-2017, where finger millet was

primarily grown and also consumed. But overtime a shift towards other crops has changed the dietary patterns of households and thus the area has witnessed a rise in undernourishment and anaemia among children and adults.

Analysing Trends in the Top Five States Producing Coarse Cereals

According to the Directorate of Millets Development, Ministry of Agriculture, Government of India, coarse cereals that include Sorghum, Pearl millet, Ragi, Small millets, Maize and Barley, are grown in states that receive less rainfall and are resource deficient. They have traditionally been associated with states that have lower incomes, than the high income states growing finer cereals like rice and wheat. More than 60% of the country’s coarse cereals is produced in Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, and Uttar Pradesh.

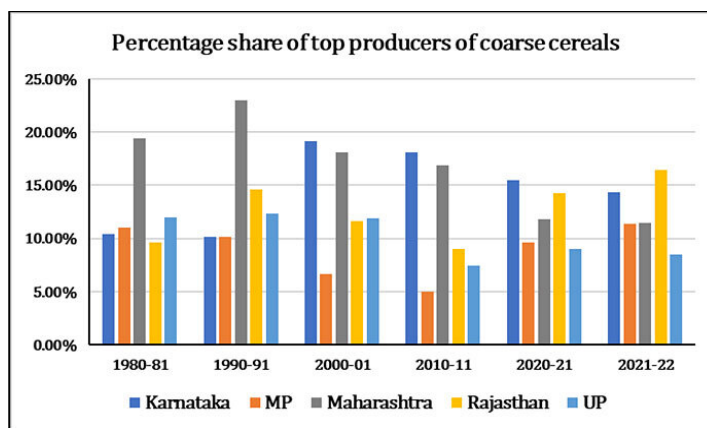


Fig. 8: Percentage share of top producers of coarse cereals in overall cereal production in India, select years

Source: Author’s own calculations using data from Handbook of Statistics on Indian Economy, RBI

Rajasthan was the lowest producer of coarse cereal among the five states in 1980-81, with a share of approximately 10%. By 2021-22 it emerged as the largest producer with a share of more than 16%. Similarly, Karnataka also emerged from being the second lowest producer to the second largest producer of coarse cereals in 2021-22. After being the top producer in the years 1980-81 and 1990-91, and producing more than 16% of overall production in 2000-01 and 2010-11, Maharashtra's share declined substantially in 2020-21 and 2021-22. As per the Economic Survey of Maharashtra, 2021-22, the state has diversified agricultural production

from coarse cereals to high value crops like cotton, sugarcane, soyabean, maize, fruits, vegetables and flowers. In case of Uttar Pradesh, its share was higher than Rajasthan and Karnataka in 1980-81, but since 2005-06 its share has remained close to 8% of overall production. In fact, the state has invested much more in the production wheat, than other cereals.

In three decades, between 1990 to 2020, the total area under cultivation of coarse cereals fell marginally from 25% to 24%. But there are differences across the top five producers.

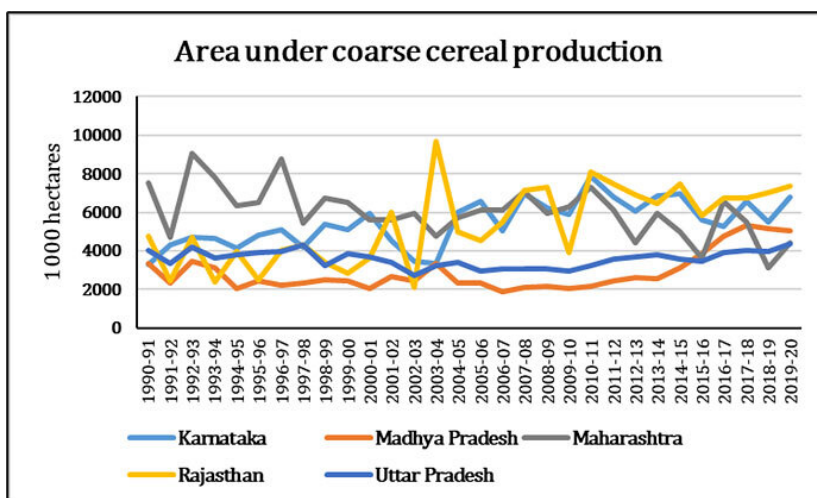


Fig. 9: State wise area under coarse cereal production (1000 hectares)
Source: Handbook of Statistics on Indian States, RBI

