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Temporal and spatial performance of rapeseed and mustard oilseed in India: A study in the context of Technology Mission on Oilseeds[!]

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ABSTRACT: Oilseed group is an important cash crop group in Indian agriculture. They are the source of edible oils for the country. The oilseed group is classified into nine oilseeds which are groundnut, sunflower, soybean, rapeseed mustard, sunflower, sesame, niger, linseed and castor. Linseed and castor are considered as inedible oilseed. India is a major producer and consumer of oilseeds and their products, and emerged as one of the world's largest importers of edible oils in the late 1990s. Oilseed are imported to meet the consumption demand of the country because despite of their increasing production the oilseed sector has shown unstable performance. The present study has examined growth and instability in one of the important oilseed crop rapeseed and mustard in major producing states in India as well as in the country as a whole in the context of Technology Mission on Oilseeds (TMO) by estimating compound annual growth rates of area, production and productivity and by constructing Cuddy Della Valle indices, respectively, during the TMO period and prior to it.

Key words: Compound annual growth rate, instability, leading states, rapeseed and mustard oilseed, Technology Mission on Oilseeds

Oilseed are considered as the important source of cash crops in Indian agriculture. They are the important sources of edible oil supply in the country. In all, there are mainly nine annual oilseed crop grown namely, groundnut, rapeseed, mustard, soybean, sunflower, linseed, sesame, castor, safflower and niger. From these nine, groundnut, rapeseed and mustard, soybean, sesame and sunflower are classified as major oilseed accounting for 89 per cent of the area and 93 per cent of the total production in oilseed of the country. The oilseed is considered as the second largest crop group grown after the food grains in India.

India is one of the largest producers of oilseed in the world and occupies an important position in the Indian agricultural economy (Reddy, 2017). Oilseed group is considered as the rain fed crop and in the domestic agricultural sector, oilseed occupy a distinct position after cereals, sharing 13 per cent of the country's gross cropped area and accounting for nearly 3 per cent of the gross domestic product and 10 per cent of the value of all agricultural products (Jha *et al.,* 2012). About 14 million persons are engaged in the production of oilseed and another one million is engaged in the processing sector in oilseed. India is the third largest vegetable oil economy in the world next to the USA and China. India is also one of the largest exporters of oil meals, particularly of soybean meals which accounted for more than 70 per cent of the total exported oil meals followed by rapeseed mustard, castor, etc. India is also one of the largest oilseed exporters for USA, UAE, Netherlands, China, etc. In Sept 2022, India exported US $ 59.11 million worth of oilseeds (Indian Trade Portal, Govt of India report, 2022). Though India has one of the largest cultivated areas under oilseeds in the world, but their performance during last few decades is quite disappointing. Domestic production of the oilseed is not according to the rising demand for oil in the country due to increase in the population, which is leading to considerable amount of increasing imports of edible oil over time. The country needs 25 MT of edible oils to meet its requirements at the consumption level of 19 kg per person per year in the year 2020

! This paper is drawn from the Post Graduate thesis submitted by first author under supervision of the second author.

(Sharma, 2020). India is not producing even half of its edible oil requirements due to lesser yield, rain-fed nature of production of oilseed, lower seed replacement ratio. As a fact, the consumption levels of crucial nutrients like oils and fats are much below than the minimum required level prescribed by the Indian Council of Medical Research who advised that 30 per cent of total daily energy intake should come from oils/fats. The Green Revolution which increased country's production by increasing the productivity of wheat and rice did not give much importance to pulses and oilseed production.

The total vegetable oil requirement in the country in 2022 had been estimated to be 33.20 million tonnes assuming per capita consumption of more than 21.70 kg per person per annum. The anticipated vegetable oil production from 45.64 million tonnes of oilseed in the year 2022 was 13.69 million tonnes (NFSM anticipated report for year 2022). This shows that gap between production and requirement has also increased over time which was at alarming rate. Therefore, the country has to spend a large amount of foreign exchange to meet domestic demand of edible oils through imports. Same scenario existed during the eighties which showed the gap between demand and supply of oilseed (Adelman, 2002) which was being bridged by importing the oils from other countries. Further in the view of heavy pressure on balance of payments, the Government of India launched, the Technology Mission on Oilseed (TMO) in May, 1986 which has been implemented as an integrated policy on oilseed with the four – pronged strategy to improve oilseed crop technology, improve post-harvest technology, strengthen services to the farmers and ensure remunerative prices to the farmers. Oilseed are generally produced in energy starved conditions with around 25 per cent of area under irrigation (considered as rain fed crop), they are generally subjected to deadly climatic variations which results in declining their yields in comparison of the irrigated cereals like wheat and rice. In this study main focus is kept on rapeseed and mustard. The oil content of the rapeseed and mustard ranges from 30 to 48 percent. The crop is grown both in subtropical and tropical countries.

