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**Almaszabeen Badekhan**
Department of Agricultural Economics, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

**Mahantesh R Nayak**
Department of Agricultural Economics, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

**Corresponding Author:**
**Almaszabeen Badekhan**
Department of Agricultural Economics, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka, India

# Analysis of growth rate and yield instability of major crops of the northern dry zone of Karnataka

**Almaszabeen Badekhan and Mahantesh R Nayak**

**Abstract**
Karnataka state has the second largest area under rain-fed agriculture *i.e.,* 7.01 m.ha after Rajasthan. It is highly vulnerable to changing climate and its extreme climatic conditions threatening the food security of state. The Northern Dry Zone (NDZ) of Karnataka was purposively selected for the study as it was drought vulnerable and was affected by changing climate. The study was undertaken to examine the growth rate in area, production, and productivity of major crops of NDZ *i.e.,* four districts namely Bagalakote, Ballari, Koppal and Vijayapura districts over the period of 22 years (1997-2019). Maize and chickpea crops, Compund Annual Growth Rate (CAGR) was found to be significantly increasing in area and production whereas, productivity was found to be increasing significantly incase of rice and sorghum crops. Farmers were practiced of growing pulses as they were short-duration crops and drought tolerant by nature. Cropping intensity (CI) was increasing over the years in all dry districts to avoid crop failures and risks. Sesamum was found unsuitable crop to be grown in the Northern Dry Zone. Based on water availability, rice can be grown in the zone as the yield instability index is low.

**Keywords:** area, CAGR, CI, instability index, production, productivity

## Introduction

Agriculture sector continues to be an important source of income to the Indian economy and the most important sector for socio-economic development of the country. Two-thirds of the population is dependent on this sector and it accounts 19 percent of the country's GDP. It is not only a source of livelihood and food security for a large population of India but also has a special significance for low-income, poor and vulnerable sections. Green Revolution in India began in the 1960s which enabled the nation to make great achievements in domestic food production and contributed to progress in agriculture and allied sectors significantly. India has achieved self-reliance in the production of food grains in the last several decades, and it is a mammoth achievement for our agriculture sector as well as the overall economy. India is one of the largest rice, wheat and sugar producing country and also inching towards self-reliance in pulse production. As per the 4$^{th}$ Advance Estimates, the production of food grains in the country is estimated at 315.72 million tonnes which is higher by 4.98 million tonnes than the production of food grains during 2020-21(Mukherjee *et al.,* 2022) [11].

Although India has attained self-sufficiency in food staples, the productivity of its farms is below that of Brazil, the United States, France and other nations. Indian wheat farms, for example, produce about a third of the wheat per hectare per year compared to farms in France. Rice productivity in India was less than half that of China. Several studies suggest India could eradicate its hunger and malnutrition and be a major source of food for the world by achieving productivity comparable with other countries. The area and production of agricultural crops is dependent on rainfall, and its temporal and spatial distribution of southwest and north east monsoon and also other factors like availability of good quality seeds, fertilisers, labour, pesticides, minimum support prices (MSP), price expectations and procurement policy of government. Whereas, agriculture in Karnataka is mostly rainfed as opposed to irrigated, making it highly vulnerable to expected changes in the monsoon (Kumar *et al*., 2016) [9]. In the Agriculture sector, a net decline of 2.5 percent in agricultural production has been projected over the next two to five decades with a major reduction in coastal regions (Anonymous, 2012) [3]. Therefore an attempt has been made by observing the past studies to study the growth rate and yield instability of major crops of the Northern Dry Zone of Karnataka.

## Methodology

Karnataka State is divided into four regions namely South Interior Karnataka, North Interior Karnataka, *Malnad*, and Coastal Karnataka. These are further divided agro-climatic zones by UAS, Bengaluru under the NARP program in 1960's based on rainfall distribution, irrigation pattern, soil characteristics, cropping pattern, and other physical and social characteristics. Among these agro-climatic zones (Table 1) there are five dry zones with relatively low rainfall and high erratic distribution. The five dry zones cover the major area with 107 taluks while the three transitional zones cover only 35 taluks in the state. The Hill and Coastal zones cover 21 and 13 taluks respectively. Among these zones, the Northern Dry Zone was purposively selected for the study because it was mainly affected by changing climate and the drought vulnerability which was found to be 81.00 percent, which comes under a very high vulnerable class according to the report published by Karnataka State Natural Disaster Monitoring Centre (Anonymous, 2017) [2]. It was also having largest area of 4.78 m.ha. and comprises 35 taluks. The annual rainfall ranges from 464.5- 785.7 mm. The elevation ranges between 450- 900 meters. The soils are shallow to deep black clay soils.

