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Study on Crop Diversification Based on Long Term Rain Fall Analysis of Dry Farming Tracts in Southern India

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Authors' contributions

This work was carried out in collaboration among all authors. Author SM contributed to the manuscript's collection and writing. Authors SK and PS did the data collection. Author GJ helped in the preparation of some figures data plotting. All authors read and approved the final manuscript.

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ABSTRACT

This study was conducted based on 30 years of rainfall data from 1985 to 2015 from the regions of semiarid districts of Karnataka, Telangana and Rayalaseema region of Andhra Pradesh states to recommend the alternate crops. This is based on the rainfall variability and potential evapotranspiration (PET) in kharif and rabi seasons. Moisture-sensitive crops, especially rice, sugarcane and banana must be taken in high rainfall areas and low moisture-sensitive crops can go at the time of rainfall shortages and vice versa to avoid farm risk at farm level and optimizing production. The crops which are suggested based on rainfall and PET can thrive well, grow very efficiently and give reasonable yields to farmers under limited rainfall situations and these are of drought-tolerant and drought resistant and short-duration types. In the rabi season, most of these regions received less rainfall (<200 mm), particularly in Telangana and the North interior Karnataka

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regions. Under this situation, avoiding more water demanded crops like cotton and sunflower crops. Instead of these crops, less water required short -duration and drought tolerant Bengal gram and Cowpea crops were suggested. These crops can survive well and give good optimum yields without crop failures.

Keywords: Diversification; drought resistant; potential evapotranspiration; rainfall.

1. INTRODUCTION

"Crop diversification: It refers to the addition of new crops or cropping systems to agricultural production on a particular farm, taking into account the different returns from value-added crops with complementary marketing opportunities" [1]. "Crop Diversification refers to a shift from the regional dominance of one crop to regional production of a number of crops, to meet ever increasing demand of cereals, pulses, vegetables, fruits, oilseeds, fibres, fodder, grasses etc. It aims to improve soil health and to maintain dynamic equilibrium of the agro-ecosystem. In the instant case, crop diversification is intended to promote technological innovations for sustainable agriculture and enable farmers to choose crop alternatives for increased productivity and income" (crop diversification programme 2013-14).

Traditionally, diversification was used more in the context of a subsistence kind of farming wherein farmers grow many crops on their farms. Farmers all over the world, especially in the developing countries, try to grow various crops in their holdings in an agricultural year. The level of crop diversification largely depends on the geo-climatic/socio-economic conditions and technological development in a region. Moreover, rich farmers prefer to specialize in agricultural enterprises, while the poor and subsistent farmers are generally more interested in diversification of crops [2-6].

"Under weather uncertainty and almost exclusive dependence of small holders on rainfall for productivity, several studies have investigated the nature and degree of crop riskiness in relation to the presence of production and market risks" [7-9]. It should be noted, however, that these earlier studies either rely on subjective measures of the riskiness of the crops or focus on selected major crops. An objective way of measuring the riskiness of individual crops and aggregating them (in a multiple-crop setting) allows a more accurate measurement of the contribution of individual crops to the riskiness, incorporating the mutual interdependence across crops at a farm-household level. It was also observed that costly risk-coping mechanisms were commonly adopted in response, leading to the recommendation that "livelihood diversification programmes be scaled up to reduce dependency on agriculture-based activities in view of climate shocks" (VAC, 2015).

"Diversification means taking on less profitable but less risky crops. It is an example of conservative crop production strategies and one such risk coping mechanism" [10]; (Morduch, 2002). "Diversification is especially important to hedge against weather risk" [11]. "In a pioneering study of crop choices under multivariate risk, Fafchamps [7] showed that crop diversification, which is a characteristic feature of small farmers in developing countries, is a response to high variance in food prices and other risks that they are poorly insured against. Similarly, using data from the Punjab area of Pakistan", Kurosaki Fafchamps [7] demonstrated that "farmer crop choices are dependent on price and yield risk. Crop diversity, crop sequencing or rotation [12,10], and intercropping [13] are all traditional methods for increasing soil productivity (renewing soil nutrients) and maximising return from cultivated land in uncertain conditions. Farmers also commonly plant varieties that mature earlier in the season (short-season crops) and protect crops from moisture shortages and yield loss". Di Falco and Chavas [14] showed that "greater diversity can reduce the risk of crop failure". Seo and Mendelsohn [15] and Kurukulasuriya and Mendelsohn [11] also looked at "the climate sensitivity of crop choices. Using cross-country data from Latin America and Africa, understanding household-level crop choices can generate important information about how farm households change the riskiness of their crop composition in reaction to weather-related risk". Haile [3] showed that "Ethiopian farmers choose crops most suited to a specific rainfall condition as a strategy for coping with unpredictable rainfall". "In times of low rainfall, farmers predominantly choose moisture- and stress-tolerant crops and not moisture-sensitive crops. All aspects of food security may be potentially threatened by the effects of changes in climate, which will include food availability, access, utilization, and stability" (e.g., Challinor et al., 2010); IPCC, [16].