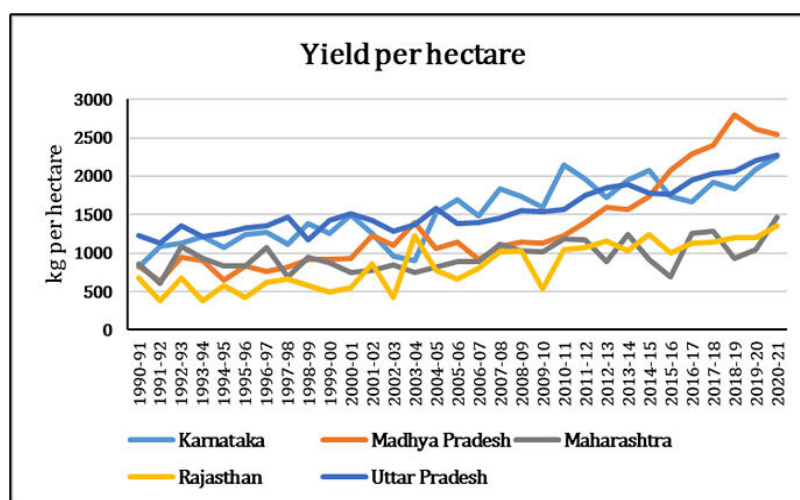


Fig.10: State wise yield per hectare of coarse cereal production (kg per hectares)
Source: Handbook of Statistics on Indian States, RBI

Data shows that the area under production of coarse cereals (thousand hectares), was the highest in Maharashtra till 2000-01. This was followed by Karnataka and Rajasthan respectively. Both states have shown a steady increase in total area. From 2010-11 onwards, Rajasthan emerged as the state with the highest area under production of coarse cereals. Uttar Pradesh, followed by Madhya Pradesh have the least area under cultivation of coarse cereals. But after 2014-15, Madhya Pradesh brought more area under coarse cereal cultivation than Uttar Pradesh. In fact as can be seen from Figure 9 above, Madhya Pradesh also recorded a rise in the decadal growth rate of production between 2011-2021, that can be attributed to a steady rise in the area under cultivation of coarse cereals.

Agricultural productivity, given by the yield per hectare, also varies considerably across states.

Uttar Pradesh was the most productive state, even though it was among the lowest in terms of area under cultivation. Rajasthan, which had among the highest areas under cultivation overtime, was among the least productive states. Out of these five states, Madhya Pradesh, Rajasthan, and Uttar Pradesh are also among the top five producers of wheat. Uttar Pradesh is also among the top five producers of rice.

Figure 11 shows the percentage of area under cultivation for rice, wheat and coarse cereals in the states that produce all or two of the major foodgrains in select years.

