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Trends and dynamics of crop diversification in Nanded district of Maharashtra: a 25 year analysis

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ABSTRACT

Crop diversification is central to risk management, resource-use efficiency and income resilience, yet a larger crop count does not necessarily imply an evenly distributed crop portfolio. This study quantified the extent and dynamics of crop diversification in Nanded district of Maharashtra over 25 agricultural years from 2000-01 to 2024-25. Annual secondary data on area under 18 mutually exclusive crop categories were analysed using the Herfindahl index, Simpson diversification index, normalized entropy, composite entropy index, effective number of crops and three-crop concentration ratio. Five-year period means, crop-group composition, base-to-terminal triennium shifts, Cuddy-Della Valle instability, heteroskedasticity-and-autocorrelation-consistent linear trends, Mann-Kendall tests and Theil-Sen slopes were used to assess robustness. Diversification improved initially and peaked during 2005-06 to 2009-10, when the mean Simpson and composite entropy indices were 0.8446 and 0.7266, respectively. Thereafter, the crop portfolio progressively reconcentrated. Between 2000-01 and 2024-25, the Simpson index declined from 0.8026 to 0.7168, the composite entropy index declined from 0.6720 to 0.5550, and the effective number of crops fell from 5.0662 to 3.5309, while the three-crop concentration ratio rose from 0.6698 to 0.7931. The decline in composite entropy was statistically significant (HAC slope = -0.0072 per year; $p < 0.001$) and was supported by non-parametric tests. Soybean gained 42.1502 percentage points of cropped area and became the leading crop; gram also expanded, whereas kharif jowar and cotton lost 23.4277 and 16.2734 percentage points. Nanded therefore experienced crop substitution followed by soybean-led concentration rather than sustained, broad-based diversification. Extension and market policy should promote economically viable crop baskets, not diversification by crop count alone.

Keywords: Composite entropy index, Crop concentration, Herfindahl index, Maharashtra, Simpson diversification index, Structural change

1 Introduction

Agricultural diversification refers to the reallocation of productive resources among crops, enterprises and value chains in response to technology, markets, natural resources and risk. At the crop level, diversification may involve replacing a dominant crop, adding crops, or distributing land more evenly across existing crops. These pathways have different implications. A portfolio with many crops can remain highly concentrated when most land is allocated to only one or two commodities; consequently, both crop richness and evenness must be examined (Simpson, 1949; Shannon, 1948) [1, 2].

Diversification is especially relevant in rainfed and semi-arid agriculture. A broader crop portfolio can spread climatic, biological and price risk, improve temporal use of labour and land, support rotations and create access to higher-value markets. However, specialization can also be a rational response when one crop benefits from superior prices, input delivery, processing facilities or procurement. Empirical assessment should therefore avoid assuming that every shift away from food grains represents durable diversification (Joshi *et al.*, 2006; Chand, 1996; Birthal *et al.*, 2020) [3, 4, 5].

Indian agriculture has undergone marked compositional change with the expansion of oilseeds, pulses, horticulture and other commercial crops. Previous studies show that irrigation, infrastructure, market access, price incentives, technology and farm resources influence whether this process produces a balanced crop mix or concentration in a profitable commodity (Chand, 1996; Birthal *et al.*, 2020; Kumar *et al.*, 2012; Negi *et al.*, 2020) [4, 5, 6, 7]. District-level evidence is particularly important because agro-climatic conditions and market linkages vary substantially within states.

Nanded district lies in the Marathwada region of Maharashtra and contains a large rainfed farming economy exposed to rainfall variability and commodity-market fluctuations. Its cropping pattern has changed markedly during the past quarter century, including expansion of soybean and gram and contraction of traditional cereals. Yet the long-run direction of diversification is not evident from crop areas alone. A fall in cereal area may initially widen the crop portfolio but later increase concentration if the released area is absorbed primarily by a single oilseed.