"The semi-arid tropics are characterised by low and highly variable rainfall in space and time, limiting potential crop yields in these areas" [17]. Very few studies have tried to quantify the spatial and temporal variability of rainfall in the semi-arid tropics. The high degree of rainfall variability, when combined with the relatively low asset base of most rural households, restricts household crop management strategies and overall crop water productivity.

Karnataka:

"Agriculture plays an important role in the overall growth of Karnataka's economy, despite a fall in its share of the state's gross domestic product. It is characterised by wide crop diversification and remains highly dependent on the vagaries of the southwest monsoon. Rainfall plays an important role in crop production in Karnataka, where more than 70 percent of the cropped area is rainfed. Districts like Bijapur, Bellary, Bagalkot, Koppal, Gadag, Raichur, and Chitra Durga can be classified as low rainfall districts where the average annual rainfall (1998–2010) is less than 650 mm. The normal number of rainy days varied from less than 40 in low rainfall districts to more than 80 in high rainfall districts" (Economic survey of Karnataka 2011–12).

Telangana:

Telangana is a semi-arid area and has a predominantly hot and dry climate. Over 80% of the original forest cover has been cleared for agriculture, timber harvesting, or cattle grazing. The more humid Eastern__Highlands'__moist deciduous_forests cover the Eastern_Ghats in the eastern part of the state. With improved agricultural technology, cropping system diversity has decreased from 23 to 10 crops in the kharif (monsoon) season. These changes are also associated with a shift from intercropping to monocrop-based systems. The results indicate that these changes in cropping systems have resulted in a decreased management of production risk with increased investments in agriculture and less flexibility in the decision-making process on crops [18,19]. Because of the differences in agro-ecology, socioeconomic characteristics, and resource availability, these regions must be distinguished in order to determine their agricultural development strategies.

1.1 Objectives of the Study

State the meaning of diversification in agriculture;

Explain How rainfall trend varies in semi-arid regions of Karnataka, Telangana and Rayalaseema.

Discuss the effect of diversification on soil health and water resources, the sustainability of production.

Suggesting crops Based on Rainfall amount, Potential Evapotranspiration and water requirement values of different crops.

1.2 Diversification Opportunities in Indian Agriculture

Suitability of the agro-climatic situation Availability of appropriate technology some remunerative avenues of diversification:

1. Diversification through pulses and oilseeds
2. Diversification with fodder crops
3. Diversification with horticultural crops
4. Diversification with medicinal and aromatic plants

Climate change is projected to cause increased temperatures and altered precipitation in the near future. Moreover, the weather extremes are also projected to increase in the future, which can have a detrimental effect on agricultural yields [20].

Crop diversification is recognised as an effective mitigation and adaptation strategy (Lakhran et al. 2017).

Climate shocks can be mitigated through crop diversification, and the benefits of adaptation are more visible in the long run [21].

Monocropping cultivation, combined with increased fertiliser and pesticide use over the years, has resulted in deteriorating soil health, increased insect pest infestation, and yield stagnation in some crops. This necessitates the diversification of crops so as to ensure the income stability of the farmers through the reduction of production and market risk [22,23]. Crop diversification has proven useful in maintaining soil health and biodiversity and ensuring sustainability in the arena of climate change.