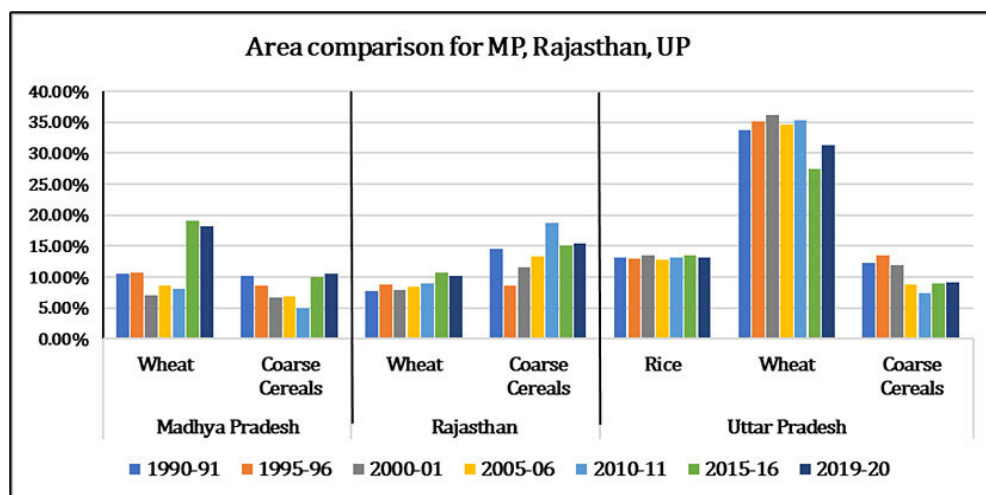


Fig. 11: Percentage area under cultivation for rice, wheat and coarse cereals in select states for select years

Source: Author's own calculations using data from Handbook of Statistics on Indian States, RBI

Data shows that the percentage of area under cultivation for wheat and coarse cereals remained almost the same in 1990-91, 1995-96 and 2000-01 for Madhya Pradesh. By 2015-16 and then 2019-20, the area under wheat cultivation had surpassed the area under coarse cereal cultivation. Rajasthan had less area under wheat cultivation and more under coarse cereals. In case of Uttar Pradesh, there is a substantial difference between the three foodgrains. Out of the total area under wheat cultivation in India, more than 30% is in Uttar Pradesh. Out of the total area under rice and coarse cereal cultivation in India, the state's share was close to 13% for rice, while

it declined from approximately 13% in 1990-91 to 9% in 2019-20 for coarse cereals.

For yield per hectare, Rajasthan and Uttar Pradesh do not show much variation. But it was significantly lower for Madhya Pradesh till 2010-11, and it rose substantially after that. However, what is important here is that Rajasthan had markedly lower area under cultivation for wheat than Uttar Pradesh, but for most years the state's yield per hectare was higher than Uttar Pradesh. But in case of coarse cereals, Uttar Pradesh is the most productive state. As per calculation. compared to Rajasthan where its

area under cultivation was more than 40% lower, its yield per hectare was more than 50% higher. Table 1 below gives a detailed inter-state comparison

in terms of differences in area under production and yield per hectare between Uttar Pradesh and the four coarse cereal producing states.

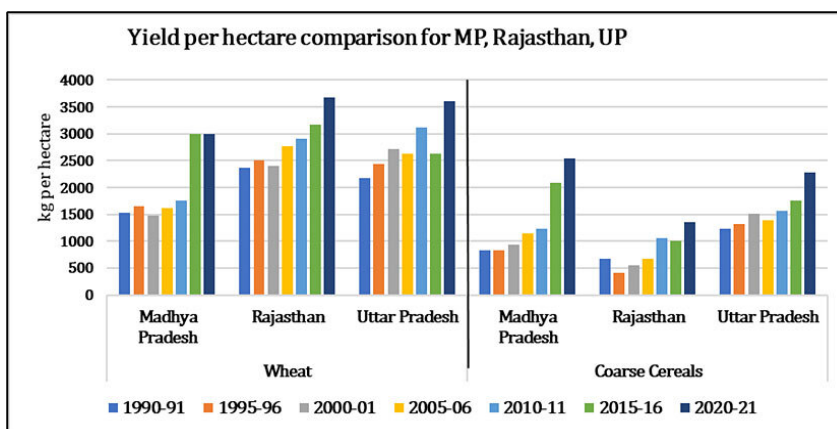


Fig. 12: Yield per hectare for wheat and coarse cereals in select states for select years

Source: Author’s own calculations using data from Handbook of Statistics on Indian States, RBI

Note: Rice is not included as UP is the only state producing it

Table 1: Percentage by which area and yield per hectare is different in Uttar Pradesh

Year	Area (%)				Yield per hectare (%)			
	Karnataka	MP	Maharashtra	Rajasthan	Karnataka	MP	Maharashtra	Rajasthan
1990	22.11	21.54	-46.21	-15.24	50.18	48.91	42.36	81.68
1995	-17.92	59.15	-39.58	57.18	6.44	59.21	57.69	217.27
2000	-37.58	80.09	-34.04	2.80	1.28	61.56	103.10	172.88
2005	-54.73	26.52	-51.19	-34.39	-18.31	20.26	55.92	106.73
2010	-58.99	48.51	-56.07	-60.24	-27.33	26.60	31.40	48.67
2015	-38.30	-10.10	-4.83	-40.44	1.15	-15.51	154.34	76.35
2020	-35.59	-12.74	-0.09	-40.16	0.71	-10.53	54.51	68.22

Note: For Area, the last year is 2019 and not 2020.

