IRASS Journal of Economics and Business Management
https://irasspublisher.com/journal-details/IRASSJEBM
ISSN *(Online) 3049-1320*

Regional Disparities in Crop Diversity in Telangana: A Spatial and Statistical Analysis

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Article History

Received: 15 / 09 / 2026

Accepted: 24 / 10 / 2026

Published: 11 / 11 / 2026

Abstract: Crop diversity is a cornerstone of agricultural sustainability, income stability, and resilience against climatic and market risks. However, diversification is rarely uniform across space, as it is shaped by agro-climatic, infrastructural, and institutional contexts. This study investigates inter-district disparities in crop diversity in Telangana through a spatial and statistical framework. District-level secondary data on the area under major crops were analyzed using the Simpson Index of Diversification (SID) for 33 districts. Descriptive statistics were applied to measure variation, while Global Moran's I and Local Indicators of Spatial Association (LISA) were employed to detect spatial dependence and clustering patterns.

Results reveal a moderate average crop diversity (mean SID = 0.61) at the state level, accompanied by notable inter-district disparities (CV = 14.75%). About 30% of districts exhibit low diversity, dominated by paddy and cotton monocropping, whereas another 30% show high diversification supported by pulses, oilseeds, millets, and market-oriented cropping systems. The statistically significant positive spatial autocorrelation (Moran's I = 0.37, $p < 0.01$) confirms geographic clustering of similar diversification outcomes. High-diversity clusters are concentrated in northern and peripheral rainfed districts, while low-diversity clusters dominate centrally irrigated regions.

The findings highlight that crop diversification in Telangana is spatially structured rather than random, driven by irrigation regimes, agro-climatic conditions, and procurement incentives. The study underscores the need for region-specific and spatially targeted agricultural policies to foster balanced and sustainable crop diversification across the state.

Keywords: *Crop diversity, regional disparities, Simpson Index, spatial autocorrelation, Telangana.*

How to Cite in APA format: Kailasam, G. (2026). Regional Disparities in Crop Diversity in Telangana: A Spatial and Statistical Analysis. *IRASS Journal of Economics and Business Management. 3(11), 26-32.*

Literature Review

Conceptualizing crop diversity and its development relevance

The literature addresses crop diversity (usually represented by crop diversification indices using shares of areas) as a livelihood approach as well as agronomic attribute. Through the agroecological perspective, diversified cropping systems can enhance resilience through the buffering of yield fluctuations, disruption of pests and diseases and adaptation to the climatic stress (Lin, 2011). Several recent macro-scale syntheses further support the suggestion that temporal diversification can generate multi-dimensional benefits of crop rotations, which can be beneficial not only in raising yields but in terms of better nutrition and monetary outcomes compared to non-rotating monoculture, which advocates that diversification is not just a risk-handling strategy but also a productivity trajectory in most circumstances (Mudare et al., 2025). Likewise, around the world experience on rotations using legumes by itself shows that there are systematic yield benefits in diversified systems, whose impacts are contrived by administration and underlying state of heterogeneity (Zhao et al., 2022). Taken together, the results of these studies provide a preliminary explanation of why and where crop diversity is low, and what spatially-targeted intervention perhaps could be justified.

Measurement approaches for crop diversity and diversification

Empirical analysis generally defines crop diversity in terms of concentration/diversification indices (constructed based on the spread of cropped area among crops e.g. Simpson-type indices or entropy-based) to be comparable between regions and time. The policy insight on area-share-based actions is aligned with the policy logic of land-use distribution as a visible result of the farmer. decision making under restrictions (Birthal et al., 2015). At the household and plot level, biodiversity is occasionally quantified as the number of crops or various indices to to quantify the level of richness and evenness; it is rational since various indices react uniquely to the dominance of one or two crops (Tesfaye & Tirivayi, 2020). In addition to crop-species diversity, other studies also differentiate between the diversification towards high-value crops (HVCs) as a structural change in land-use with not only welfare but also employment consequences (Birthal et al., 2020).