The study therefore aimed to quantify the extent, trend and structural dynamics of crop diversification in Nanded district from 2000-01 to 2024-25. It asked three questions: whether diversification increased over the entire period; whether conclusions were robust across complementary indices and statistical tests; and which crop groups and individual crops drove the observed movement. The paper contributes a transparent district-level assessment that separates crop substitution from broad-based diversification and connects index movements to extension and policy priorities.

2 Materials and methods

2.1 Study area data and period

The unit of analysis was Nanded district, Maharashtra. The study used annual secondary data for 25 agricultural years, 2000-01 to 2024-25, compiled from published district-level statistical records. The analytical file contained area under rice, wheat, kharif jowar, rabi jowar, bajra, maize, gram, mung, tur, udid, total groundnut, sunflower, safflower, soybean, sesamum, cotton, sugarcane, and fruits and vegetables. These 18 categories were mutually exclusive. Total groundnut was used to avoid double counting its seasonal components. Crop areas and total cropped area were expressed in hundred hectares.

A missing cotton-area observation for 2007-08 was reconstructed from the reported cotton production and productivity using the source units and the standard bale conversion. The reconstructed value was 2,078 hundred ha. No other observation was altered. Annual totals were recalculated from the mutually exclusive crop categories before the indices were estimated. The 25 years were also grouped into five consecutive five-year periods: I (2000-01 to 2004-05), II (2005-06 to 2009-10), III (2010-11 to 2014-15), IV (2015-16 to 2019-20) and V (2020-21 to 2024-25).

2.2 Diversification and concentration measures

For crop i in year t , the area share was $p_{it} = \frac{A_{it}}{\sum_i A_{it}}$. The Herfindahl index (HI) was the sum of squared crop shares and the Simpson diversification index (SID) was $1 - HI$. Shannon entropy was $E_t = - \sum_i p_{it} \ln(p_{it})$. Because the number of crops with positive area varied slightly, entropy was normalized as $NEI_t = \frac{E_t}{\ln(N_t)}$, where N_t is the number of positive-area crops. The composite entropy index was $CEI_t = NEI_t \left(1 - \frac{1}{N_t}\right)$. The effective number of crops was $\frac{1}{HI}$, and CR3 was the combined share of the three largest crops. Higher SID, NEI, CEI and effective crop number indicate greater diversification; higher HI and CR3 indicate concentration (Simpson, 1949; Shannon, 1948; Herfindahl, 1950) [1, 2, 8].

Table 1. Measures used to assess crop diversification and concentration

Measure	Specification	Interpretation
Herfindahl index (HI)	$\sum p_i^2$	Lower value indicates greater diversification
Simpson diversification index (SID)	$1 - HI$	Higher value indicates greater diversification
Normalized entropy index (NEI)	$-\sum p_i \ln(p_i) / \ln(N)$	Higher value indicates greater evenness
Composite entropy index (CEI)	$NEI \times \left(1 - \frac{1}{N}\right)$	Higher value indicates greater diversification
Effective number of crops	$1 / HI$	Equivalent number of equally represented crops
Three-crop concentration ratio (CR3)	Sum of three largest p_i	Higher value indicates greater concentration

2.3 Trend structural change and instability analysis

Annual indices were summarized by arithmetic means within each five-year period. Crop-group shares were calculated for cereals, pulses, oilseeds, commercial crops, and fruits and vegetables. Structural change at crop level was measured as the difference between mean shares in the terminal triennium (2022-23 to 2024-25) and base triennium (2000-01 to 2002-03), reducing sensitivity to a single endpoint year.

Linear index trends were estimated against a time variable. Statistical inference used Newey-West heteroskedasticity-and-autocorrelation-consistent standard errors with lag one and finite-sample correction (Newey *et al.*, 1987) [9]. Robustness was checked with the distribution-free Mann-Kendall trend test and Theil-Sen median slope (Mann, 1945; Sen, 1968) [10, 11]. Crop-area instability was assessed with the Cuddy-Della Valle index, $CDVI = CV \sqrt{(1-R^2)}$, where R^2 came from a linear time trend (Cuddy *et al.*, 1978) [12]. Results were reported to four decimal places throughout so numerical statements correspond exactly with tables.