Secondary data pertaining to area, production, productivity and cropping intensity were collected from the Directorate of Economics and Statistics, Bengaluru, and respective district offices. Data was collected for Bagalakote, Ballari, Koppal and Vijayapura districts. These districts cover 63 percent (22 taluks out of 35 taluks) of Northern Dry Zone area. Although there were certain limitations (COVID- pandemic) for the collection of secondary data. Data based assessments such as the authenticity of data, data inconsistency, or data gaps provide a useful means of assessment at the macro level.

Analytical tools employed in the study were as follows:

### a. Compound Annual Growth Rate (CAGR)

The exponential compound annual growth rates were estimated by using log-linear functions on the time series data. That is, the growth rate is estimated by using the following semi-log functional form:

$\log Y_t = a + bt$............................ (1)

**This equation (1) can be elaborated in detail as**

$Y_t = Y_o (1+r)^t$....................... (i)

Taking log on both sides, we get

$\log Y_t = \log Y_o + t \log (1+r)$................. (ii)

Equation (ii) can be rewritten as

$Y = a + bt$............................ (iii)

Where

$Y = \log Y_t$;

$a = \log Y_o$;

$b = \log (1+r)$, In equation (iii)

$Y_t$= time series variable

a= constant

t= Time variable in year (1, 2, 3……….n)

b= Regression Coefficient that shows the rate of change or growth rates in a series

**The annual compound growth rate (s) can be worked out by using**

Antilog (b) =Antilog (log (1+r)).

Antilog (b) =1+r and r = Antilog b-1

When multiplied by 100, it gives the percentage growth rate of that time series variable. That is, Compound Annual Growth Rate

(CAGR) (%) = r = (Antilog B-1) x100.

By applying Regression, we get the p-value to check the significance of CAGR value.

### b. Yield instability index

This index was originally developed by John Cuddy and Della valle for measuring the instability in time series data in 1978. This index is a better measure compared to coefficient of variation, as it is inherently adjusted for trend, often observed in the time series data. This measure includes instability as a component of all cyclical fluctuations present in the time series data, whether regular or irregular, as well as any component which could be defined as white noise. The instability in the yield of the crop was calculated by

$$CD = C.V\sqrt{(1-R^2)}$$

Where,

CD= Cuddy-Della valle index

C.V= Co-efficient of Variation

$R^2$ = ESS/TSS i.e., Ratio of explained variation to total variation

ESS= Variation explained by explanatory variable

TSS= Total variation

### c. Cropping Intensity (CI)

Cropping intensity can be defined as gross cropped area divided by net cropped area are multiplied by 100.

$$CI = \frac{\text{Gross cropped area (ha)}}{\text{Net cropped area (ha)}} \times 100$$

## Results and Discussions

Compound Annual Growth Rates (CAGR) of major crop's area, production, and productivity was calculated for four Northern Dry Zone districts *i.e.*, Bagalakote, Ballari, Koppal, and Vijayapura from the year 1998-1999 to 2018-2019 (table 2).

