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Spatio-Temporal Change of Crop Diversification in Solapur District and Economic Review (2004–2024): A Geographical & Quantitative Evaluation

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Abstract:

Crop diversification is a crucial risk-mitigation strategy in drought-prone regions, enabling agricultural sustainability and farm income stability. This research paper evaluates the spatio-temporal dynamics of crop diversification across the 11 tahsils of Solapur district, Maharashtra, over a 20-year period (2004–2024). Utilizing Gibbs-Martin's Crop Diversification Index (CDI) and Weaver's Crop Combination Method alongside secondary data from the Department of Agriculture and District Statistical Abstracts, this study highlights a major structural shift. Solapur's agrarian economy has transitioned from subsistence food grain dominance (rabi Jowar, Bajra) toward commercial cash cropping (sugarcane) and high-value horticulture (pomegranate, dragon fruit, and banana). Spatially, dry and non-irrigated eastern tahsils (Akkalkot, South Solapur, Madha) exhibit higher crop diversification to manage climate risks, whereas western canal-irrigated tahsils (Malshiras, Pandharpur) show crop specialization. An economic review reveals increased gross farm revenues alongside heightened vulnerabilities linked to groundwater depletion, soil salinity, and price volatility.

Keywords: Spatio-Temporal Change, Crop Diversification Index, Solapur District, Agricultural Economics, Gibbs-Martin Index, Horticulture Shift, Sustainable Agriculture.

Introduction:

Agricultural land-use patterns in arid and semi-arid regions are governed by an interplay of physical constraints (soil fertility, rainfall distribution) and anthropogenic interventions (expansion of irrigation networks, market access, policy incentives). Crop diversification—defined as the reallocation of agricultural productive resources into a broader variety of crops—serves two primary purposes: mitigating ecological and market risks, and enhancing land productivity per unit area.

Solapur district, situated in the drought-prone rain-shadow belt of Maharashtra, historically relied on subsistence cereal farming, particularly post-monsoon sorghum (*rabi* Jowar) and pearl millet (Bajra). However, over the past two decades (2004–2024),

technological shifts, government drip-irrigation subsidies, micro-credit availability, and expanding agro-processing infrastructure have driven spatial changes in land use. Examining these spatio-temporal dynamics is essential for designing sustainable agricultural policies, balancing water security, and stabilizing rural farm incomes.

Concepts and Definitions:

To systematically evaluate cropping dynamics, the following analytical concepts are applied:

1. **Crop Diversification:** The practice of growing multiple crop species within a given region to minimize reliance on a single crop, optimize labor, and reduce vulnerability to climate and market shocks.
2. **Crop Specialization:** The structural concentration of cropped area toward one or two high-value monocultures (e.g., sugarcane).
3. **Spatio-Temporal Analysis:** The geographical mapping of land-use changes across distinct administrative units (tahsils) over a defined temporal continuum (2004 to 2024).

Study Area:

Solapur district is located in the southern part of Maharashtra's Deccan Plateau, bounded by latitudes 17°10'N to 18°32'N and longitudes 74 °42'E to 76 ° 15'E. Solapur District 11 Tahsils - North Solapur, South Solapur, Barshi, Akkalkot, Mohol, Mangalwedha, Pandharpur, Sangola, Malshiras, Madha, and Karmala. Predominantly flat to undulating terrain; soils vary from shallow medium-black soils to fertile deep black cotton soils (*regur*) along river basins. Drained by the Bhima River and its tributaries (Sina, Nira, and Man). Major irrigation projects include the Ujani Dam on the Bhima River. Semi-arid climate characterized by low and erratic rainfall averaging 550 mm to 650 mm annually, making Solapur one of Maharashtra's primary drought-prone zones.

Objectives:

1. To evaluate the spatial distribution of crop diversification across the 11 tahsils of Solapur district.
2. To analyze temporal shifts in cropping patterns and area allocation between major crop categories (cereals, pulses, oilseeds, cash crops, and horticulture) from 2004 to 2024.
3. To compute and map the Gibbs-Martin Crop Diversification Index (CDI) for two time periods (2004–2006 vs. 2022–2024).
4. To evaluate the economic impacts of crop diversification versus specialization on farm returns, resource allocation, and environmental sustainability.