3 Results and discussion

3.1 Long run extent of crop diversification

The annual indices provide a direct test of whether cultivated area became more evenly distributed. All complementary measures pointed to the same long-run outcome (Table 2 and Figure 1). SID declined from 0.8026 in 2000-01 to 0.7168 in 2024-25, while HI increased

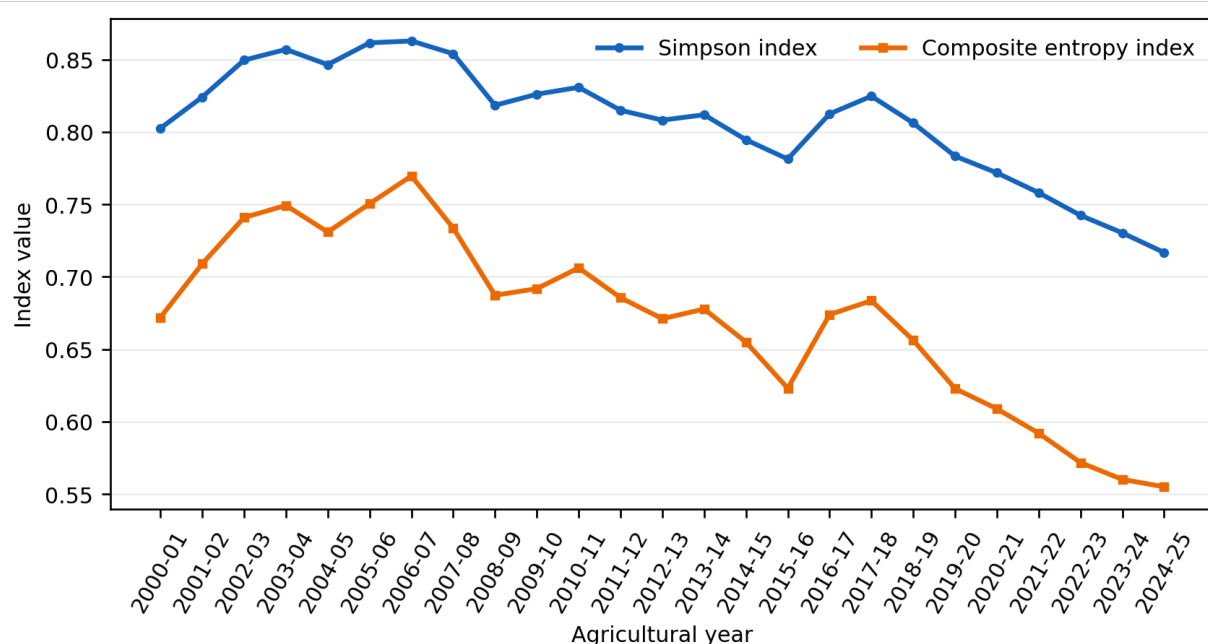
from 0.1974 to 0.2832. CEI fell from 0.6720 to 0.5550. The effective number of crops declined by 1.5353, from 5.0662 to 3.5309, whereas CR3 increased by 0.1233, from 0.6698 to 0.7931. Thus, by 2024-25 almost four-fifths of total crop area was concentrated in the three leading crops.

The simultaneous fall in SID, CEI and effective crop number, together with the rise in HI and CR3, rules out an interpretation based on a peculiarity of one index. Nanded continued to report a large crop count, but area became progressively less even. This distinction is important: crop richness remained broadly present, whereas economic land allocation became concentrated. Comparable Indian evidence shows that diversification outcomes depend on the interaction of relative profitability, markets, irrigation and technology rather than on the mere availability of alternative crops (Chand, 1996; Bithal *et al.*, 2020; Kumar *et al.*, 2012; Negi *et al.*, 2020) [4, 5, 6, 7].