In Bagalakote district, the area and production under rice was decreasing significantly at the rate of 9.49 and 7.19 percent respectively. The sorghum crop, area and production was found to be decreasing over the years significantly in Bagalakote, Ballari, Koppal, and Vijayapura districts at different levels of significance. But it was observed that sorghum crop's productivity had increased positively and significantly in Bagalakote (1.40%) and Vijayapura (1.38%) districts. Even though the area and production of cereal crops were low, productivity was high due to use of high-yielding varieties and intensive cropping in study area. Maize crop's area and production was showing a positive growth rate over the years, it was found replacing area and production of other cereal crops. Maize was a preferred and desired crop of study area, and suited the climatic conditions. Finger millet crop was grown only in Ballari district with negative growth rate in area of 1.26 percent. The CAGR value in case of pulse crops showed that, Chickpea crop was the trending crop in area as well as production for all four districts. It was also found that, chickpea crop productivity was decreasing minimally in Bagalakote and Vijayapura dry taluks, with significant CAGR value of 0.90 and 0.69 percent respectively. Chickpea crop productivity was decreased may be due to the scarcity water. Blackgram crop was grown only in Ballari district with negative growth rate in area of 5.25 percent. Farmers were found growing pulses as an alternative coping strategy as they were short-duration crops and drought tolerant by nature. The CAGR values in the case of major oilseed crops, productivity of safflower crop was showing a significant negative growth rate in Bagalakote (CAGR=4.20%) and Vijayapura dry taluks (CAGR=3.4 7%). The cotton crop, area and production was showing significant negative growth rate of 12.18 and 9.64 percent percent over the years in Bagalakote district. Whereas, cotton crop productivity was increasing significantly at the rate of 2.90 in Bagalakote district. The main reason for decrease in area of major crops may be due to changes in climate like droughts and floods. Farmers were found practicing intensive cultivation *i.e.*, the crop spacing is reduced, intercropping or mixed cropping *etc*. Thus, the land area under crops seemed to decrease due to the diversification of crops. The main issues regarding decreasing the productivity were decrease in farm holdings, dependence on monsoon, inadequate irrigation facilities, loss of soil nutrients, lack of access to modern technology and agricultural credit. Similar results were found with Meena *et al.* (2009) [10] and Agarwal (2013) [1]. Whereas, decrease in production of major crops was also due to changes in climatic parameters like rainfall, temperature and relative humidity. These changes caused weed and pest infestation due to crop diversification. The unavailability of labor and need for irrigation water may be the other reasons. Similar results were reported by Raychaudhuri *et al*. (2015) [12] in the study titled "Impact of Climatic Variability on Crop Production in the Mahanadi Delta Area of Orissa". Similar results were found in studies conducted by Kumar *et al.* (2014) [8] and Delince *et al*. (2015) [5] on the decrease in crop productivity due to changes in climate.

## Cropping Intensity of Northern Dry Zone

Cropping Intensity (CI) for Northern Dry Zone districts was calculated from the year 1998-99 to 2018-2019 and was presented in table 2. The Cropping Intensity ranged from 100.21 to 95.52 percent. The highest Cropping intensity was in Bagalakote district in the year 2003-2004. *i.e.*, 122.54 percent and the lowest was of Vijayapura district *i.e.*, 100.21 percent in the year 2018-2019. Cropping intensity was found to be increasing in districts to avoid crop failures and risks due to changes in climate. Similar results were reported by a review article by Iizumi and Ramankutty (2015) [6] on how do weather and climate influence the cropping area and intensity.

## Yield instability index of crops of Northern Dry Zone

Yield instability index of major crops was calculated using the Cuddy-Della index from the year 1998-2019 as shown in table 3. The average yield instability indices for Northern Dry Zone major crops, the highest yield instability index was of sesamum (38.09) whereas the lowest incase of rice crop (5.21). Sesamum was found less suitable crop to be grown in the Northern Dry Zone. However, based on water availability, rice can be grown in the zone as the yield instability index was low.

In Bagalakote district, the highest yield instability index among cereals, pulses and oilseed crops were sorghum (31.49), greengram (67.67) and linseed (47.90) whereas lowest yield instability index crops were wheat (12.99), chickpea (30.04) and groundnut (18.81). Cotton and sugarcane yield instability index was 24.62 and 24.38 respectively. Sorghum had the highest yield instability index due to intensive cultivation or use of low yielding varieties. Greengram and linseed were found less suitable crops in Bagalakote district. The highest yield instablity index of among cereals, pulses and oilseed crops in Ballari district were finger millet (34.08), horsegram (35.97) and sesamum (61.93) whereas lowest yield instablity index crops were rice (7.03), blackgram (23.73) and soyabean (18.32). Yield instability index in cotton and sugarcane was 32.60 and 18.34, respectively. Wheat, horsegram, and sesamum were found less suitable crops in Ballari district. In Koppal district, the lowest yield instability index among cereals, pulses and oilseed crops crops were rice (8.78), pigeon pea (34.95) and groundnut (21.89) whereas the highest yield instablity index crops were pearl millet (59.29), green gram (90.16) and sesamum (51.61). Yield instability index in cotton and sugarcane was 33.35 and 15.19 respectively. Pearl millet, green gram, and sesamum were less suitable crops in Koppal districts. The highest yield instability index among cereals, pulses and oilseed crops in Vijayapura district were rice (32.68), green gram (66.78) and sesamum (48.88) whereas lowest yield instability index crops were sorghum (20.27), chickpea (27.85) and niger (16.41). Yield instability index in cotton and sugarcane was 24.11 and 19.45 respectively. Rice, greengram, and sesamum were less suitable crops in Vijayapura dry taluks. Reasons for less suitability of crops in the Northern Dry Zone due to climatic parameters like droughts, floods, extreme temperatures and desirability of farmers. Similar results were found in the studies of Deb and Pramanik (2015) [4] and Krishnan and Chanchal (2014) [7].