Uttar Pradesh’s area under cultivation for coarse cereals is lower than most states in most years, yet it has extremely high yield per hectare. Area under production was the highest for Maharashtra from 1990-91 to 2002-03, with Uttar Pradesh falling far below, with 34% to 46.21% lower than Maharashtra. However, the yield per hectare was substantially higher in Uttar Pradesh than Maharashtra during this period. Similarly, compared to Karnataka or Rajasthan, the area under production of coarse cereals was considerably lower in Uttar Pradesh, while the yield per hectare was strikingly higher, especially compared to Rajasthan.

Numerous factors could have been responsible for this type of inter-state variation. Uttar Pradesh has had the second highest state gross domestic product, among the sample states. This will mean higher investment, including in agriculture. The state has the highest consumption of N+P+K fertilizers, where N+P+K refers to Nitrogen + Phosphorous + Potassium, as well as the highest amount of credit by commercial banks going into the agricultural sector.

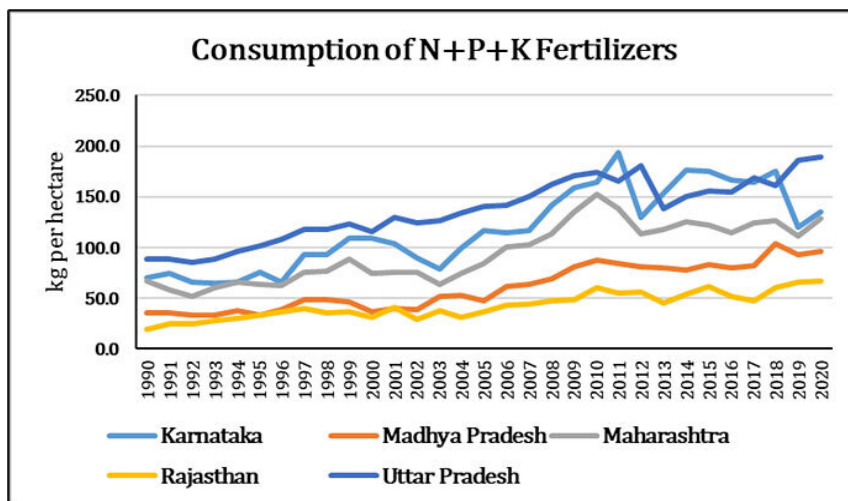


Fig. 13: State wise consumption of N+P+K fertilizers
Source: Handbook of Statistics on Indian States, RBI

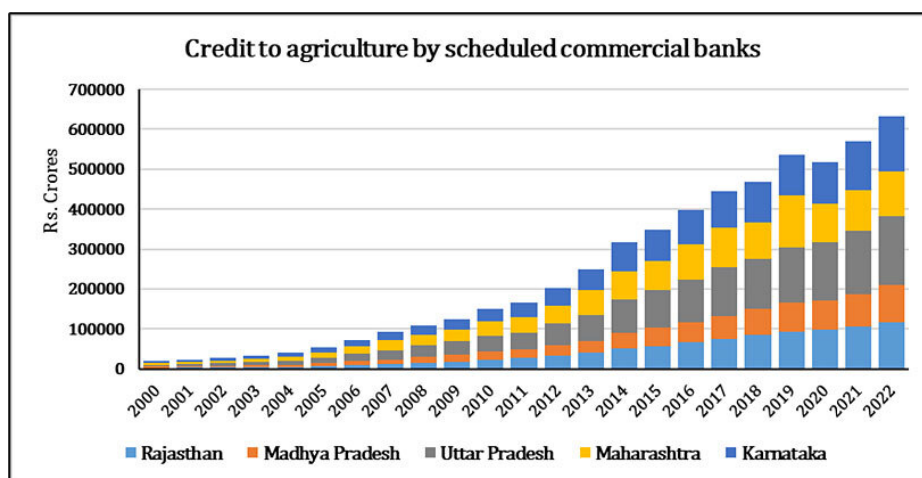


Fig. 14: State wise credit to agriculture by scheduled commercial banks
Source: Handbook of Statistics on Indian States, RBI (various years)