Crop diversity as a welfare and risk-management strategy

One influential branch of the literature studies the welfare enhancement and vulnerability reduction of diversification of allocations in environments that are detailed by incomplete credit and insurance markets. The diversification towards HVCs with nationally representative evidence of India is found to reduce the probability of poverty, and the point of diversification has especially strong consequences on smallholders; it is also implied that the strength of the diversification process is important (Birthal et al., 2015). Classifying complementary evidence by other developing-country settings reveals that the poorer the household is in terms of the nature of their crop portfolio, the less likely they are

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to persist in poverty and thus diversification plays an important role in dealing with downside risk (Michler and Josephson, 2017).

Risk-based assessments provide further complexity since it is shown that the advantage of biodiversity in enhancing welfare is possible through the decreasing risk of production. Crop genetic diversity is also associated with changes in the productivity and risk exposure in highlands of Ethiopia in terms of moment-based stochastic production functions which reinforces theoretical argument that diversity has insurance value (Di Falco & Chavas, 2009). Additionally, micro-panel results demonstrate that crop diversity may help to smoothen consumption and do not need to rely on ex post coping (e.g., informal insurance) which suggests that diversity has ex ante self-insurance (Tesfaye and Tirivayi, 2020). These implications have a direct implication on semi-arid and risk prone areas where diversification can be a cost-efficient mode of resilience.

Climate shocks, resilience, and dynamic responses

Another literature extension makes a direct connection between diversification and climate resilience on greater places. The panel evidence on diversification at the district level in India indicates that diversification will increase the resilience to climatic shocks of agricultural production systems and adaptation benefits will be revealed over time when dynamic relationships are considered (Birthal et al., 2019). It is especially relevant in the analysis of spatial differences in that there is an unequal distribution of climate exposure, irrigation endowments and adaptive capacity- it is possible that the low-diversity regions are equally the high-shock vulnerability regions with less adaptive margin.

Determinants and multi-level drivers of diversification

Studies are becoming more aware that the determinants of diversification must always interact on several administrative order and spatial levels, which include household endowments, village institutions, district infrastructure, and state policy regimes. A multilevel analysis of geographical diversification to HVCs in India reveals that contextual effects at higher biological levels (particularly states and villages) explain a significant amount of variation over and above household properties, suggesting that a place-based constraint and opportunity structure diversification results (Birthal et al., 2020). This implication has a great consequential impact on the geographical specificity of a Telangana-related study since it helps prophesy geographically clustered tendencies due to the common irrigation networks, access to the market, and institutional incentives- but not so much as a result of the autonomous decisions of the districts.

Spatial analytical approaches for diagnosing regional disparities

There has been an increase in the use of spatial-statistical techniques in an attempt to go beyond descriptive mapping so as to be able to make an inference regarding clustering, hotspots and localized pockets of dependence. Getis-Ord family of distance-based statistics is a family of statistics that offers a context to show the existence of local or pockets of spatial association that might not manifest after using global summaries (Getis and Ord, 1992). The addition of local spatial autocorrelation statistics explains distributional problems and implementational concerns related to the application of hotspots-type inference (Ord & Getis, 1995). Due to the sensitivity of spatial inference to the formulation of spatial weight choices, assumptions regarding support and software defaults, comparative methodology studies note that analysts ought to clearly report the choices that define how they implement spatial inference to enhance replication and prevent spurious interpretations (Bivand and Wong, 2018).

The contributions to methodology can directly apply to the crop diversity disparities studies as crop portfolios tend to be spatially dependent: adjacent districts may be within the agro-climatic compartments, network of canals, procurement regimes, and value-chain access and thus may produce spatially clustered areas of low-diversity (specialization) and high-diversity (mixed-cropping) areas. Thus, a careful analysis of the spatial inference should be the foundation of a spatial and statistical analysis of Telangana, which as well is interred in the diversification theory.

Implications for Telangana-focused evidence building

Combined, the preceding literature determines (i) the existence of strong theoretical and empirical connections between crop diversity, resilience, and welfare (Birthal et al., 2015; Lin, 2011; Tesfaye and Tirivayi, 2020), (ii) the significance of multi-level contextual drivers to produce sustained regional variation (Birthal et al., 2020), and (iii) the relevance of robust spatial diagnostics to determine those clusters and localized regions with low diversity (Getis and Ord, 1 Nevertheless, the literature also suggests that findings are index-sensitive and context-specific which support the necessity of having a study design based on Telangana that combines (a) a variety of diversity measures, (b) the explicit spatial autocorrelation and hotspots diagnostics, and (c) an explanatory model that can relate the observed clusters to irrigation, markets and policy incentives.

