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Crop planning strategies under changing rainfall scenario

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Abstract
An attempt has been made to study the impact of annual rainfall and its trend on crop production and productivity of different crops at Banka district of Bihar state by using 19 years rainfall data (2000-2018) and crop data for 21 years (1998-2017). In this district, rice is cultivated in 80% of area posing high risk of crop failure due to late onset and unusual behaviour of monsoon during kharif season. During rabi season, large area of the district is under wheat and low water demand crops like pulses and oilseeds cultivation. An average annual rainfall of 1063.1 mm was observed from 19 years rainfall data and a decreasing trend of annual rainfall was noticed in recent years. This changing rainfall pattern is the result of climate change and it responsible for drought like situation during monsoon month and heavy rainfall at crop maturity or harvesting stage which directly or indirectly damage the crop and its yield. The trend of area, production and productivity of major field crops (Rice, Wheat, Maize, Gram, Lentil and Rapeseed/Mustard) of Banka district was analysed for the period of 1998-2017. The results showed that there was a non-significant decreasing trend of acreage of all these crops were found mainly due to untimely and uneven distribution of rainfall. But a significant increasing trend of productivity was shown in all crops except rapeseed/mustard. The production trend of rice and maize crops are increasing with a significant value. From the analysis, it was concluded that the water requirement will increase in future. Therefore, it is suggested that water saving practices or techniques for water conservation and ground water recharge should be adopted over wide areas and short duration, drought resistant, less water loving crops or varieties need to be used in this district.

Keywords: Annual rainfall trend analysis, analysis of area, production and productivity trend of major crops, crop planning based on rainfall and crop data

Introduction

One of the most interesting aspects of weather is rainfall and its variance from one place to another. The amount of rainfall received over an area is an important factor in assessing the amount of water available to meet the various demands of agriculture, industry, irrigation, hydroelectric power generation and other human activities. Therefore, distribution of rainfall in time and space is an important factor in determining the economic status of a region or a state or a nation. The term ‘rainfall’ is most commonly applied for the liquid precipitation.

According to Gates (1988) [3], experience of the world is sufficient to convince people that even a temporary change of climate can have profound impact on agricultural production and on the use of energy and water resources. In India despite recent progress in industrlization, the soundness of economy is significantly dependant upon the gross production of agricultural commodities and agriculture is the mainstay of millions of teeming population with crops pre-dominantly dependant upon natural rainfall. Excepting the south-eastern part of the peninsula and Jammu and Kashmir, the south west monsoon (June – Sept.) is the principle source of rain in the entire country. During monsoonal period more than 75% of annual rainfall is received over a major portion of the country. The shortage of water results from uneven distribution of rains, significant gaps between rain events and field water losses rather than from low seasonal or annual rainfall totals. Although water in form of precipitation is available freely and right at the site where it is to be used, yet so tenuous and delicate is the balance between the demand for water by crops and its supply by precipitation that even short term deficit periods often reduce the production significantly (Gupta *et al*. 1990) [4].

The district of Banka has 60% of area under hilly zone. Hilly areas possess a good rainfall as compared to the plain regions of the district. The Climate of this district is characterized by a hot Summer and a pleasant Winter Season. March to June comprises the summer months while the cold season lasts from November to February. Monsoon sets sometimes in the part of June and the rains continue till September, October being a transitional month. The district also received some winter rains. The south west monsoon generally breaks in during the second half of June. The bulk of the rainfall occurs in July and August. The average annual rain fall is 1150 mm almost uniformly throughout the district.

Rainfall analysis is important in view of crop planning for any region. Rainfall studies, particularly its variability and trend analysis can give more information for rainfed region crop planning. The knowledge of total rainfall and its distribution throughout the year is extremely useful and important for better planning of cropping pattern, developing irrigation and drainage plans for an area. Here annual and Monthly rainfall trend analysis for Banka district has been undertaken.

By keeping above facts in mind, the present analysis has been carried out with the following objectives:

1. To study the annual rainfall trend in Banka districts of Bihar State.
2. To develop suitable strategy for increasing production and productivity in the district.