Along with Uttar Pradesh, Karnataka also has a high amount of fertilizer use. They are also the top two states with respect to yield per hectare. The average decadal rate of growth in the consumption of fertilizers is higher for Madhya Pradesh than Maharashtra, and the yield per hectare of the former has grown rapidly as well. Rajasthan has been the lowest consumer of fertilizers, and also has the least yield per hectare, in spite of having one of the largest areas under coarse cereal cultivation.

Explaining the Inter-State Variations: Impact of Agricultural Credit

Credit from scheduled commercial banks to the agricultural sector can also help to boost productivity by giving farmers access to funds for investment.

Trends are not reported for the period 1990-2000 because after the economic reforms of 1991 the rate of growth of agricultural credit fell and became negative (Gulati and Juneja, 2019). After 1999-2000,

there has been a tremendous rise in agricultural credit, though it did fall between 2008-17 mainly due to the agricultural debt waiver introduced by the government. The inter-state variations remain. The agricultural sector in Uttar Pradesh received more credit than the other sample states. Overtime the gap widened with respect to some states like Maharashtra and Karnataka. Uttar Pradesh received 16% and 32% more credit than Maharashtra and Karnataka respectively in 2010, and more than 90% more credit than Rajasthan and Madhya Pradesh. In 2022, it received more than 50% more

credit than Maharashtra and Rajasthan, 86% more credit than Madhya Pradesh and 27% more credit than Karnataka.

Results From the Fixed Effects Model

This section presents the econometric results from a panel data fixed effects model to analyze the factors affecting the yield per hectare of coarse cereals and finer cereals which includes rice and wheat. Table 2 presents the summary statistics for coarse cereals and finer cereals.

Table 2: Summary statistics for coarse cereals and finer cereals

Variable	Coarse Cereals					Finer Cereals (Rice and Wheat)				
	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max
Yield per hectare (kg/hectare)	155	1246.8	488.9	377	2796	310	3100.4	1063.5	876	10542
Area under cultivation ('000 hectares)	150	4657.3	1753.4	1849.6	9674.8	300	8490.4	7005.3	1396.6	33815.5
Annual rainfall (millimeter)	155	818.9	239.5	188.9	1459.1	248	885.4	369.7	274.7	1961.3
Fertilizer use (kg/hectare)	155	90.7	44.9	19.7	193.7	310	141.7	60.1	19.7	278.4
MSP (Rs./quintal)	155	768.4	502.4	180	1850	310	886.3	523.3	205	1975

Table 3: Factors affecting the yield per hectare of coarse cereals and finer cereals

Variables	(Model 1) Coarse Cereals	(Model 2) Finer Cereals
ln(Area under cultivation)	0.622***	0.1
ln(Annual rainfall)	-0.034	-0.079
ln(Fertilizer use)	0.0408	0.0954*
ln(MSP)	-0.048	-0.057
Constant	0.158**	0.357***
	-0.079	-0.132
	0.184***	-0.0858
	-0.033	-0.254
	-0.306	5.074***
	-0.402	-1.691
Observations	150	240
R-squared	0.963	0.784

Note: Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Log of Yield per hectare is the dependent variable.

Data shows that the average yield per hectare is more for finer cereals, and the average area under cultivation is also almost 82% more. The dispersion around the mean value is much less for coarse cereals than finer cereals. Therefore, the yield per hectare is more spread out for rice and wheat. The average fertilizer use is 56% more for finer

cereals. The difference in average annual rainfall is not large, but that could be because coarse cereals include states that are also among the top producers of rice and wheat. Minimum support price for the two set of foodgrains does not show a large difference either.