MATERIALS AND METHODS

Methodology

The time series data on the area, production, productivity, of rapeseed and mustard in major states and country as a whole was collected from various published and unpublished sources such as, Department of Agriculture, Directorate of Economics and Statistics, Ministry of Agriculture and Farmers' Welfare, Government of India, commodities.cmie.com, etc. Major states were selected (according to 2018 production data) for this study based on their cumulative contribution of at least 95 per cent of total production of rapeseed and mustard oilseed in the country as shown in Table 1. The states such as Madhya Pradesh (included Chhattisgarh) and Uttar Pradesh (included Uttarakhand), which were not carved up earlier are taken as such in the present study because study used the time series data from 1970-71 to 2017-18.

Table 1: Production of rapeseed and mustard in different states during 2018-19

S. No.	States	Production (MT)	% share	Cumulative %
1	Rajasthan	4.08	45.13	45.13
2	UP (Undivided)	1.25	13.82	58.96
3	MP (Undivided)	1.12	12.38	71.34
4	West Bengal	1.11	12.27	83.62
5	Gujarat	0.72	7.96	91.59
6	Maharashtra	0.34	3.76	95.35
7	Karnataka	0.16	1.76	97.12
8	Tamil Nadu	0.05	0.55	97.67
9	Others	0.21	2.32	100
10	Total	9.04	100	-

The study time period is further divided into phases as mentioned: Pre-Technology Mission on Oilseed (Pre TMO) period from 1970-71 to 2017-18, Technology Mission on Oilseed Phase one (TMO-I) from 1986-87 to 2001-02, Technology Mission on Oilseed phase two (TMO-II) from 2002-03 to 2017-18, Overall Period of Technology Mission on Oilseed (TMO) from 1986-87 to 2017-18 and Overall period from 1970-71 to 2017-18. After the introduction of Technology Mission on Oilseed there has been a continuous increase in the production of oilseed (Kaushik, 1993), therefore the present study was divided on the basis of TMO time period. To

examine the temporal performance of this oilseed across major states and in the country as a whole, compound annual growth rates (Kalra and Srivastava, 2024) have been estimated using exponential growth function of the following form:

$$Y_t = ae^{bt}$$

Where, Y_t is value of the variable i.e. area/ production/ productivity of rapeseed and mustard, a is constant and b is trend coefficient.

The log transformation of this function is as follows:

$$\text{Log}_e Y_t = \text{Log}_e a + bt$$

Compound annual growth rate (CAGR) in worked out as:

CAGR in percentage = [(Antilog b)-1] * 100

(Detailed methodology may be viewed from; Chadha and Srivastava, 2020; Kalra and Srivastava, 2022; Kalra and Srivastava, 2023; Wahid and Srivastava, 2023).

Instability index is used as an analytical tool to find the fluctuations in any given time series data. Cuddy – Della Valle instability (Cuddy and Della Valle, 1978) index has been constructed to measure the instability in the time series data in different periods across major states and in the country. The Cuddy index is constructed as follows,

Cuddy – Della Valle Instability index (per cent) $= CV\sqrt{(1-\bar{R}^2)}$

Where,

$\bar{R}^2$ = Adjusted Coefficient of Multiple Determination

CV (Coefficient of Variation) in per cent $=(\frac{\sigma}{\bar{x}})*100$

σ = Standard deviation and x bar is mean value.

The present study divides the Cuddy Della Valle Index value into three categories, which represent the different range of instability (Sihmar, 2014; Geetha and Srivastava, 2019; Kalra and Srivastava, 2023; Wahid and Srivastava, 2023).