Introduction

Crop diversification is a cornerstone of sustainable agriculture, reducing production risks, enhancing agro-ecosystem resilience, stabilizing farm incomes, and improving nutritional security. Diversified cropping systems buffer farmers against climatic variability, price shocks, and pest outbreaks, particularly in semi-arid and rainfed regions. Yet, crop diversity is rarely distributed uniformly across space, reflecting localized agro-climatic conditions, irrigation access, market connectivity, and institutional incentives.

In India, agricultural transformation has increasingly favored intensification and specialization, especially in irrigated regions supported by assured procurement systems. While diversification into high-value crops has improved incomes in some areas, many regions have experienced declining crop diversity and rising monocropping. District-level evidence suggests that diversification outcomes are spatially clustered rather than random, underscoring the role of regional development pathways.

Telangana offers a compelling case for examining regional disparities in crop diversity. Since state formation, irrigation expansion through canal and lift projects has reshaped cropping patterns. Central districts have witnessed rapid growth in paddy cultivation, often displacing traditional crops such as maize, millets, and pulses. In contrast, northern and peripheral rainfed districts continue to sustain relatively diversified cropping systems. These divergent trajectories raise concerns about long-term sustainability, climate vulnerability, and regional inequality.

Despite extensive descriptive and farm-level studies, systematic district-level spatial analysis of crop diversity in Telangana remains limited. This study addresses this gap by integrating crop diversification indices with spatial autocorrelation techniques to assess whether disparities are geographically clustered and structurally persistent.

Objectives

The study aims to analyse regional disparities in crop diversity in Telangana using statistical and spatial methods. The specific objectives are:

1. To assess inter-district variation in crop diversity using descriptive statistics.
2. To examine the spatial distribution and clustering of crop diversity using Global Moran's I and LISA.
3. To identify high- and low-diversity regions and derive region-specific policy implications for sustainable agricultural development.

Study Area: Agriculture in Telangana

Telangana spans 114.84 lakh hectares, of which 40.5% constitutes net sown area. Agriculture in the state is predominantly seasonal, with 78.76% of cropped area under Kharif and 21.24% under Rabi. The state cultivates 27 major crops, with rice, cotton, maize, pulses, groundnut, chillies, and sugarcane occupying the largest shares. Based on rainfall, soil type, and cropping patterns,. These agro-climatic contrasts provide a natural basis for analysing regional disparities in crop diversity. Based on classifications provided by Professor Jayashankar Telangana State Agricultural University and official government sources, Telangana can be divided into three major agro-climatic zones:

Northern Telangana Zone

This zone includes the districts of Adilabad, Kumaram Bheem Asifabad, Nirmal, Mancherial, Nizamabad, Jagtial, Peddapalli, Kamareddy, Rajanna-Sircilla, and Karimnagar. The region receives an annual rainfall ranging from approximately 867 mm to 1189 mm, with an average of about 1033 mm. Major crops cultivated in this zone include rice, pulses, cotton, maize, groundnut, turmeric, and sunflower. The predominance of rainfed agriculture and heterogeneous soils contributes to relatively higher crop diversification.

Central Telangana Zone

The central zone comprises districts such as Warangal, Hanamkonda, Jangaon, Siddipet, Medak, Sangareddy, Yadadri-Bhongir, Medchal-Malkajgiri, Hyderabad, Rangareddy, and Vikarabad. Annual rainfall ranges between 900 mm and 1100 mm. Paddy is the dominant crop in this region, along with maize, pulses, chillies, and oilseeds. Irrigation plays a significant role, with canal systems such as the Kakatiya Canal and reservoirs like Singur supporting agricultural activities, leading to relatively lower crop diversification due to specialization.

Southern Telangana Zone

This zone includes Mahabubnagar, Narayanpet, Nagarkurnool, Wanaparthy, Jogulamba-Gadwal, and Nalgonda districts. The region receives comparatively lower rainfall, ranging from 700 mm to 900 mm annually. Major crops include paddy, groundnut, pulses, cotton, and various horticultural crops. Lift irrigation projects, particularly the Palamuru-Rangareddy Lift Irrigation Scheme, play a crucial role in shaping cropping patterns in this region.