2. MATERIALS AND METHODS

The study was conducted in semi-arid regions of Telangana, Karnataka states, and the Rayalaseema region of Andhra Pradesh for the period 1985 to 2015. Telangana, a state on the south-eastern coast of India, has a net cropped area of 4.5 million hectares, of which 2.5 million hectares (56% of the net cropped area) are under rainfed agriculture (Directorate of Economics and Statistics 2011). Telangana is located between latitudes 18.1124^{0}N and 79.0193^{0}E longitudes; Rayalaseema is located between latitudes 15.7722^{0}N and 78.0641^{0}E longitudes; and Karnataka is located between latitudes 15.3173^{0}N and 75.7139^{0}E longitudes. Quantitative Analysis: A 30-year rainfall data set (1985–2015) is used to compute seasonal rainfall in Telangana and Karnataka states, as well as the Rayalaseema region of Andhra Pradesh, from the Hydrology Section at IMD Pune. Each district trend was taken from each region, and the tendency of the trend was taken using Microsoft Excel. Drought severity is conventionally assessed by drought indices. A powerful drought index, the Reconnaissance Drought Index (RDI), is gaining wide acceptance, mainly in the arid and semiarid climatic regions. It is achieved by potential evapotranspiration and precipitation. Potential evapotranspiration was calculated with the Penman and Monteith equations. Based on the values of precipitation and potential evapotranspiration, appropriate crops were suggested. Soil condition, moisture holding capacity, texture details, and the minimum water requirement of crops to complete their life cycle for a season are collected from CRIDA (the Central Research Institute for Dryland Agriculture).

3. RESULTS AND DISCUSSION

Based on 30 years of rainfall data from the regions of semiarid districts of Karnataka, Telangana, and the Rayalaseema region of Andhra Pradesh states, the following trends were observed in corresponding regions: The rainfall trends of different districts of south interior Karnataka during the *kharif* season, i.e., Chickmangalore, Mysore, Kodagu, Hassan, and Chitradurga, showed an increasing trend, whereas Shivamogga, Bangalore urban, and Chamarajanagar districts showed a decreasing trend. Kolar, Tumkur, and Bangalore rural districts showed no trend. In the *Rabi* season, Kolar, Tumkur, and Mysore districts showed an increasing trend, whereas Shivamogga district showed a decreasing trend. There was no trend in the remaining districts of southern interior Karnataka. The rainfall trends of different districts of north interior Karnataka during the *kharif* season, i.e., Haveri, Gadag, Gulbarga, and Koppal districts, showed an increasing trend, whereas decreasing trends were observed in Raichur, Dharwad, Bidar, and Belgaum districts. Bagalkot and Bijapur districts showed no trend. During the *rabi* season, Koppal and Belgaum districts showed an increasing trend, but Haveri, Raichur, Gulbarga, Dharwad, Bidar, and Bijapur districts showed a decreasing trend. Gadag and Bagalkot districts showed no trend. In terms of rainfall trends in different districts of Rayalaseema during the *kharif* season, Anantapur district showed a decreasing trend and Kurnool district showed an increasing trend, whereas Chittoor and Kadapa districts showed no trend. In the case of *rabi* season rainfall, Anantapur district showed an increasing and Kurnool district showed a decreasing trend. where Chittoor and Kadapa districts showed no trend. In case of the rainfall trends in different districts of Telangana during the *kharif* season, Karimnagar, Adilabad, Medak, Ranga Reddy, Nalgonda, Nizamabad, and Medak showed a decreasing trend, whereas Hyderabad, Khammam, and Mahbubnagar districts showed an increasing trend, and Warangal district showed no trend. In case of the rainfall during the *rabi* season, Mahbubnagar, Adilabad, Karimnagar, Medak, Nalgonda, Nizamabad, Ranga Reddy, Warangal, and Hyderabad districts showed a decreasing trend, whereas Khammam district showed no trend.

In semiarid regions of Karnataka, Telangana, and Rayalaseema districts, agriculture is almost exclusively rainfed, so rainfall variability comprises an important source of uncertainty in agricultural production decisions. A better understanding of production risk and its management is important to help farmers make informed and critical decisions about their crops because their welfare depends on their ability to withstand the risk of crop loss. In line with this, the study demonstrates crop selection as a risk management mechanism when crop insurance is limited or non-existent. Our central premise is that in an alternate-cropping system, the crops chosen are likely to be sensitive to weather risk, measured by *kharif* and *rabi* rainfall variability.