Materials and Methods

The present study is confined to Banka district is located in between latitude 24.7757° N and longitude 86.8220° E at an altitude of 85-247 meters above Sea level (MSL) having annual average rainfall of 1150 mm and area 3,019 km². Much of the information about the rainfall climatology of any region is mostly based on its availability and distribution. Crop planning strategies have been developed by using crop and weather data of the district. Rainfall data was analysed for a period of nineteen years (2000 to 2018) and area, production and productivity trend of some major field crops by using linear regression equation. Crop data required for analysis (1997-2017) was collected from the sites of Directorate of Economics and Statistics.

Rainfall Analysis

Time trend analysis

The time trend analysis was done by regression equation. This is also known as mathematical model for linear regression. On the basis of regression analysis, trend analysis was also done. The equation is

$$Y = a + bx$$

Where, Y = rainfall

b = slope

a = intercept and

x = year (time)

Crop analysis

Time trend analysis was done for assessment of the impact of rainfall on area, production, productivity in Banka district of Bihar for rice, wheat, maize, gram and lentil crops. Time trend analysis was done by using regression equation as mentioned above.

Results and Discussion

Trend analysis of annual rainfall pattern of Banka district

Rajegowda *et al.* (2009) [7] reported that the Karnataka state's mean annual rainfall was in decreasing trend from 1204 mm (in the first half century 1901-1950) to 1140 mm (during the second half the century 1951-2000). Singh and Dev (2012) [10] analysed the rainfall data and future trend for the period of 50 years (1959 to 2008) in Saharanpur region of Uttar Pradesh state which is showing the negative trend at present as well as in future projections also.

For trend analysis, the annual rainfall data of the Banka district are available from 2000 to 2018. By using the available data, the rainfall trend of a particular district was analysed through linear regression equation and plotted in a graph from which the increasing and decreasing trend of rainfall can be detected. From the graph, it is clearly shown that the annual rainfall trend for the district are coming out to be significant at five percent level of significance and showing a decreasing trend of annual rainfall with @ 30 mm per year (Fig.1). The time trend equations of annual rainfall from the data have been worked out and are shown below in Table 1.

Table 1: Time trend equation of annual rainfall for Banka district

Districts	Period	Equation	R^2
Banka	2000-2018	y = -30.047x + 1363.5	0.5107*

(*-significance at 5% level and **- significance at 1% level)

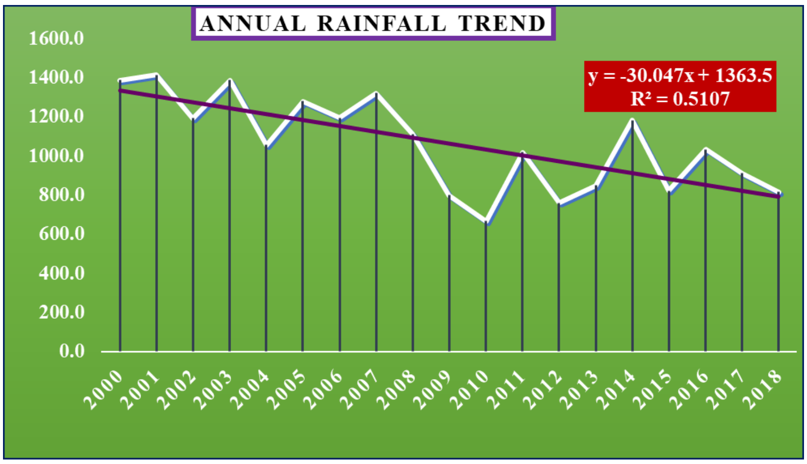

Fig 1: Graphical representation of Annual Rainfall trend for Banka district

For Chhattisgarh state, Baghel and Sastri (1992) [1] reported the decreasing trend in annual rainfall in some pockets. Chaudhary and Sastri (1999) [2] reported the decreasing trend of annual rainfall in Raipur, Durg, Bilaspur, Rajnandgaon and Raigarh districts and not only the quantum of rainfall, but also the number of rainy days was in decreasing trend during the cropping season. Later Sastri (2010) [9] again observed that the rainfall had decreased from 35 to 0 percent in different parts of the state during the period 1951-2000 as compared to the normal values of the period 1901-1950.