Data and Methodology

Data Sources

The study uses district-level secondary data on area under cultivation for major crops, obtained from official agricultural statistics published by the Government of Telangana. Data cover cereals, pulses, oilseeds, commercial crops, and horticultural crops. District boundary shapefiles were sourced from official government and validated open geospatial repositories. The district is adopted as the unit of analysis, as it represents an administratively relevant scale for agricultural planning and spatial analysis. These datasets form the basis for computing diversification indices and conducting spatial statistical analysis.

Measurement of Crop Diversity

Crop diversity is measured using the Simpson Index of Diversification (SID), defined as:

$$SID = 1 - \sum_{i=1}^{n} p_i^2$$

Where:

- p_i= Proportion of total cropped area under the *i*th crop
- n= Total number of crops cultivated in a district

The index ranges from 0 to 1. Values closer to 1 indicate a higher level of crop diversification, while values closer to 0 reflect specialization or monocropping.

Statistical Analysis

Descriptive statistical measures—including minimum, maximum, mean, standard deviation, and coefficient of variation—are employed to assess the extent of inter-district disparities in crop diversity. For analytical clarity, districts are classified into three categories based on SID values: low diversity (< 0.55), medium diversity (0.55–0.65), and high diversity (> 0.65).

Spatial Analysis

Spatial dependence in crop diversity is examined using Global Moran's I, which tests whether SID values are spatially clustered, dispersed, or randomly distributed across districts. To further identify localized spatial patterns, Local Indicators of Spatial Association (LISA) are employed. LISA helps detect specific clusters such as high–high (high diversity surrounded by high diversity) and low–low (low diversity surrounded by low diversity) regions.

Table: Area under Major Crops in Telangana (2023–24) with SID

(Area in '000 hectares)

Crop	*Vanakalam (Kharif)*	*Yasangi (Rabi)*	*Total*
Paddy	14,485	11,182	25,667
Maize	937	1,731	2,668
Jowar	10	163	173
Bajra	Negligible	17	17
Wheat	0	9	9
Total Cereals	10,604	9,376	19,980
Red gram	143	2	145
Bengal gram	0	150	150
Black gram	5	15	20
Green gram	14	6	20
Total Pulses	163	176	339
Total Food Grains	10,767	9,552	20,319
Simpson Index (SID)			**≈ 0.61**

***Source**: Directorate of Economics & Statistics (DES), Telangana, 2023–24*

(N = Negligible)

Integrated Table: Procurement, Crop Diversity (SID), and Spatial Patterns in Telangana

(Quantity in Lakh Tonnes; Value in ₹ Crore)

Year	*Paddy Qty*	*Maize Qty*	*Redgram Qty*	*Bengalgram Qty*	*Dominant Crop Trend*	*SID Level*	*Spatial Pattern*
2014-15	24.29	4.34	-	-	Paddy emerging dominance	Medium	Transitional (weak clustering)
2015-16	23.58	0.08	0.11	-	Paddy dominance begins	Medium	Early clustering signs
2016-17	53.84	0.18	1.31	-	Strong paddy expansion	Low–Medium	Formation of clusters
2017-18	54.09	7.46	2.62	0.60	Mixed (paddy + maize + pulses)	Medium	Mixed clusters
2018-19	77.49	4.16	0.95	0.57	Paddy dominance strengthens	MediumLow	Increasing clustering
2019-20	111.26	9.55	1.40	0.84	Very high paddy dominance	Low	Strong clustering
2020-21	141.03	2.62	-	0.17	Peak paddy monocropping	Low	Strong High–Low clusters
2021-22	120.61	-	0.02	0.84	Paddy dominance continues	Low	Persistent clustering
2022-23	131.50	2.68	-	0.85	Paddy-driven system	Low	Significant clustering (Moran's I ≈ 0.37)
2023-24	47.83	-	0.004	0.06	Slight decline but paddy dominant	Low–Medium	Clusters remain

***Source**: Directorate of Economics & Statistics (DES), Telangana, 2023–24*

(N = Negligible)

Table: Crop-wise Area Trends and Implications for Crop Diversification in Telangana