**Table 1:** Agro climatic Zones of Karnataka

| Sl. No. | Agro climatic zones | Area (m.ha) | Percentage share to total area (%) | Normal annual rainfall (mm) |
|---|---|---|---|---|
| 1 | Northern Dry Zone | 4.78 | 25.11 | 464.50-785.70 |
| 2 | Central Dry Zone | 1.94 | 10.19 | 453.50-717.70 |
| 3 | Eastern Dry Zone | 1.81 | 9.51 | 679.10-888.90 |
| 4 | North Eastern Dry Zone | 1.76 | 9.24 | 633.20-806.60 |
| 5 | Southern Dry Zone | 1.74 | 9.14 | 670.60-888.60 |
| 6 | Southern Transition Zone | 1.22 | 6.41 | 611.70-1053.90 |
| 7 | Northern Transition Zone | 1.19 | 6.25 | 619.40-1303.20 |
| 8 | Coastal Zone | 1.17 | 6.14 | 904.40-3695.10 |
| 9 | North Eastern Transition Zone | 0.87 | 4.57 | 830.00-890.00 |
| 10 | Hilly Zone | 2.56 | 13.45 | 904.40-3695.10 |

***Source***: http://wgbisathe boutet.in/energy/paper/TR109/tr109_anne,xure2.htm

**Table 2:** Compound annual growth rate analysis of area, production and productivity of major crops of northern dry zone (1998-2019) (ha)