Analysis of area, production and productivity trend of major crops of Banka district:

Kumar *et al.* (2004) [5] studied the Impact of Climate on Indian Agriculture which is highly dependent on the spatial and temporal distribution of monsoon rainfall. The paper presents an analysis of crop–climate relationships for India, using historic production statistics for major crops (rice, wheat, sorghum, groundnut and sugarcane) and for aggregate food grain, cereal, pulses and oilseed production. In this paper the area, production and productivity trend for the Banka district was analysed for six major crops viz. Rice, Wheat, Maize, Gram, Lentil and Rapeseed/Mustard. The crop data required for its analysis was collected from the sites of Directorate of Economics and Statistics and time trend equation of area, production and productivity for the crops are shown in table 2, table 3 and table 4 respectively.

Rice is major crop in kharif season followed by maize and in rabi season, wheat occupies large area than other crops. Chickpea is the main rabi crop among pulse followed by lentil. A graphical representation of area covered under different field crops from 1999-2017 was given in Fig.2. In case of Paddy, more cropping area was found in past years as compare to recent year mainly due to availability of plenty of rainfall during cropping season for crop growth and development.

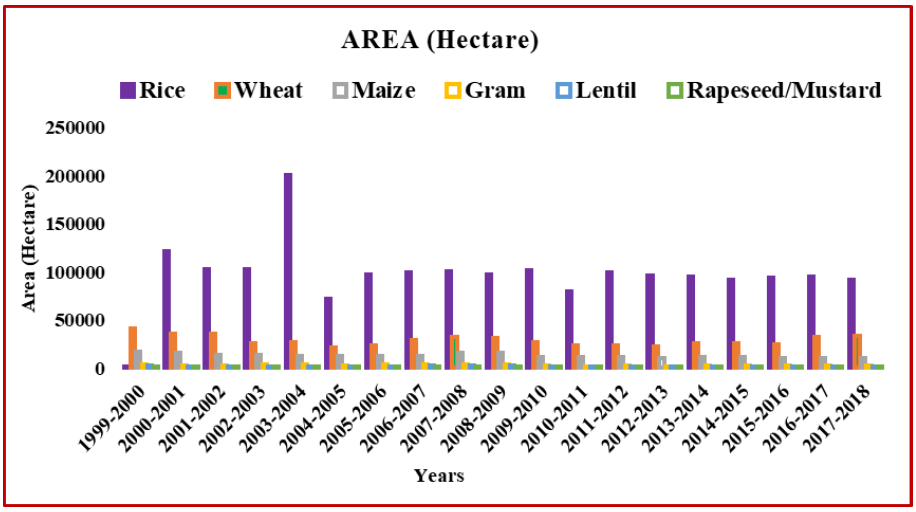

Fig 2: Area covered under different crops in past 18 years (1999-2017)

There was a non-significant decreasing trend of acreage of all major crops was found from the equation as in table 2 and it's mainly due to unusual monsoon behaviour as well as untimely and erratic rainfall which affect crop at any stage of its growth. From last two to three years, the district was suffering from severe drought situation mainly due to late unset of monsoon and monsoon break during middle of the cropping season that ultimately reduce crop production.

Table 2: Time trend equation of major crop acreage for Banka district

Crops	Periods	Banka district	
		Area	
		Equation	R^2
Rice	1997-2017	y = -164.72x + 99606	0.0009
Wheat	1997-2017	y = -175.25x + 30270	0.0447
Maize	1997-2017	y = -207.52x + 14875	0.396
Gram	1997-2017	y =-69.239x + 3843.9	0.380
Lentil	1999-2017	y =-38.782x + 2167.6	0.1285
Rapeseed/ Mustard	1997-2017	y =-20.326x + 896.25	0.1613

(*-Significant at 5% level and **-Significant at 1% level)

Production pattern of different crops are shown in Fig. 3. From the graph, it is revealed that the production pattern was found out to be increased against cropping area. In past year, although there was plenty of rainfall for cultivation, the district experienced a huge crop loss due to excessive rainfall at flowering and milking stage that responsible for further reduction in crop production. Highest rice production was found in the year 2011-12 (390622 tonnes) due to availability of ample amounts of water as well as proper management practices and lowest in the year 1999-2000 (235 tonnes) due to more heavy rainfall events at flowering stage leads to less production.