Low instability = between 0 to 15
Medium instability = greater than 15 to 30
High instability = greater than 30

RESULTS AND DISCUSSION

Performance of rapeseed and mustard production across leading states in India

Growth in area, production, productivity of rapeseed and mustard is discussed in this section. The major rapeseed and mustard producing states discussed here are, Madhya Pradesh (undivided), Maharashtra, Karnataka, Gujarat, Rajasthan, Tamil Nadu, West Bengal and Uttar Pradesh (undivided) as they together contributed more than 97 per cent of production in the country. To examine the performance CAGR has been estimated for different time periods in the context of TMO phases.

Compound annual growth of rapeseed and mustard area during different periods

Compound annual growth rate of rapeseed and mustard with respect to area is presented in Table 2. The table reveals that during Pre TMO period, except Uttar Pradesh (undivided) and Karnataka in which area declined at the rate of 3.29 and 2.07 per cent per annum, respectively, all the states have shown positive growth in the area of rapeseed and mustard. Gujarat has shown highest rate of growth in the area at 13.13 per cent per annum while in Maharashtra this area remained stagnant. During the overall study period, highest CAGR is found in the state of Madhya Pradesh (undivided) at the rate of 5.02 per cent per annum, except in Uttar Pradesh (along with Uttarakhand) and Karnataka wherein area declined at the rate of 2.81 and 0.39 per cent per annum, respectively. In all the phases of the study the area under rapeseed and mustard increased remarkably. The CAGR is found more in TMO period compared to that of Pre TMO period. The actual and estimated area of rapeseed and mustard for different leading states is shown through figures 1 to 6.

Compound annual growth of rapeseed and mustard production during different periods

Table 3 presents growth in the production of rapeseed and mustard for different periods. The table reveals that during Pre TMO period, except Tamil Nadu and Karnataka where production almost remained stagnant and Uttar Pradesh with negative growth at the rate of 2.62 per cent per annum, all the other major states registered positive growth in the production of rapeseed and mustard, in which West Bengal at the rate of 11.18 per cent per annum remained on the top. During the entire TMO period, production in Karnataka had declined during second phase of TMO has now shown almost stagnant

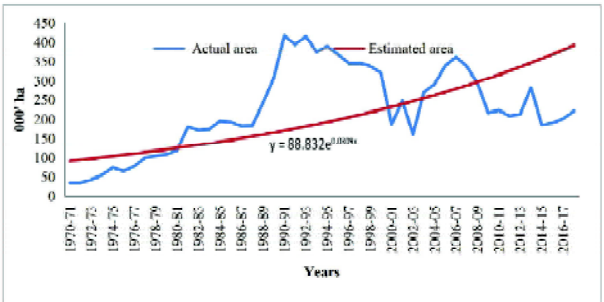

Fig 1: Actual and estimated area of rapeseed and mustard in Gujarat from 1970-71 to 2017-18

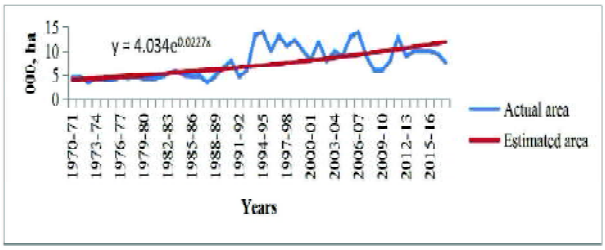

Fig 2: Actual and estimated area of rapeseed and mustard in Maharashtra from 1970-71 to 2017-18

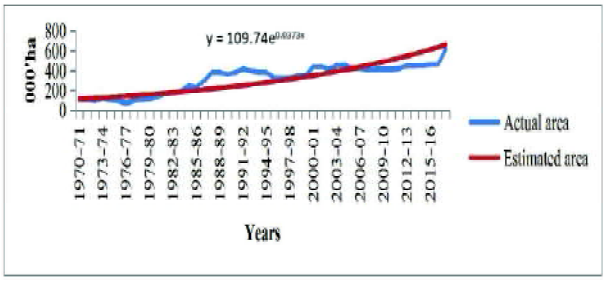

Fig. 3: Actual and estimated area of rapeseed and mustard in West Bengal from 1970-71 to 2017-18