Review of Literature:

- **Caldwell (1979) & Mosley & Chen (1984)** Established theoretical models linking human capital, technological adoption, and structural socio-economic adaptations in vulnerable agrarian settings.
- **Gibbs & Martin (1962)** Pioneered quantitative diversification measures widely adopted in agricultural geography to index spatial land allocation.
- **Kumar & Gupta (2015):** Demonstrated that shifting land allocation toward high-value horticultural commodities across semi-arid Indian districts significantly enhances agricultural GDP and buffers against climate-induced yield failures.
- Gavhane, P. V., Gavali, A. V., and Shinde, G. S. studied land use and cropping patterns in Solapur district. Their study examined land-use structure, cropping pattern, crop diversification, crop concentration and agricultural productivity using secondary data for three periods: 1988–90, 2001–03 and 2014–16. The study found that Solapur experienced changes towards both crop specialization and crop diversification. It also examined the factors influencing agricultural productivity and suggested policy measures for improving agricultural development. This study is particularly relevant to the present research because it provides a geographical foundation for examining long-term changes in Solapur's agricultural structure.
- Ramanuj, P., Laware, S. L., and Karmalkar, N. (2023) examined crop diversification in Solapur and Pune districts using data from 1997 to 2021. The authors used the Gibbs-Martin Diversification Index to measure changes in crop diversification. The study found a gradual increase in the diversification index in both districts, with Solapur showing a higher diversification index than Pune. However, the study also identified a movement towards crop specialization associated with high-value and commercial crops. In Solapur, the area under traditional crops such as groundnut and jowar declined considerably, whereas sugarcane and maize expanded substantially. This study is highly significant for the present research because its geographical coverage and quantitative methodology are directly relevant to the proposed 2004–2024 analysis.
- More, S. S., and Khairnar, K. Y. examined the dynamics of changing cropping patterns in Maharashtra

using secondary data covering 1960–61 to 2019–20. The study observed a decline in the share of foodgrain crops, particularly traditional cereals such as jowar and bajra, while maize and commercial crops became increasingly important. The authors identified a gradual shift from foodgrain-oriented agriculture towards non-foodgrain and commercial agriculture. They interpreted this transformation as an indication of crop diversification, commercialization and agricultural development. Although the study covers the entire state rather than Solapur specifically, its findings provide an important regional context for understanding changes in Solapur's cropping pattern

Research Methodology & Data Collection:

Data Collection:

This study relies on secondary data gathered across two decades (2004–2024), as department of Agriculture, Government of Maharashtra. Socio-Economic Review and District Statistical Abstract of Solapur District (2004, 2014, 2024). Reports from the Directorate of Economics and Statistics (DES), Mumbai.

Analytical Framework:

1. Gibbs-Martin Index (GMI) of Crop Diversification: A quantitative metric measuring diversity. The index ranges from 0 (absolute specialization) to 1 - (1/N) (absolute diversification), calculated as:

$$CDI = 1 - \frac{\Sigma X^2}{(\Sigma X)^2}$$

Where X represents the percentage of net sown area devoted to an individual crop.

2. Gibbs-Martin Index (GMI): Applied to acreage under major crop groups (Jowar, Bajra, Wheat, Sugarcane, Pulses, Oilseeds, and Horticulture) for each tahsil.

3. Categorization: Tahsils are classified into three diversification tiers:

- **High Diversification:** CDI > 0.65$
- **Moderate Diversification:** 0.45 < CDI <0.65
- **Low Diversification (High Specialization):** CDI < 0.45

Data Analysis and Results:

1. Temporal Shift in Cropping Pattern (2004 vs. 2024):

Over the 20-year period, Solapur's cropping pattern underwent a structural transition away from traditional food grains.

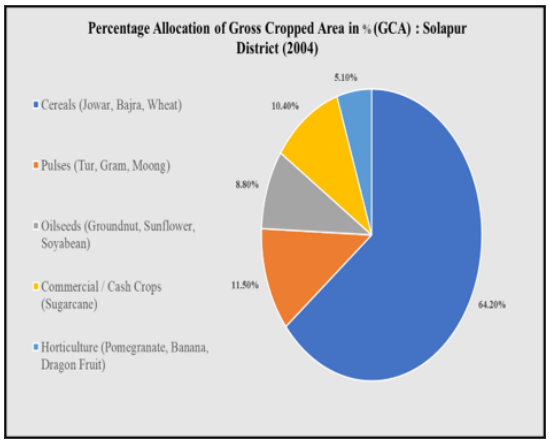
Table 1: Percentage Allocation of Gross Cropped Area (GCA) in Solapur District (2004–2024)