| Particulars | Crops | CAGR (%) of dry taluks | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bagalakote | | | Ballari | | | Koppal | | | Vijayapura | | |
| | | Area (ha) | Production (tonnes) | Productivity (tonnes/ha) | Area (ha) | Production (tonnes) | Productivity (tonnes/ha) | Area (ha) | Production (tonnes) | Productivity (tonnes/ha) | Area (ha) | Production (tonnes) | Productivity (tonnes/ha) |
| Cereals | Rice | -9.49* | -7.19* | 2.54 | 2.56 | 3.45 | 0.86 | -0.26 | -0.41 | -0.16 | -3.66 | 1.29 | 5.14 |
| | Sorghum | -2.74 | -1.37* | 1.40* | -5.65* | -3.46** | 2.32 | -3.63** | -3.12* | 0.53 | -4.66 | -3.34* | 1.38* |
| | Pearl millet | -2.69 | 0.27 | 3.05 | -9.39 | -11.72 | -2.57 | 0.54 | 6.77 | 6.2 | -4.28 | -2.89 | 1.45 |
| | Maize | 3.11* | 4.38* | 1.23 | 5.97** | 5.47** | -0.47* | 11.38* | 8.87* | -2.26* | 10.16** | 11.21 | 0.96 |
| | Finger millet | -- | -- | -- | -1.26 | -1.01 | 0.25 | -- | -- | -- | -- | -- | -- |
| | Wheat | 0.1 | 0.13 | 0.04 | -14.80* | -15.27 | -0.56 | -5.13 | -1.28 | 4.06 | -1.02 | -0.69 | 0.33 |
| Pulses | Pigeon pea | 9.61 | 10.67 | 0.97 | -0.85 | 1.16 | 2.02 | 2.18 | 6.09 | 3.83 | 18.44* | 20.9 | 2.08 |
| | Blackgram | -- | -- | -- | -5.25 | -2.64 | 2.75 | -- | -- | -- | -- | -- | -- |
| | Horsegram | -10.75** | -12.03* | -1.43 | -9.65 | -7.60* | 2.26 | -2.38 | -1.12 | 1.29 | -19.31* | -20.69** | -1.71 |
| | Greengram | 5.98 | 6.2 | 0.21 | -16.71 | -15.42 | 1.55 | 5.44 | 2.75 | -2.55 | -6.26 | -8.19 | -2.07 |
| | Chickpea | 10.93* | 9.93* | -0.90* | 7.54* | 7.19 | -0.33 | 11.20** | 12.92* | 1.54 | 10.13* | 9.37 | -0.69* |
| Oilseeds | Groundnut | 1.23 | 1.78 | 0.54 | -2.08 | -0.06 | 2.07 | -2.93 | -1.85 | 1.12 | -3.4 | -1.86 | 1.59 |
| | Castor | -- | -- | -- | -9.39 | -11.72 | -2.57 | -7.76 | -8.88 | -1.21 | -- | -- | -- |
| | Sesamum | -9.72 | -9.88 | -0.17 | -16.84 | -13.14 | 4.45 | -3.33 | -0.79 | 2.63 | -10.17 | -11.14 | -1.08 |
| | Linseed | -8.51 | -12.02 | -3.84 | -- | -- | -- | -9.7 | -10.4 | -0.78 | -17.87 | -19.14 | -1.55 |
| | Soybean | -3.15 | -0.61 | 2.63 | 0.63 | 0.11 | -0.51 | -- | -- | -- | -- | -- | -- |
| | Nigerseed | -- | -- | -- | -17.1 | -18.44 | -1.62 | -7.98 | -4.04 | 4.28 | -15.62 | -12.98 | 3.13 |
| | Sunflower | -4.87 | -3.09 | 1.87 | -8.91 | -4.69 | 4.63 | -2.39 | 0.78 | 3.25 | -11.34 | -8.85 | 2.81 |
| | Safflower | -9.42 | -13.23 | -4.20* | -25.46 | -25.45 | 0.02 | -10.56 | -12.32 | -1.97 | -10.52 | -13.62 | -3.47** |
| Commercial Crops | Cotton | -12.18* | -9.64** | 2.90* | 1.73 | 7.83 | 6 | -3.8 | 0.61 | 4.58 | 6.48 | 8.48 | 1.88 |
| | Sugarcane | -4.87 | -3.09 | 1.87 | 0.63 | 0.11 | -0.51 | 0.36 | 0.77 | 0.4 | 6.73 | 6.07 | -0.63 |
| Horticulture crops | Fruits and Vegetables | -1.32 | 2.65 | 2.23 | -2.12 | 3.11 | 2.54 | 0.66 | 1.27 | 0.84 | 0.85 | 1.11 | 0.56 |

***Source***: DES, Bengaluru,(1998-2019) ***, ** and * indicate significance at the one, five and ten percent level respectively

**Table 3:** Cropping Intensity of Northern Dry Zone from 1998 to 2019

| District dry taluks | Bagalakote | Ballari | Koppal | Vijayapura | Average |
|---|---|---|---|---|---|
| 1998-99 | 117.15 | 114.54 | 118.09 | 103.18 | 113.24 |
| 1999-00 | 112.19 | 112.09 | 114.12 | 103.74 | 110.54 |
| 2000-01 | 115.79 | 111.50 | 113.48 | 104.08 | 111.21 |
| 2001-02 | 115.84 | 112.11 | 113.42 | 104.42 | 111.45 |
| 2002-03 | 116.74 | 109.21 | 110.34 | 102.22 | 109.63 |
| 2003-04 | 122.54 | 106.42 | 106.44 | 102.00 | 109.35 |
| 2004-05 | 119.69 | 109.07 | 109.22 | 101.47 | 109.86 |
| 2005-06 | 121.82 | 105.49 | 105.94 | 101.22 | 108.61 |
| 2006-07 | 119.89 | 104.24 | 105.30 | 101.55 | 107.74 |
| 2007-08 | 115.17 | 105.22 | 106.10 | 101.77 | 107.06 |
| 2008-09 | 116.32 | 104.11 | 104.85 | 103.03 | 107.08 |
| 2009-10 | 113.24 | 105.69 | 105.99 | 102.30 | 106.81 |
| 2010-11 | 107.46 | 108.58 | 109.88 | 102.03 | 106.99 |
| 2011-12 | 109.98 | 109.56 | 111.85 | 103.10 | 108.62 |
| 2012-13 | 109.87 | 113.85 | 115.53 | 102.14 | 110.35 |
| 2013-14 | 110.15 | 116.80 | 117.86 | 101.71 | 111.63 |
| 2014-15 | 109.76 | 116.82 | 118.98 | 102.12 | 111.92 |
| 2015-16 | 106.95 | 115.38 | 118.14 | 102.54 | 110.75 |
| 2016-17 | 107.12 | 115.37 | 115.13 | 101.16 | 109.70 |
| 2017-18 | 107.22 | 114.59 | 114.43 | 101.47 | 109.43 |
| 2018-19 | 107.91 | 104.87 | 106.09 | 100.21 | 104.77 |