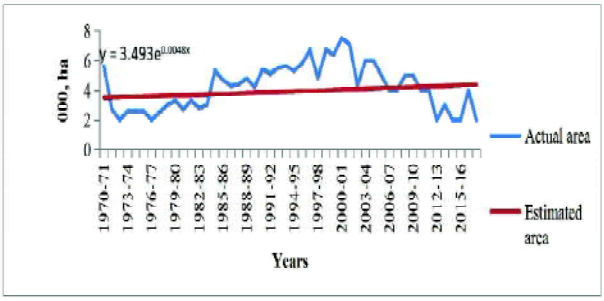

Fig.4: Actual and estimated area of rapeseed and mustard in Karnataka from 1970-71 to 2017-18

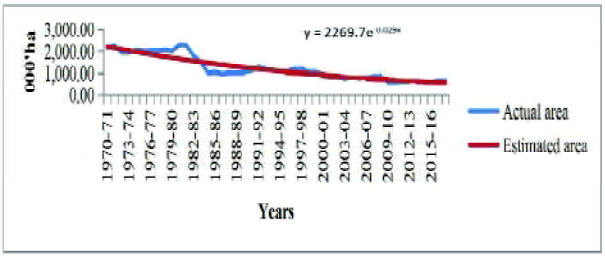

Fig 5: Actual and estimated area of rapeseed and mustard in Uttar Pradesh (undivided) from 1970-71 to 2017-18

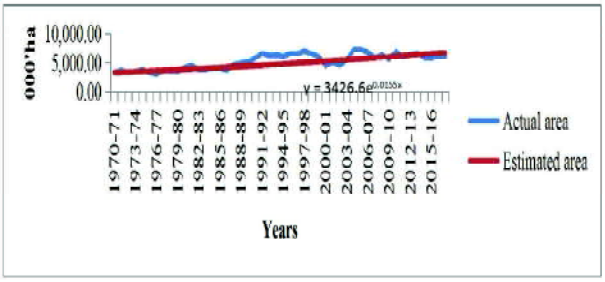

Fig. 6: Actual and estimated area of rapeseed and mustard in Rajasthan from 1970-71 to 2017-18

production along with Tamil Nadu and Maharashtra. Rest of the other major producing states registered positive growth in which Madhya Pradesh (undivided) has shown highest rate of growth in production at the rate of 6.92 per cent per annum, except Uttar Pradesh (undivided) which have shown decline in the production at the rate of 0.71 per cent per annum. During the entire study period, Maharashtra and Tamil Nadu production remained stable and rest other states and country's production grew significantly except in Uttar Pradesh where production declined at the rate of 0.68 per cent per annum. During this period, maximum growth rate in production registered by Madhya Pradesh (undivided) at the rate of 7.35 per cent per annum. From figure 7 to 12 the actual and estimated production in the leading states of rapeseed and mustard is shown.

Compound annual growth of rapeseed and mustard productivity during different periods

Compound annual growth rate in the productivity of rapeseed and mustard for different periods is given in the Table 4. The table reveals that during Pre TMO period, except Tamil Nadu, Karnataka and Uttar Pradesh (undivided) where productivity almost remained stagnant, all the other states and country as a whole registered positive growth in the productivity of rapeseed and mustard, in which Gujarat with the CAGR of 7.04 per cent remained on the top. During the entire TMO period in Karnataka, Tamil Nadu and Maharashtra

Table 2: Compound annual growth rate in area (000'ha) of rapeseed and mustard for different periods