Table 1. South interior Karnataka *Kharif*

S.NO	District	Existingcrops	Rain Fall (mm)	Pet (mm)	Recommended crops
1	Chickmangalur	Ragi, Paddy, Sunflower, Jowar, Horse gram	1307.4	416.1	Ragi, Paddy, Sunflower, Jowar, Red gram
2	Kolar	Ragi,Ground nut, Maize, Red gram and Pulses	368.8	595.2	Ragi, Red gram and Pulses
3	Tumkur	Ragi, Maize, Redgram, Ground nut and Horsegram	353.3	460.2	Ragi, Redgram, and Horsegram
4	Shimoga	Paddy, Maize, Sugarcane,and Cotton	2176.4	41.1	Paddy, Maize, Sugarcane,and Cotton
5	Mysore	Maize,Ragi, Cotton and pulses	351.5	429	Ragi and pulses
6	Kodagu	Horti crops	2186.4	416.1	Bajra and Sesame
7	Banglore Urban		445.3	460.2	
8	Hassan	Paddy, Ragi, Maize and Cowpea	805.8	435.9	Ragi, Maize and Cowpea
9	Chithradurga	Groundnut, maize, Ragi, Sunflower, Jowar and Redgram	299.7	537.7	Bajra, Bengal gram and Sesame
10	Chamarajnagar	Ragi, Paddy, Sunflower, Horsegram Sorghum and Bengal gram	331.1	424.2	Ragi, Soybean, Horsegram and Bengal gram
11	Banglore Rural	Ragi, Maize, Redgram and Ground nut	436.2	456.4	Ragi, Redgram and Soybean

Table 2. South interior Karnataka *Rabi*

S.NO	District	Existing crops	Rain Fall (mm)	Pet (mm)	Recommended crops
1	Chickmangalur	Black gram, Green gram and Bajra	233	613.2	Bengal gram
2	Kolar	Horse gram	212.9	609	Bengal gram
3	Tumkur	Bengal gram	189.3	582.5	Horsegram
4	Shimoga	Fallow	203.1	613.2	Bengal gram
5	Mysore	Fallow	210.4	593.5	Bengal gram
6	Kodagu	Fallow	305.8	602	Bengal gram and Soybean
7	Banglore urban	Fallow	219.3	582.5	
8	Hassan	Ragi, Maize and Cowpea	236.6	596.6	Blackgram Green grm and Bengal gram
9	Chithradurga		162.5	609.3	Bengal gram
10	Chamarajnagar	Sunflower, Sorghum, Bengal gram and Horsegram	266	544.5	Bengal gram and Horsegram
11	Banglorerural		209.9	571.7	Bengalgram

**Water requirement of Bengal gram is 150 mm, Black gram 250 mm, Green gram 250 mm Horsegram 200 mm*

Table 3. North interior Karnataka *Kharif*

S.NO	District	Existing crops	Rain fall	Pet (mm)	Recommended crops
1	Gadag	Greengram, Groundnut and Sorghum	320.4	422.7	Greengram and Bajra
2	Haveri	Maize, Oilseed, Sorghum, Paddy and Cotton	454.8	410.9	Maize, Sunflower and Safflower and Sorghum
3	Raichur	Sunflower,Sorghum, Bajra, Groundnut, Cotton,Redgram	402.4	633.1	Sunflower and Redgram
4	Koppal	Sunflower,Sorghum, Bajra, Groundnut and Maize	346.2	551.4	Greengram and Bajra
5	Gulbarga	Redgram, sorghum, Sunflower and Bajra	507	560.2	Redgram, sorghum, Sunflower and Bajra
6	Dharwad	Cotton, Chilli, Sorghum,Groundnut, Paddy,Soybean and Greengram	460.6	453.1	Redgram, Sorghum,Soybean and Greengram
7	Bidar	Sorghum, Redgram, Soybean,Blackgram, Green gram	616.6	753.7	Cotton, Sorghum,Grpundnut, Redgram and Soybean
8	Bijapur	Redgram, Sunflower and Bajra	349.1	483.1	Soybean and Bajra
9	Belgaum	Soybean,Maize,Groundnut, Sorghum and Cotton	780.4	453.1	Maize,Groundnut, Sorghum and Cotton
10	Bagalkote	Gram, Sorghum and Groundnut	330.6	540.1	Gram, Greengram and Bajra