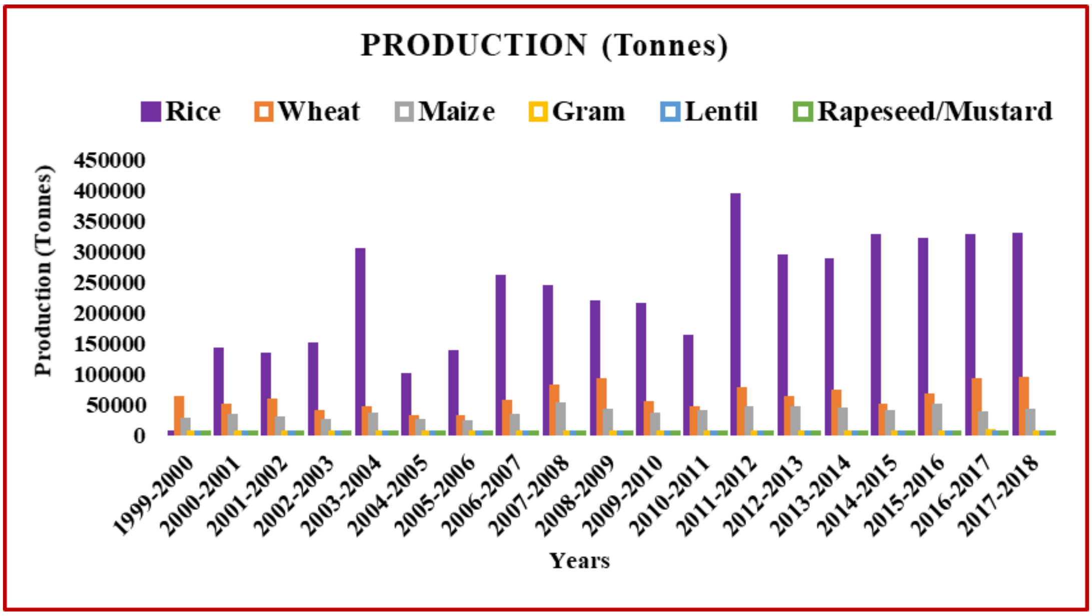

Fig 3: Production of different crops in past 18 years (1999-2017)

From the regression equation (Table 3), it can be well observed that the production of rice and maize crops has been increasing @ 11986 tonnes and @ 1248 tonnes per year but in rest of crops the value was found out to be non-significant.

Table 3: Time trend equation for production of major crops of Banka district

Crops	Periods	Banka district	
		Production	
		Equation	R^2
Rice	1997-2017	y = 11986x + 87844	0.5818**
Wheat	1997-2017	y = 1876.9x + 35208	0.3574
Maize	1997-2017	y = 1247.6x + 18222	0.5701**
Gram	1997-2017	y = 13.721x + 2405	0.0119
Lentil	1999-2017	y =12.798x + 1193.8	0.0177
Rapeseed/ Mustard	1997-2017	y =-6.2351x + 679.5	0.0109

(*-Significant at 5% level and **-Significant at 1% level)

The graphical representation of productivity of different crops are presented in Fig.4. Highest rice productivity was found in 2011-12 (3910 Kg/ha) due to availability of water at proper time at proper phenological stages of water scarcity and less crop loss at maturity stage.

Maximum productivity of maize crop was found in the year 2015-16 (4280 Kg/ha) including both kharif and rabi season.