States	Time period	Initial year observation	Final year observation	Constant	Trend coefficient	Standard error	R^2	CAGR (%)
Gujarat	Pre TMO	34.60	192.40	3.47	0.123***	0.006	0.96	13.13
	TMO (I)	181.70	247.10	5.63	0.009*	0.016	0.65	0.97
	TMO (II)	160.80	221.00	5.66	-0.020*	0.012	0.36	-2.06
	TMO Total	181.70	221.00	5.80	0.011**	0.005	0.59	1.10
	Overall Period	34.60	221.00	4.48	0.030***	0.005	0.43	3.14
Maharashtra	Pre TMO	4.50	4.80	1.38	0.015	0.004	0.10	1.52
	TMO (I)	4.90	12.00	1.51	0.069**	0.016	0.55	7.16
	TMO (II)	8.00	7.70	2.25	-0.003	0.013	0.09	-0.32
	TMO Total	4.90	7.70	1.93	0.013**	0.006	0.73	1.38
	Overall Period	4.50	7.70	1.39	0.022***	0.002	0.55	2.29
West Bengal	Pre TMO	108.20	231.60	4.35	0.057**	0.011	0.62	5.91
	TMO (I)	294.90	439.60	5.86	0.005*	0.006	0.43	0.51
	TMO (II)	408.30	615.00	5.99	0.011**	0.004	0.30	1.16
	TMO Total	294.90	615.00	5.81	0.010***	0.001	051	1.08
	Overall Period	108.20	615.00	4.69	0.037***	0.002	0.77	3.80
Karnataka	Pre TMO	5.60	4.70	0.92	-0.021*	0.016	0.11	-2.07
	TMO (I)	4.30	7.10	1.42	0.033***	0.005	0.75	3.35
	TMO (II)	4.30	2.00	1.83	-0.063**	0.014	0.59	-6.10
	TMO Total	4.30	2.00	1.88	-0.023**	0.005	0.35	-0.02
	Overall Period	5.60	2.00	1.25	-0.004*	0.004	0.59	-0.39
Tamil Nadu	Pre TMO	0.50	0.80	-0.52	0.019*	0.015	0.30	1.97
	TMO (I)	0.60	1.00	-0.30	0.002	0.013	0.001	0.20
	TMO (II)	0.50	0.30	-0.77	-0.024	0.017	0.12	-2.04
	TMO Total	0.60	0.30	-0.04	-0.035***	0.006	0.53	-3.49
	Overall Period	0.50	0.30	-0.11	-0.017**	0.003	0.33	0.01
Uttar Pradesh+	Pre TMO	2163.70	1069.30	7.80	-0.033**	0.010	0.43	-3.29
Uttarakhand	TMO (I)	973.50	846.90	7.02	-0.004*	0.005	0.46	-0.47
	TMO (II)	847.80	679.00	6.75	-0.021**	0.005	0.51	-2.10
	TMO Total	973.50	679.00	7.15	-0.022***	0.002	0.76	-2.23
	Overall Period	2163.50	679.00	7.72	-0.028***	0.001	0.87	-2.81
Rajasthan	Pre TMO	3323.10	3979.90	8.08	0.013**	0.003	0.49	1.36
	TMO (I)	3718.60	5073.00	8.50	0.015*	0.009	0.46	1.57
	TMO (II)	4544.00	5977.20	8.70	0.001*	0.006	0.41	0.17
	TMO Total	3718.60	5977.20	8.57	0.006**	0.002	0.35	0.61
	Overall Period	3323.10	5977.20	8.13	0.015***	0.001	0.67	1.55
Madhya Pradesh	Pre TMO	2964.26	3615.26	7.96	0.035***	0.005	0.57	3.56
+ Chhattisgarh	TMO (I)	3869.06	4632.09	8.09	0.043***	0.003	0.63	4.39
	TMO (II)	4796.06	5137.06	8.15	0.039***	0.001	0.76	3.97
	TMO Total	3869.06	5137.06	8.26	0.042***	0.004	0.79	4.28
	Overall Period	2964.26	5137.06	8.16	0.049***	0.003	0.57	5.02
India	Pre TMO	11263.23	12673.03	7.91	0.039***	0.002	0.63	3.97
	TMO (I)	12976.75	16324.06	7.63	0.048***	0.001	0.78	4.91
	TMO (II)	17563.02	18697.67	8.01	0.053***	0.003	0.80	5.44
	TMO Total	12976.75	18697.67	8.36	0.057***	0.002	0.84	5.86
	Overall Period	11263.23	18697.67	8.23	0.059***	0.001	0.87	6.07

***, ** and * shows significant at 1, 5 and 10 per cent levels of probability.

productivity declined at the rate of 0.69, 0.41 and 0.48 per cent per annum, respectively. Rest of the other major producing states registered positive growth where Madhya Pradesh (undivided) registered highest rate of growth in productivity at the rate of 3.35 per cent per annum. During the entire study period in Maharashtra and Tamil Nadu productivity remained stable and in rest of the other states and country this productivity grew significantly except in Karnataka where it