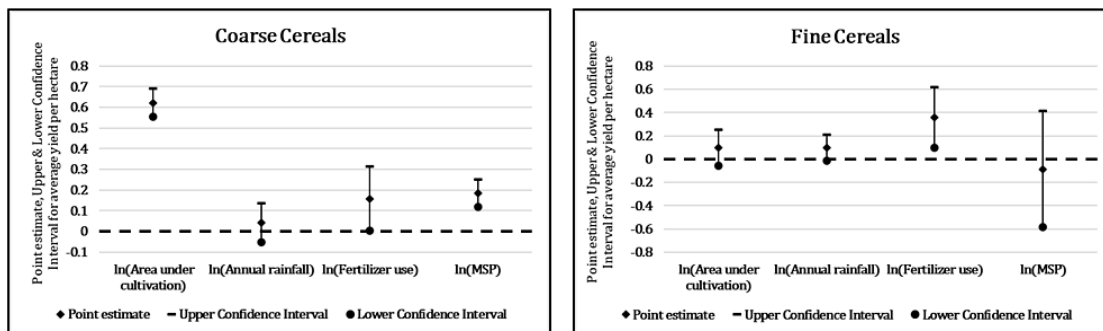


Fig. 15: Illustrating the levels of significance for the coefficients

The results from Table 3 and the illustration given in Figure 15 show that an increase in area under cultivation, fertilizer and minimum support price have a statistically significant and positive effect on the yield per hectare of the coarse cereals. For finer cereals like rice and wheat, an increase in annual rainfall and fertilizer use help to raise the yield per hectare, with a statistically significant effect. A 1% rise in fertilizer use causes yield per hectare to rise by 0.158% and 0.357% respectively for coarse and finer cereals, with fertilizer use having a greater impact on finer cereals. Similarly, annual rainfall does not have a statistically significant effect on the yield of coarse cereals, which further establishes that these cereals are not water dependent. While on the other hand, rice and wheat have a greater dependence on fertilizer use and monsoons. Various studies in the literature have also stressed on the importance of coarse cereals because of their low dependence on groundwater resources, rainfall or irrigation (Saxena *et al.*, 2018; Davis *et al.*, 2019; Mukherjee, 2020).

Conclusion

Coarse cereals formed an important part of the diet of the Indian population in the years following independence. But overtime with changing consumption patterns and rising shares of finer cereals, especially after the Green Revolution,

both the area under cultivation and total production of coarse cereals declined. Area under cultivation for jowar showed a sharper decline, compared to bajra, while the area under cultivation for ragi remained almost stable till the 1980s with a decline thereof. These cereals have mostly been associated with resource constraint parts of the country with rainfall below the average for the country. But despite the unflattering reference to coarse cereals as “cereals of the poor”, their contribution towards health and environment cannot be sidelined. For example, one possible way to reduce iron deficiency is through a more balanced diet comprising of iron rich cereals. The adverse effects of erratic monsoon on agriculture that is likely to grow with global warming, can also be diminished with climate resilient crops. This is important because agriculture still continues to support a large part of the rural population with a significant contribution to gross domestic product.

Government of India has taken steps to promote production and consumption of coarse cereals. It launched the “Initiative for Nutritional Security through Intensive Millet Promotion (INSIMP)” in 2011-12. These cereals became a part of the National Food Security Mission from 2014-15 onwards. They are also being distributed through the Public Distribution System at subsidized rates.

The minimum support price for coarse cereals has been rising as well. MSP for ragi and jowar from 2017 onwards has been higher than both rice and wheat. These steps by the government will also encourage farmers to move towards cultivation of coarse cereals. Besides this, various campaigns can be undertaken to make people more aware of the associated health benefits of these cereals.

Primarily, growing concerns related to malnutrition as well as environmental damage and climate change have brought the mitigating role of coarse cereals to the forefront. India's efforts that led to 2023 being declared as the International Year of Millets is an example in place. With India being in the forefront of popularising the importance of millets in particular

and coarse cereals in general, we will hopefully experience more sustainable agricultural practices, nutritional food supply and farmer welfare.

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Conflict of Interest

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