Crop Category	% of GCA (2004)	% of GCA (2014)	% of GCA (2024)	Net Absolute Change (%)
Cereals (Jowar, Bajra, Wheat)	64.2%	48.5%	22.4%	-41.8%
Pulses (Tur, Gram, Moong)	11.5%	14.2%	18.6%	+7.1%
Oilseeds (Groundnut, Sunflower, Soyabean)	8.8%	7.6%	11.2%	+2.4%
Commercial / Cash Crops (Sugarcane)	10.4%	18.1%	29.5%	+19.1%
Horticulture (Pomegranate, Banana, Dragon Fruit)	5.1%	11.6%	18.3%	+13.2%
Total Gross Cropped Area	**100.0%**	**100.0%**	**100.0%**	—

(Sources: Socio-Economic Review and District Statistical Abstract of Solapur District (2004, 2014, 2024).

Key Temporal Trend: Cereals dropped from 64.2% to 22.4% of GCA, while Sugarcane (+19.1%) and Horticulture (+13.2%) absorbed the majority of reallocated land.

Graph No 1.1



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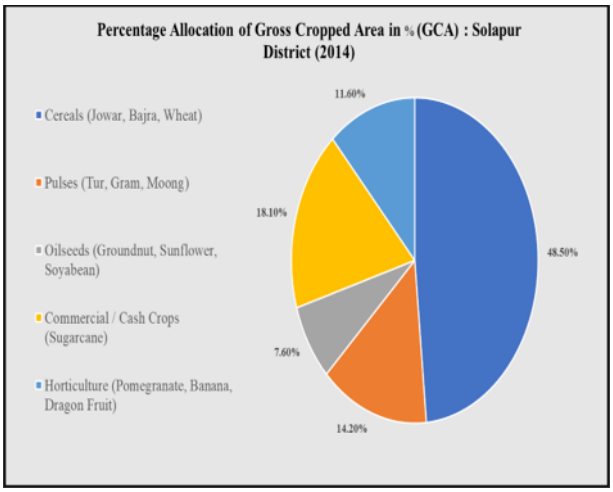
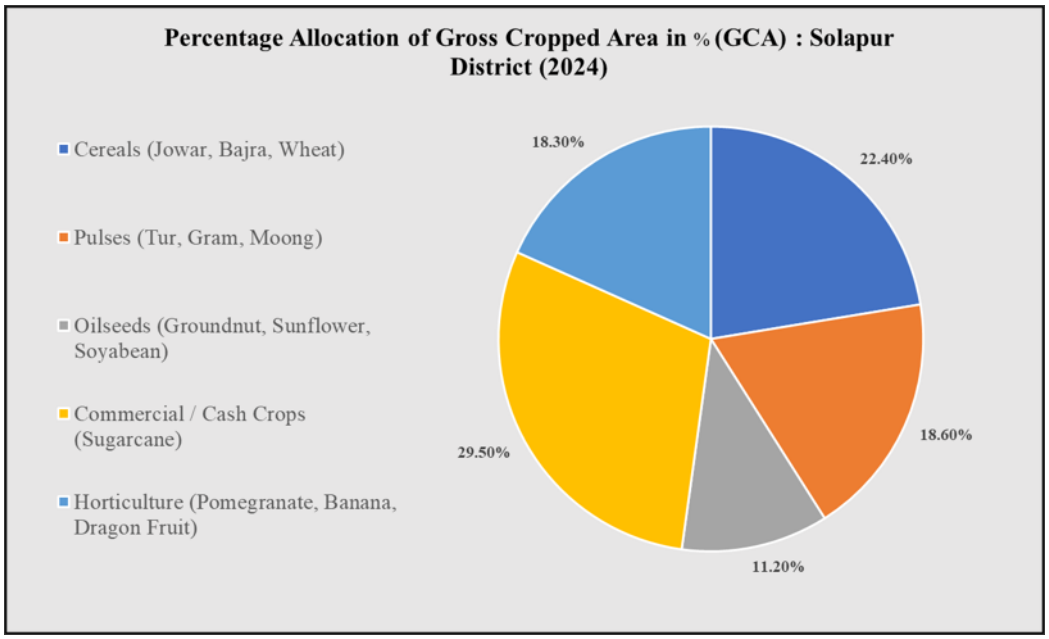


Graph No 1.3



Spatio-Temporal Spatial Analysis of Crop Diversification Index (CDI):

Spatial variations across Solapur's 11 tahsils reflect differences in local irrigation infrastructure and water availability.