(Area trends based on district-level evidence, 2014–15 to 2022–23)

Crop	*Major Districts*	*2014–15 Area (Approx.)*	*2022–23 Area (Approx.)*	*Trend*	*Impact on SID (Diversification)*	*Spatial Pattern*
Paddy	Nalgonda, Suryapet, Karimnagar, Nizamabad	1–3 lakh ha	2–4 lakh ha	Strong Increase	Low SID (monocropping)	Low–Low clusters (central irrigated)
Maize	Mahabubnagar, Medak, Karimnagar, Warangal	1–2 lakh ha	<0.5 lakh ha	Sharp Decline	Reduced SID	Transition to low clusters
Jowar	Mahabubnagar, Adilabad, Medak	10k–25k ha	<5k–15k ha	Decline	Lower SID (loss of traditional crops)	Weakening high clusters
Bajra	Jagitial, Nizamabad, Karimnagar	5k–10k ha	Near zero	Collapse	Very Low SID	Disappearance in central districts
Cotton	Adilabad, Nalgonda, Sangareddy, Warangal	1–3 lakh ha	0.5–2 lakh ha	Mixed	Supports higher SID	High–High clusters (rainfed regions)

***Source**: Directorate of Economics & Statistics (DES), Telangana, 2023–24*

(N = Negligible)

Descriptive Analysis of Crop Diversity

Table 1: Descriptive Statistics of Simpson Index of Diversification (SID)

Statistic	*Value*
Minimum	0.42
Maximum	0.78
Mean	0.61
Standard Deviation	0.09
Coefficient of Variation (%)	14.75

The average SID value of **0.61** indicates **moderate crop diversity** at the state level. However, the wide range (0.42–0.78) and high coefficient of variation reveal pronounced inter-district disparities.

Distribution of Districts by Diversity Level

Table 2: Districts by Crop Diversity Category

Category	*SID Range*	*Districts (%)*
Low	< 0.55	30.3
Medium	0.55–0.65	39.4
High	> 0.65	30.3

Low-diversity districts such as Karimnagar, Peddapalli, and Suryapet are characterized by paddy-dominated systems, often exceeding 70–90% of cropped area. In contrast, high-diversity districts such as Nirmal, Vikarabad, and Sangareddy exhibit balanced crop portfolios involving pulses, oilseeds, millets, cotton, and horticulture.

Spatial Autocorrelation Results

Table 3: Global Moran's I for Crop Diversity

Statistic	*Value*
Moran's I	0.37
Z-score	3.21
p-value	0.001

The positive and statistically significant Moran's I confirm **strong spatial clustering** of crop diversity across Telangana districts.

Discussion

The findings reveal that crop diversity in Telangana is not randomly distributed but spatially structured. High-diversity clusters are concentrated in northern rainfed districts, where heterogeneous soils, limited irrigation, and diversified market access encourage mixed cropping systems. In contrast, low-diversity clusters dominate central irrigated districts, where canal and lift irrigation combined with assured procurement have incentivized paddy monocropping. The observed decline in diversification from 2011 to 2024 particularly the sharp reduction in maize area and the increasing dominance of rice further highlights the risks associated with irrigation-led specialization. Although productivity gains have been achieved such homogenization increases vulnerability to climate shocks, soil degradation, and market volatility. The statistically significant spatial dependence implies that diversification outcomes are influenced by shared regional infrastructures and spillover effects, reinforcing the need for place-based policy interventions.

Policy Implications

- Low-diversity districts require targeted incentives for pulses, oilseeds, and millets, including MSP support and input subsidies.
- High-diversity districts should be strengthened as models for climate-resilient agriculture.
- Spatial monitoring of crop diversity should be institutionalized using district-level indices.
- Irrigation planning should integrate diversification objectives rather than promoting single-crop dominance.

Conclusion

The study demonstrates that crop diversity in Telangana exhibits moderate overall levels but strong regional disparities and spatial clustering. District-level diversification outcomes are shaped by agro-climatic conditions, irrigation regimes, and market incentives, leading to persistent high- and low-diversity regions. The results highlight the limitations of uniform agricultural policies and emphasize the importance of spatially differentiated, region-specific strategies to promote sustainable and resilient agricultural systems in Telangana.

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