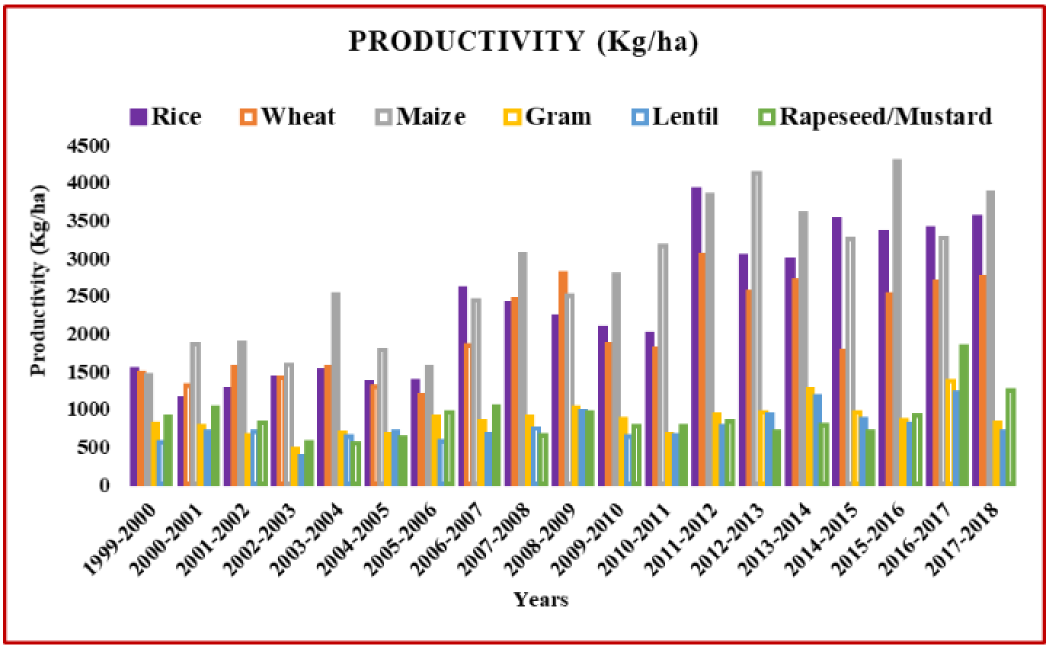

Fig 4: Productivity of different crops in past 18 years (1999-2017)

From the observed results, a significant increasing trend of productivity was found in all crops except rapeseed/mustard. The productivity of rice crop showed a statistically significant increasing trend (increasing @ 128.2 Kg/ha per year). This is mainly due to development of short duration high yielding varieties with less water requirement. The productivity of maize, wheat, gram and lentil crop was found out to be increasing @ 148 Kg/ha, 75.5 Kg/ha, 22.5 Kg/ha and 23 Kg/ha per year respectively due to application of improved technologies and timely weather information at district as well as block level.

Table 4: Time trend equation for productivity of major crops of Banka district

Crops	Periods	Banka district	
		Productivity	
		Equation	R^2
Rice	1997-2017	y = 128.26x + 858.67	0.7679**
Wheat	1997-2017	y = 75.494x + 1141	0.5923**
Maize	1997-2017	y = 147.9x + 993.62	0.8343**
Gram	1997-2017	y = 22.468x + 592.38	0.4372*
Lentil	1999-2017	y = 23.158x + 521.05	0.4089*
Rapeseed/ Mustard	1997-2017	y = 15.299x + 706.95	0.1167

(*-Significant at 5% level and **-Significant at 1% level)

The principal cropping pattern of the district is rice-wheat. However, gram, lentil, mustard and other crops are being grown after rice harvest under assured irrigation source. From the analysed crop data, Rice – Gram / Lentil, Rice – Maize, Rice –Wheat+ Rai, Rice – Gram+ Rai cropping system existing nowadays in the district. Majority of area remains fallow during summer season because of shortage of water.

Rainfall Based Crop Planning

Crops require soil moisture during the growth and development phase. The only source for soil moisture is rainfall under rainfed conditions. Since, crops depend on rainfall, they must be adjusted to a particular period during which rainfall is assured. Plenty of rainfall is noticed during the south-west monsoon in all parts of country with the exception of Tamil Nadu in the south and Jammu and Kashmir in the north, where considerable amount of rainfall is seen during the north-east monsoon. The distribution of rainfall in both the seasons is erratic and unpredictable. The whole year is divided into four seasons viz. south-west monsoon, post-monsoon, winter and summer or pre-monsoon which is coinciding with the agricultural seasons i.e. kharif, rabi and summer. The kharif season is nothing but the south-west monsoon or autumn while rabi coincides with post monsoon and winter seasons. In summer, the cultivable land under seasonal crops is kept fallow in many partss of the district. Almost all the field crops are sown or planted based on the onset of monsoon. The crops are never in shortage of water during the first crop season if monsoon is normal otherwise crops are grown under soil moisture stress even in kharif because the number of rainy days and the amount of rainfall received are less than that of the average rainfall and rainy days of a particular district.