Table 2. Change in principal diversification measures between 2000-01 and 2024-25

Measure	2000-01	2024-25	Change
HI	0.1974	0.2832	+0.0858
SID	0.8026	0.7168	-0.0858
CEI	0.6720	0.5550	-0.1170
Effective crops	5.0662	3.5309	-1.5353
CR3	0.6698	0.7931	+0.1233

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HI + SID = 1 by construction. Values are calculated from the same 18-category crop universe.

Figure 1. Annual movement in Simpson and composite entropy indices, 2000-01 to 2024-25.

3.2 Period wise dynamics

Five-year averages smooth weather-driven annual movements and reveal a clear two-stage path (Table 3). Diversification improved modestly between Period I and Period II: mean SID rose from 0.8360 to 0.8446 and CEI from 0.7205 to 0.7266. The effective crop number also increased from 6.1838 to 6.5268. This early gain was reversed

thereafter. By Period V, SID had declined to 0.7439, CEI to 0.5775 and effective crop number to 3.9277, while CR3 had risen to 0.7751. The period evidence indicates that Nanded did not follow a uniform linear transition. Initial reallocation away from traditional cereals produced a somewhat more even portfolio, but subsequent expansion became concentrated in a narrower set of crops. This pattern is consistent with the proposition that market development can first facilitate diversification and later encourage regional specialization where one crop acquires a strong comparative advantage (Chand, 1996; Kumar *et al.*, 2012) [4, 6].

Table 3. Five-year period averages of diversification and concentration indices

Period	HI	SID	CEI	Effective crops	CR3	Cropping intensity (%)
I	0.1640	0.8360	0.7205	6.1838	0.6119	112.68
I	0.1554	0.8446	0.7266	6.5268	0.6231	122.34
I	0.1879	0.8121	0.6791	5.3442	0.6633	134.79
I	0.1983	0.8017	0.6519	5.0785	0.6828	149.00
V	0.2561	0.7439	0.5775	3.9277	0.7751	155.40

Periods I-V correspond to successive five-year intervals from 2000-01 through 2024-25.

3.3 Statistical evidence on the direction of change

The decline was statistically systematic rather than an artifact of end-point selection (Table 4). CEI recorded a HAC slope of -0.0072 per year ($p < 0.001$) and a Theil-Sen slope of -0.0079. SID declined at -0.0050 per year ($p < 0.001$), while HI increased by the same magnitude because $SID = 1 - HI$. CR3 rose by 0.0078 per year ($p < 0.001$). Mann-Kendall tests supported the same directions. The agreement be-

tween parametric and rank-based methods is important because agricultural time series can contain heteroskedasticity, serial dependence and influential weather years.

The effective number of crops fell by about 0.1437 per year in the linear specification. This metric translates concentration into an intuitive equivalent crop count: the observed distribution in the final year had the same concentration as only 3.5309 equally represented crops. The evidence therefore supports a conclusion of statistically significant reconcentration over the full study horizon.

Table 4. Parametric and non-parametric trends in diversification measures

Measure	HAC slope	HAC SE	p value	R^2	Kendall τ	MK p value	Sen slope	Sen 95% interval
Herfindahl Index	0.0045	0.0010	< 0.001	0.6809	0.6467	< 0.001	0.0052	[0.0034, 0.0065]
Simpson Diversification Index	-0.0045	0.0010	< 0.001	0.6809	-0.6467	< 0.001	-0.0052	[-0.0065, -0.0034]
Composite Entropy Index	-0.0072	0.0013	< 0.001	0.7493	-0.7133	< 0.001	-0.0079	[-0.0095, -0.0059]
Effective number of crops	-0.1184	0.0278	< 0.001	0.6496	-0.6467	< 0.001	-0.1385	[-0.1719, -0.0968]
CR3	0.0076	0.0015	< 0.001	0.7150	0.6600	< 0.001	0.0087	[0.0060, 0.0107]

(continued on next page)

HAC inference uses Newey-West standard errors with lag one. MK denotes the Mann-Kendall test.