***Source***: DES, Bengaluru (1998-2019)

**Table 4:** Yield instability index of crops of Northern Dry Zone (1998-2019)

| Particulars | Crops | Bagalakote | Ballari | Koppal | Vijayapura | Average |
|---|---|---|---|---|---|---|
| Cereals | Rice | 13.86 | 7.03 | 8.78 | 32.68 | 5.21 |
| | Sorghum | 31.49 | 22.14 | 40.11 | 20.27 | 15.56 |
| | Pearl millet | 30.42 | 23.91 | 59.29 | 24.77 | 18.67 |
| | Maize | 13.52 | 14.47 | 25.63 | 18.87 | 8.89 |
| | Finger millet | -- | 34.08 | -- | -- | 34.08 |
| | Wheat | 12.99 | 31.49 | 52.01 | 15.46 | 15.35 |
| Pulses | Pigeon pea | 46.3 | 26.51 | 34.95 | 30.79 | 17.22 |
| | Blackgram | -- | 23.73 | -- | -- | 23.73 |
| | Horsegram | 53.07 | 35.97 | 38.02 | 37.09 | 22.6 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Greengram | 67.17 | 32.63 | 90.16 | 66.78 | 27.26 |
| | Chickpea | 30.04 | 23.86 | 47.62 | 27.85 | 13.91 |
| Oilseeds | Groundnut | 18.81 | 39.87 | 21.89 | 20.84 | 14.57 |
| | Castor | -- | 20.46 | 44.9 | -- | 32.68 |
| | Sesamum | 41.44 | 61.93 | 51.61 | 48.88 | 38.09 |
| | Linseed | 47.9 | -- | 46.12 | 41.14 | 26.62 |
| | Soybean | 22.87 | 18.32 | -- | -- | 20.59 |
| | Niger | -- | 22.23 | 36.47 | 16.41 | 25.03 |
| | Sunflower | 28.62 | 26.55 | 35.13 | 39.92 | 18.55 |
| | Safflower | 47.3 | 69.31 | 47.6 | 38.39 | 31.15 |
| Commercial crops | Cotton | 24.62 | 32.6 | 33.35 | 24.11 | 22.06 |
| | Sugarcane | 24.38 | 18.34 | 15.19 | 19.45 | 9.79 |
| Horticultural crops | Fruits and vegetables | 15.69 | 20.86 | 12.31 | 10.40 | 14.81 |

***Source*:** DES, Bengaluru (1998-2019)

## Conclusions
Maize and chickpea crops were replacing area and production of major cereal crops like rice, sorghum, bajra, pigeonpea, greengram etc because of its desirability and suited climatic conditions. Maize and chickpea crop productivity was found low due to the scarcity of water in some dry-zone districts. Farmers found growing pulses as an alternative coping strategy as they were short-duration crops and drought tolerant. Cropping intensity was found to be increasing in dry-zone districts to avoid crop failures and risks. Based on Yield instability index, Sesamum had the highest instability index in four dry districts of Northern Dry Zone, thus it is an unsuitable crop for the zone. Farmers of the Dry Zone should be encouraged to raise other cereals and pulse (excluding maize and chickpea) otherwise this will affect the food security of the state. Appropriate strategies to sustain area and production in cereal crops is necessary. Some important drought resistant varieties suited for the zone collected while interviewing farmers were CSH-19R and CHS15R (sorghum), DHM-121 (maize), HHB-67 (pearl millet), ICPL332WR and hanuma (pigeonpea), Vikash, Vijay and Pusa 362 (Chickpea) and Girnaril (groundnut). Agriculture extension system should assist farmers in having weather based crop plans and contingent plans.

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