Table 4. North interior Karnataka *Rabi*

S.NO	District	Existing crops	Rain Fall(mm)	Pet (mm)	Recommended crops
1	Gadag	Sorghum, Bengalgram	138	585.2	Bengalgram
2	Haveri	Maize,Oilseed, Sorghum and cotton	158.3	599.9	Sorghum
3	Raichur	Sorghum, Bengalgram	131.3	608	Sorghum, Bengalgram
4	Koppal	Sunflower,Sorghum,Maize,Bengalgram and cotton	144.3	632.7	Bengalgram and Sesamum
5	Gulbarga	Sorghum, Bengalgram and Sunflower	114.9	613.3	Sesame
6	Dharwad	Cotton, Bengalgram and Sorghum	145.7	585.2	Bengalgram and Sorghum
7	Bidar	Bengalgram, Sorghum and Sunflower	118.9	616.5	Sesame
8	Bijapur	Sorghum,Bengal gram and Sunflower	121.8	592.5	Sesame
9	Belgaum	Maize and cotton	134.6	585.2	Sesame
10	Bagalkote	Sorghum and Bengalgram	133.6	592.5	Sorghum and Bengalgram

** Water requirement of Bengal gram is 150 mm, Sesamum 150 mm and Sorghum 500 mm*

Table 5. Rayalaseema *Kharif*

S.NO	District	Existing crops	Rain fall(mm)	Pet(mm)	Recommended crops
1	Ananthapur	Groundt, Sunflower, Redgram,Maize and Cotton	296.3	789.6	Redgram, Black gram and Green gram
2	Chittoor	Groundnut and Redgram	433.6	726	Redgram and sunflower
3	Kadapa	Groundnut,Sunflower, Cotton andRedgram	385.8	689.2	Red gram and Bajra
4	Karnool	Groundnut,Sunflower, Sorghum, Redgram,	449.8	738.8	Sunflower and Redgram,

Table 6. Rayalaseema *Rabi*

S.NO	District	Existing crops	Rain fall(mm)	Pet(mm)	Recommended crops
1	Ananthapur	Bengalgram and Sorghum	185.9	675.2	Bengal gram and Vegetables
2	Chittoor	Groundnut, Paddy, Redgram and sunflower	421.2	635	Redgram
3	Kadapa	Sunflower, Bengalgram,Cotton and Sesamum	266	641.4	Bengalgram, Black gram, Sesame and Green gram
4	Karnool	Bengalgram and Chilli	152.9	643	Bengal gram and Chilli, Lablab

**Water requirement of Lablab is 160 mm*

Table 7. Telangana *Kharif*

S.NO	District	Existing crops	Rain fall(mm)	Pet(mm)	Recommended crops
1	Adilabad	Cotton, Soybean, Redgram and Sorghum	931.8	576.1	Cotton, Redgram and Soybean
2	Hyderabad	Redgram, Sorghum and Maize	602.2	426.3	Redgram, Sorghum and Maize
3	Karimnagar	Cotton, MaizeandGreengram	755.6	539.1	Cotton, MaizeandGreengram
4	Khammam	Cotton, Maize, Greengram and Redgram	900.1	576.8	Cotton,Maize, and Redgram
5	Mahbubnagar	Maize, Cstor, Groundnut,Redgram, Sorghum and Cotton	485.1	668.4	Castor, Redgram and Sorghum
6	Medak	Maize, Sorghum Cotton Greengram, Redgram and Blackgram	613.3	581.5	Maize, Sorghum and Cotton
7	Nalgonda	Cotton, Castor, Redgram and Groundnut	506.6	586.8	Castor and Redgram
8	Nizamabad	Maize and Redgram	824.7	581.5	Maize and Redgram
9	Warangal	Cotton, Maize, Paddy, Groundnut, Green gram	819.1	601.5	Cotton, Maize, Groundnut, Green gram
10	Rangareddy	Redgram, Sorghum, Maize and Cotton	606.5	426.3	Redgram, Sorghum, Maize and Cotton

**Water requirement of Castor crop 500mm*

Table 8. Telangana *Rabi*

S.NO	District	Existing crops	Rain fall(mm)	Pet(mm)	Recommended crops
1	Adilabad	Sorghum, Redgram and Bengal gram	108.8	549.1	Bengal gram
2	Hyderabad	Sorghum and Bengal gram	151.5	544.5	Bengal gram and Green gram
3	Karimnagar	Green gram	115.5	544	Bengal gram and Fodder crop
4	Khammam	Maize, Green gram and Redgram	151.5	580.1	Bengalgram and Greengram
5	Mahbubnagar	Maize and Sorghum	128.6	297.5	Bengalgram and Sesame
6	Medak	Sorghum,Safflower and Bengalgram	100	549.2	Fodder crop(cowpea)
7	Nalgonda	Groundnut	149.7	567.8	Bengal gram
8	Nizamabad	Maize	126.25	549.2	Bengal gram and Sesame
9	Warangal	Maize and Chilli	124.2	591.9	Bengal gram and Sesame
10	Rangareddy	Sorghum, Bengal gram and Groundnut	93.6	544.5	Fodder crop(cowpea)