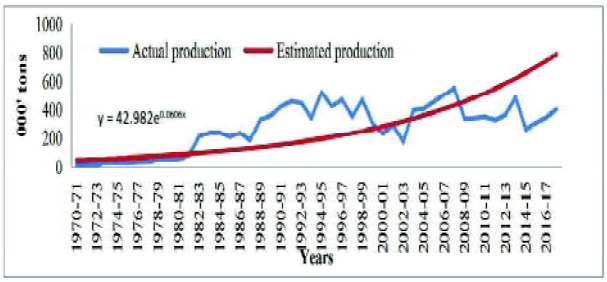

Fig. 7: Actual and estimated production of rapeseed and mustard in Gujarat from 1970-71 to 2017-18

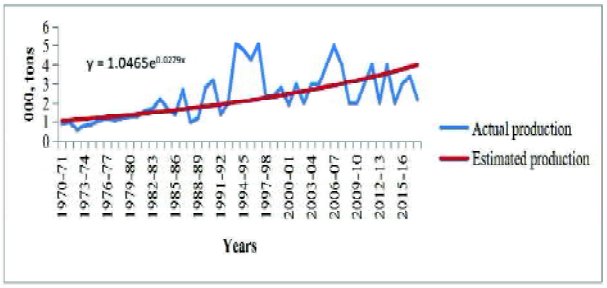

Fig. 8: Actual and estimated production of rapeseed and mustard in Maharashtra from 1970-71 to 2017-18

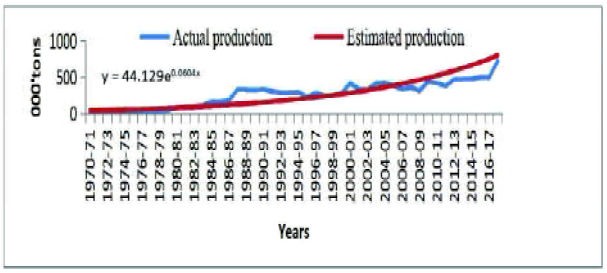

Fig. 9: Actual and estimated production of rapeseed and mustard in West Bengal from 1970-71 to 2017-18

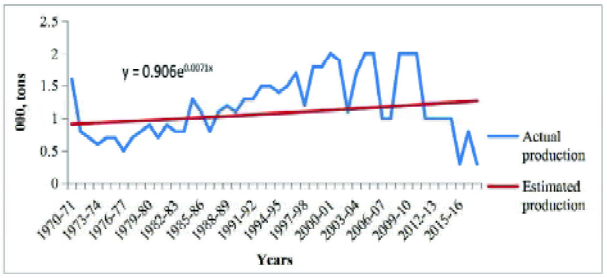

Fig.10: Actual and estimated production of rapeseed and mustard in Karnataka from 1970-71 to 2017-18

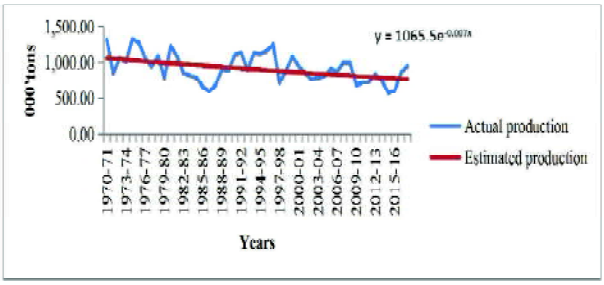

Fig. 11: Actual and estimated production of rapeseed and mustard in Uttar Pradesh (undivided) from 1970-71 to 2017-18

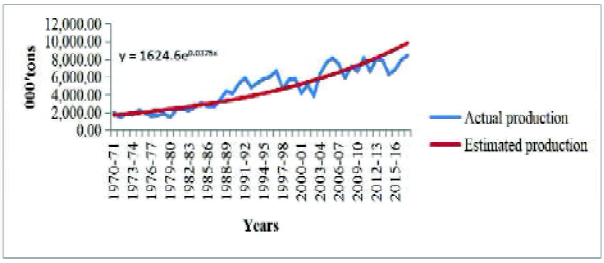

Fig. 12: Actual and estimated production of rapeseed and mustard in Rajasthan from 1970-71 to 2017-18