3.4 Transformation of broad crop groups

The broad crop composition explains the shift in the indices (Table 5 and Figure 2). Cereals declined from 33.0900% of cropped area in Period I to 5.4226% in Period V. Oilseeds increased from 11.0022% to 44.6281%, while pulses rose from 23.1984% to 28.4396%. Commercial crops accounted for 31.3380% in Period I, peaked at

35.6672% in Period III, and declined to 20.0650% in Period V. Fruits and vegetables remained below 2% in every period.

The early reduction in cereal dominance contributed to diversification, but the later oilseed expansion was overwhelmingly soybean-led. Hence, movement away from cereals should not automatically be interpreted as continuing diversification. Diversification toward high-value commodities can support agricultural growth and income (Joshi *et al.*, 2006; BIRTHAL *et al.*, 2020) [3, 5], but durable resilience requires several viable alternatives and supporting value chains rather than dependence on a new dominant commodity.

Table 5. Period-wise average shares of broad crop groups

Period	Cereals (%)	Pulses (%)	Oilseeds (%)	Commercial crops (%)	Fruits and vegetables (%)
I	33.0900	23.1984	11.0022	31.3380	1.3714
I	25.4418	22.1788	22.1038	29.6084	0.6671
I	19.0759	21.1462	22.4446	35.6672	1.6662
I	13.9271	23.7553	30.9653	30.1148	1.2375
V	5.4226	28.4396	44.6281	20.0650	1.4447

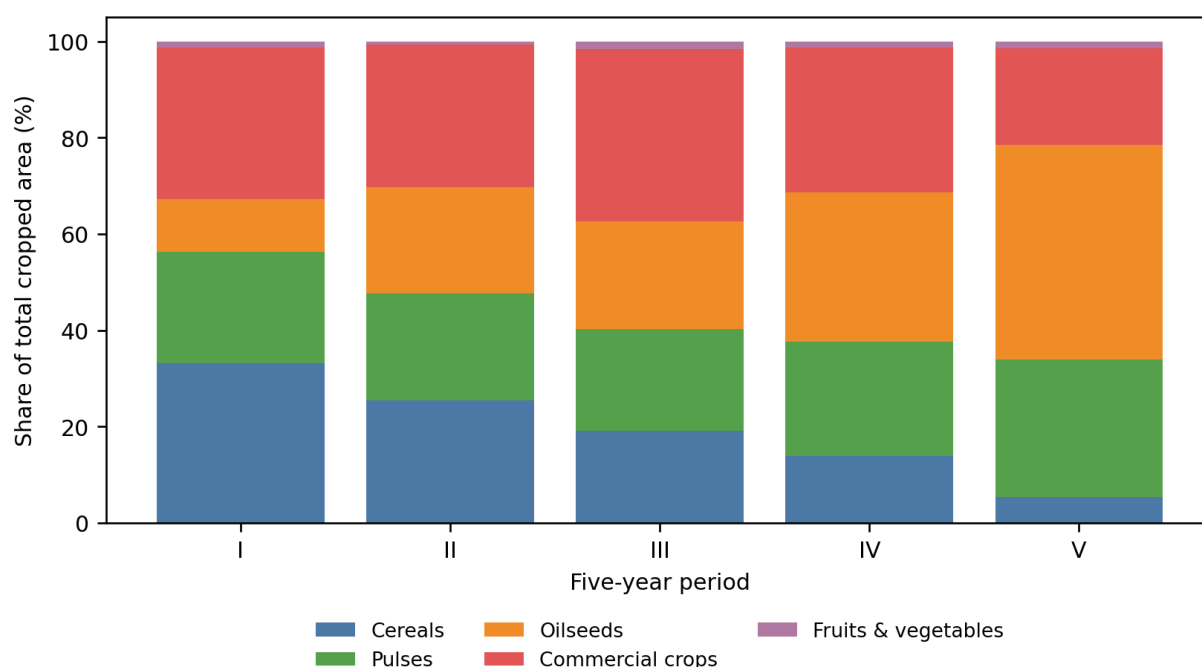


Figure 2. Structural change in broad crop-group composition across five periods.