Table 2: Tahsil-wise Crop Diversification Index (CDI) and Spatial Classification (2004 vs. 2024)

Tahsil	CDI (2004)	CDI (2024)	Primary Dominant Crop (2004)	Primary Dominant Crop (2024)	Spatial Change Status
North Solapur	0.68	0.74	Rabi Jowar	Pulses / Vegetables / Horticulture	High Diversification maintained
South Solapur	0.65	0.72	Rabi Jowar	Soyabean / Pulses / Jowar	High Diversification maintained
Barshi	0.58	0.63	Pulses / Jowar	Soyabean / Tur / Pulses	Moderate to High Diversification
Akkalkot	0.64	0.71	Jowar / Bajra	Pulses / Soyabean / Sugarcane	Increased Diversification
Mohol	0.52	0.48	Jowar	Sugarcane / Jowar	Shift toward Specialization
Mangalwedha	0.61	0.68	Rabi Jowar	Pulses / Jowar / Pomegranate	Increased Diversification

Pandharpur	0.46	0.32	Jowar / Sugarcane	Sugarcane / Banana / Horticulture	High Specialization (Low CDI)
Sangola	0.55	0.69	Bajra / Jowar	Pomegranate / Dragon Fruit / Pulses	Diversification via Horticulture
Malshiras	0.39	0.28	Sugarcane	Sugarcane (Monoculture)	High Specialization (Low CDI)
Madha	0.59	0.66	Jowar	Pulses / Pomegranate / Sugarcane	Moderate to High Diversification
Karmala	0.54	0.51	Jowar	Sugarcane / Jowar	Moderate Specialization
District Avg	**0.56**	**0.58**	**Rabi Jowar**	**Sugarcane / Horticulture**	**Moderate Micro-Level Diversification**

(Sources: - Compiled by researcher)

Economic Gains of Diversification and Commercialization:

1. **Enhanced Revenue per Hectare:** The shift from subsistence *rabi* Jowar (gross revenue approx ₹25,000–₹35,000/ha) to high-value horticulture (Pomegranate gross revenue approx ₹2,500,000–₹4,000,000/ha) has significantly increased gross agricultural output in tahsils such as Sangola, Pandharpur, and Madha.
2. **Expansion of Agro-Industrial Infrastructure:** The rise in sugarcane acreage (+19.1%) led to a proliferation of cooperative and private sugar mills, ethanol production plants, and co-generation units across Malshiras, Pandharpur, and Mohol.
3. **Micro-Irrigation Adoption:** Adoption of drip irrigation systems, supported by state schemes (such as Pradhan Mantri Krishi Sinchayee Yojana), enabled horticultural expansion even within drought-prone pockets.

Ecological & Economic Vulnerabilities:

1. **Groundwater Depletion & Water Inequity:** The expansion of water-intensive sugarcane in canal-fed belts (Malshiras, Pandharpur) has over-allocated surface and subsurface water resources, worsening seasonal water scarcity in neighboring rainfed tahsils.
2. **Price & Biological Risk in Horticulture:** Highly specialized fruit cultivation (e.g., Sangola's pomegranate clusters) faces biological hazards (e.g., bacterial blight) and market price fluctuations, highlighting the need for balanced inter-cropping strategies.
3. **Decline in Staple Grain Security:** The sharp drop in local *rabi* Jowar acreage raises long-term concerns regarding regional food security and crop residue availability for livestock.

Conclusion:

Between 2004 and 2024, Solapur district transitioned from a subsistence-

based cereal agricultural economy into a commercialized agro-ecosystem characterized by cash crops and high-value horticulture. Spatially, non-irrigated eastern and southern tahsils maintain higher crop diversification levels to buffer against erratic rainfall. In contrast, western canal-fed zones have leaned toward crop specialization (primarily sugarcane). While this transition has raised gross farm revenues, it has also introduced environmental stresses, including groundwater overdraft and soil degradation.

Recommendations:

Enforce strict micro-irrigation mandates for water-intensive sugarcane and restrict its expansion in over-exploited groundwater blocks. Encourage inter-cropping within orchards (e.g., pulses alongside young fruit plantations) to maintain soil health and boost the Crop Diversification Index. Re-introduce yield protection guarantees and minimum support price (MSP) procurement networks for *rabi* Jowar and pulses to preserve regional food security.

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