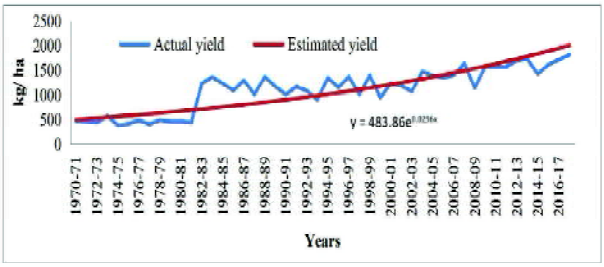

Fig. 13: Actual and estimated productivity of rapeseed and mustard in Gujarat from 1970-71 to 2017-18

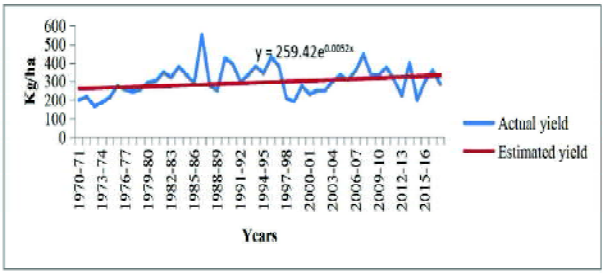

Fig. 14: Actual and estimated productivity of rapeseed and mustard in Maharashtra from 1970-71 to 2017-18

declined at the rate of 0.19 per cent per annum. During this period, maximum growth rate in productivity has been found in Madhya Pradesh (undivided) at the rate of 3.76 per cent per annum. During the TMO period productivity of rapeseed and mustard in the country grew at highest CAGR compared to that of the Pre TMO period indicating good impact of TMO on this oilseed. The aforementioned figures from 13-18 have been graphed to show the actual and estimated yield in the respective oilseed among its leading states.

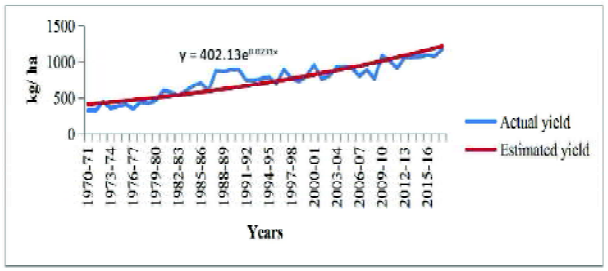

Fig. 15: Actual and estimated productivity of rapeseed and mustard in West Bengal from 1970-71 to 2017-18

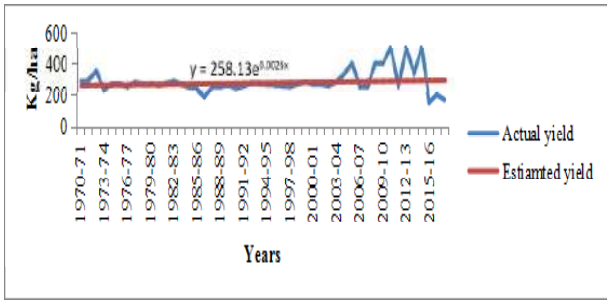

Fig: 16: Actual and estimated productivity of rapeseed and mustard in Karnataka from 1970-71 to 2017-18

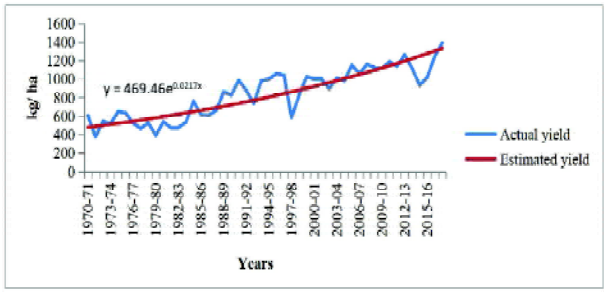

Fig. 17: Actual and estimated productivity of rapeseed and mustard in Uttar Pradesh (undivided) from 1970-71 to 2017-18