3.5 Crop level drivers of diversification and concentration

Base-to-terminal triennium comparison identifies the crops responsible for reconcentration (Table 6 and Figure 3). Soybean gained 42.1502 percentage points and moved from rank 10 to rank 1. Gram gained 15.3798 points and rose from rank 8 to rank 2. Sugarcane, tur, maize, fruits and vegetables, and groundnut registered smaller gains. These increases were offset chiefly by kharif jowar (-23.4277 points), cotton (-16.2734), udid (-7.4298), rice (-3.0842), mung (-2.9781) and wheat (-2.6771).

The crop portfolio therefore underwent substitution rather than a uniform expansion of alternatives. Soybean and gram together absorbed much of the area released from kharif jowar, cotton and minor crops. The soybean area trend was 207.2997 hundred ha per year, with end-point CAGR of 18.1098%, while gram also displayed strong expansion. Although this transition may reflect perceived profitability, production suitability and market access, soybean dominance exposes farm households and the district economy to correlated rainfall, pest and price risks. Extension advice should consequently focus on economically coherent rotations and enterprise combinations, not indiscriminate addition of crops.

Table 6. Crop ranking and share change between base and terminal triennia

Crop	Base share (%)	Base rank	Terminal share (%)	Terminal rank	Change (percentage points)
Rice	3.1640	9	0.0797	15	-3.0842
Wheat	3.5290	7	0.8519	11	-2.6771
Jowar (K)	23.7974	2	0.3697	13	-23.4277

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Crop	Base share (%)	Base rank	Terminal share (%)	Terminal rank	Change (percentage points)
Jowar (R)	3.9093	6	2.2922	6	-1.6171
Bajra	0.0597	18	0.0222	16	-0.0375
Maize	0.1199	17	0.8882	10	+0.7683
Gram	3.4406	8	18.8204	2	+15.3798
Mung	4.9762	5	1.9981	7	-2.9781
Tur	6.7998	4	7.6367	4	+0.8369
Udid	8.2713	3	0.8416	12	-7.4298
Groundnut	1.0705	14	1.3034	9	+0.2329
Sunflower	1.9005	11	0.0009	18	-1.8997
Safflower	0.9880	16	0.0172	17	-0.9708
Soybean	3.0319	10	45.1822	1	+42.1502
Sesamum	1.0335	15	0.2113	14	-0.8223
Cotton	30.9241	1	14.6507	3	-16.2734
Sugarcane	1.8610	12	3.4151	5	+1.5542
Fruits & Vegetables	1.1231	13	1.4184	8	+0.2953

Base triennium: 2000-01 to 2002-03; terminal triennium: 2022-23 to 2024-25.