Rainfall pattern is determining the suitability of crops and change in cropping pattern accordingly. As it is under rainfed area so, maximum amount of annual rainfall was received during the monsoonal months (June-September). About approximate 80 per cent of the total average annual rainfall concentrated in the south-west monsoon and received during a short span between June to September. Despite advance technology, still monsoonal rains influence the food grain production to a considerable extent. Kharif food grain production is adversely affected due to monsoon break or failure.

If there is well distributed rainfall in sufficient quantity then this stored water can be utilized to grow second crop in *rabi* season. This rainfall studies can help to plan conservation of excess water and its utilization during their peak requirement. The crops already sown with the advent of monsoon are also adversely affected due to dry spells, which result in soil moisture stress. The onset and withdrawal of monsoon influence the crop growing season and selection of crops to a large extent. Rainfall received during summer (March-May) season can be utilized for summer ploughing to make the land ready for final field preparation for rice crop.

Mostly farmers follow mono-cropping of rice but now a days inter-cropping, multiple cropping and double cropping have a great importance in agriculture for sustainable crop development. Inclusion of legumes in the cropping system is beneficial in many ways like legumes fix atmospheric nitrogen in root nodules and thus improve the nitrogen status of the soil. It saves upto 25% of recommended level of nitrogen application to the associated cereals when grown as inter-crop. The crop residues and root nodules of legumes release nitrogen during decomposition for the use of the succeeding crop.

In rabi season, few rains are received as a result of which almost all the crops suffer due to soil moisture stress if irrigation facilities are not available during rabi. Hence, irrigation facilities are pre-requisite to raise successful crop during rabi as well as summer.

Most of the farmers construct huge bunds in the rice fields and they impound this water for rice cultivation to avoid the uncertainty factor of monsoonal rainfall. This practice of making huge bunds often becomes adverse for rice crop seedlings as higher bunds submerge the rice seedlings and hence growing of tall, long duration, photo-sensitive varieties which can sustain higher water levels has become a traditional practice of rice cultivation in this area.

Harvesting and storage of excess rainfall received during period of south west monsoon season can be used in drought and dry spell situations as per intensity and frequency from year to year and good crop can be harvested. If there is well distributed rainfall in sufficient quantity then this stored water can be utilized to grow second crop in *rabi* season. The productivity level of crops has to be enhanced and sustained and this is possible only when efficient water management practices have been provided for the crops. These uneconomical crops will be replaced by the crops with good potential to achieve the sustainability and self-sufficiency.

Water conservation as well as water recharge are two important popularised practices to fulfill the required demand for water for irrigated agriculture. The approaches that support farming communities to self-mobilize and self-organize for participatory learning and action could lead farmers to enhance their uptake of better technologies and improved use of farm-level resources in the wake of increased climate change and variability (Mapfumo *et al*., 2013) [6].

Conclusion

From the present investigation, there was a significant decreasing trend of annual rainfall over a period of 2000-2018 in Banka district was observed which shows the water scarcity level of the district. In this district, rice is cultivated in 80% of area posing high risk of crop failure. Looking into the challenges in rainfed crop cultivation in Banka district of Bihar that our future agricultural planning must be taken into account of this rainfall. Short duration but high yielding varieties need to be developed in this region because as since last two to three years the district is suffering from Drought situation due to unusual monsoon behaviour and uneven distribution of rainfall. To cope with this climatic condition, we need to adjust our cropping pattern and cropping system accordingly. From this study, we concluded that day-by-day water get scared and with continuing this trend we will suffer a severe water scarcity condition. So, to avoid such situations we should apply some technologies that helps in rain water harvesting and ground water recharging.

Erratic climatic conditions and their variability with time play an important role in the crop production and overall yield. Most of the crop failures worldwide are associated with either a lack or excess of rainfall. Precise climate forecasting can reduce the risks of crop failure and also help in the pre and post decision making processes for better agricultural yield. Further the nature of the forecasting also influences the ability of farmers to respond like farmers are more concerned about within-season characteristics of rainfall rather than the amount of total seasonal rainfall. The value of forecasts diminishes if information is received after the number of pre-planting decisions are made, therefore the forecasting should be in time and specific.

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