**Most drought tolerant, as per the followmg ranking· Soybean < black gram < moong bean < ground nut <maize< sorghum < pearl mlliet< lab lab bean < cowpea*

“The ability to adjust in response to a change in temperature is common in plants and includes both higher and lower values relative to the optimum temperature. Besides, the availability of liquid water depends not only on the amount of water present but also on temperature” (Tiziana et al. 2000). Heat and drought are undoubtedly the two most important stresses, having a huge impact on the growth and productivity of the crops (Google.com). “The crop water stress index is a means of irrigation scheduling and crop water stress quantification based on canopy temperature measurements and prevailing meteorological conditions. Plant temperature is an indicator of plant water status because stomata close in response to soil water depletion, causing a decrease in water uptake and an increase in leaf temperature” (Payero et al., 2006). “Inadequate rainfall and soil-bound water lead to water deficiency in crops” [24,25]. “Plant-water relations and water-stress tolerance at the scale of physiology and molecular biology can significantly improve plant productivity and environmental quality” [26].

Drought severity is conventionally assessed by drought indices. Several drought indices with varying complexity have been used in many geographical areas. Recently, a powerful drought index, the Reconnaissance Drought Index (RDI), has gained wide acceptance, mainly in the arid and semiarid climatic regions. Since RDI is based both on precipitation and potential evapotranspiration (PET), it is interesting to assess the effect of the PET calculation method on the drought severity characterization obtained by RDI. The FAO Penman–Monteith method is used as a reference method.

In south and north interior Karnataka, Telangana, and Rayalaseema areas, PET was calculated based on the Penman and Monteith equation. In districts wherever rainfall is less than potential evapotranspiration, one or two irrigations should be given at critical stages of crop growth.

In the districts of south and north interior Karnataka, Telangana, and Rayalaseema regions, the existing crops under cultivation are shown in Tables 1–8 in both the *kharif* and *rabi* seasons. According to rainfall patterns and potential evapotranspiration in different districts, suitable crops were suggested. The crops that are suggested based on rainfall and potential evapotranspiration can thrive well, grow very efficiently, and give reasonable yields to farmers in limited rainfall situations. Drought-tolerant and drought-resistant short-duration crops were mostly recommended.

4. SUMMARY AND CONCLUSIONS

Based on 30 years of average rainfall and potential evapotranspiration losses in regions of semiarid districts of Karnataka, Telangana, and the Rayalaseema region of Andhra Pradesh states, the results indicate that the rainfall variability both in the *kharif* and *rabi* seasons means that moisture-sensitive crops like rice, sugarcane, and banana have to be taken up in high rainfall areas and in areas with good irrigation facilities, and farmers should go for less moisture-sensitive crops at times of rainfall shortages and vice versa to avoid risk at farm level.

The timely arrival of southwest monsoon rains is crucial for seed-bed preparation for short- and long-duration *kharif* crops such as maize, sorghum, and rice. This implies that favourable southwest monsoon rains are important for crop production.

In semiarid regions of Karnataka, Telangana, and Rayalaseema districts of Andhra Pradesh, agriculture is almost entirely rainfed, so rainfall variability becomes an important factor of uncertainty in agricultural production decisions. A better understanding of production risk and its management is important to help farmers become informed and to take critical decisions about their crops because their welfare depends on their ability to withstand the risk of crop loss. If the monsoon rains stop early in the season, normal sowing of short-duration upland rice, blackgram, and sesame crops can be resumed. If the rain ceases very early, i.e., by the end of August or the first week of September, only fodder crops or grain legumes could be harvested. Depending upon the soil moisture condition, relay sowing of crops like chickpea, lentil, mustard, linseed, and barley could be done in the *rabi* season.

The crops that are suggested based on rainfall and potential evapotranspiration can thrive well, grow very efficiently, and give reasonable yields to farmers under limited rainfall situations. In districts where the rainfall is less than the potential evapotranspiration, one or two irrigations may be given at critical stages of crop growth.

5. ADVANTAGES OF DIVERSIFICATION

- More Income, Poverty Alleviation, and Social Upliftment
- Improved Soil Health
- More Employment Generation at the Farm
- Effective and Profitable Utilization of Farm Waste and By-Products
- Risk Reduction

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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