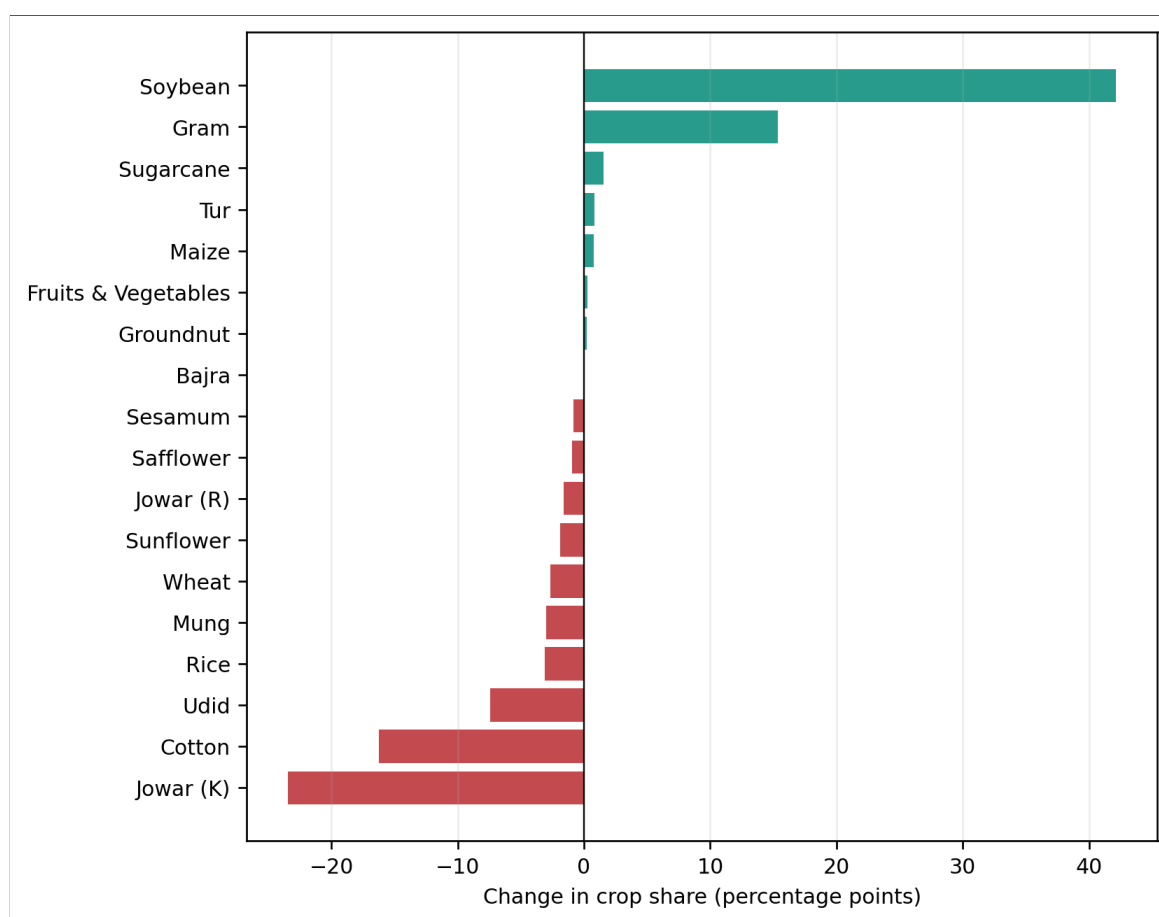


Figure 3. Crop-share gains and losses between the base and terminal triennia.

3.6 Implications for agricultural extension and development

The results alter the practical interpretation of diversification in Nanded. The central challenge is not the absence of multiple crops but the declining evenness of their area distribution. Extension programmes should demonstrate locally suitable soybean-pulse-cereal and soybean-oilseed rotations, incorporate farm-budget and risk comparisons, and link recommendations to seed availability, mechanization, storage, aggregation and assured market channels. Traditional and climate-resilient cereals require attention where they remain agro-nomically and nutritionally suitable.

Policy should monitor both profitability and concentration. District planning systems can report SID or CEI alongside crop area, yield

and value of output. A diversification programme should be judged by whether several alternatives acquire viable shares and stable value chains, rather than whether a minor crop was introduced. Farmer producer organisations, market intelligence, pulse and oilseed processing, water management and weather-based advisories can lower transition costs and help farmers choose portfolios suited to farm resources and risk preferences.

4 Conclusion

Crop diversification in Nanded district improved only during the early part of the study and then reversed. Over 2000-01 to 2024-25, SID and CEI declined significantly, effective crop number contracted, and

the share of the three leading crops increased. The decisive structural change was the rise of soybean, accompanied by gram, against a sharp decline in kharif jowar, cotton and several minor crops. Thus, the district shifted crops but did not achieve sustained broad-based diversification; it moved toward soybean-led concentration. The policy priority is to develop profitable, agronomically compatible and market-supported crop baskets that preserve farm income opportunities while reducing dependence on a small number of commodities.

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