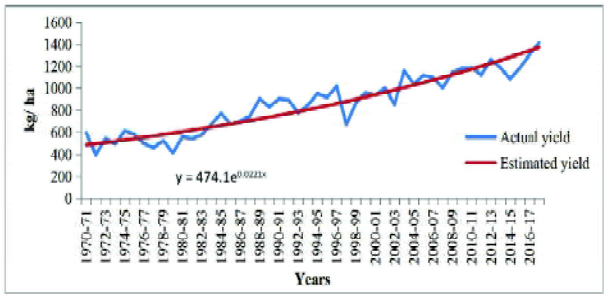

Fig. 18: Actual and estimated productivity of rapeseed and mustard in Rajasthan from 1970-71 to 2017-18

Instability in the area, production, productivity of rapeseed and mustard"Instability in the area, production and productivity of rapeseed and mustard in the country and the major producing states is discussed in this section. " Instability in the area of rapeseed and mustard"Instability indices in area of rapeseed and mustard are shown in Table 5.

The table indicates that during Pre TMO period Karnataka (33.27) and Tamil Nadu (33.06) registered higher instability with respect to area of rapeseed and mustard. During the overall TMO period higher instability in the area of rapeseed and mustard observed in Gujarat (45.97 per cent), Maharashtra (30.26 per cent) and country as a whole (41.34) while other states have shown lower instabilities in the area of rapeseed and mustard. For the entire study period only Karnataka (36.27 per cent), Tamil Nadu (33.38 per cent) and India (48.34 per cent) registered higher instabilities in the area of rapeseed and mustard.

Instability in the production of rapeseed and mustard

Instability indices for production of rapeseed and mustard for major rapeseed and mustard producing states and India are shown in Table 6.

It can be inferred from the table that during Pre TMO period Gujarat (31.43), Karnataka (32.84), Tamil Nadu (32.63) and West Bengal (31.38) have shown higher instability in the production of rapeseed and mustard and rest other states registered instability in the production ranging from 17.06 to 17.75 per cent. During the entire period of study instability in the production of rapeseed and mustard in Gujarat decreases to 16.07 per cent from 60.39 per cent in the TMO II. Higher instability was also observed with respect to production in the states of Karnataka, Maharashtra, Tamil Nadu and country as a whole from 33.99 to 45.10 per cent.

Instability in the productivity of rapeseed and mustard

The instability indices in productivity of rapeseed and mustard for major rapeseed and mustard producing states are presented in Table 7.

It can be deduced from the table that during Pre TMO period only Gujarat (39.40) registered higher instability in the productivity of rapeseed and mustard and rest other states and country as a whole experienced instability in the production of rapeseed and mustard ranging from 7.57 to 21.77 per cent.

Table 3: Compound annual growth rate in production (000'tons) of rapeseed and mustard for different periods

States	Time period	Initial year observation	Final year observation	Constant	Trend coefficient	Standard error	R^2	CAGR (%)
Gujarat	Pre TMO	16.30	208.90	2.35	0.16***	0.016	0.91	2.11
	TMO (I)	234.90	292.10	5.77	0.009	0.016	0.02	1.00
	TMO (II)	172.30	399.60	5.88	0.05*	0.015	0.80	5.12
	TMO Total	234.90	399.60	5.82	0.002*	0.005	0.70	0.29
	Overall Period	16.30	399.60	3.76	0.06***	0.006	0.62	6.24
Maharashtra	Pre TMO	0.90	1.40	-0.32	0.058***	0.009	0.73	6.02
	TMO (I)	2.70	3.00	0.64	0.035	0.026	0.11	3.62
	TMO (II)	2.00	2.20	1.13	0.008	0.017	0.015	0.80
	TMO Total	2.70	2.20	0.85	0.008	0.007	0.04	0.89
	Overall Period	0.90	2.20	0.04	0.027	0.004	0.50	2.82
West Bengal	Pre TMO	35.70	163.40	3.17	0.105***	0.015	0.77	11.18
	TMO (I)	176.90	336.90	5.60	0.007*	0.010	0.45	0.79
	TMO (II)	328.50	722.60	5.78	0.032**	0.007	0.56	3.28
	TMO Total	176.90	722.60	5.48	0.022***	0.003	0.60	2.32
	Overall Period	35.70	722.60	3.78	0.060***	0.004	0.81	6.23
Karnataka	Pre TMO	1.60	1.10	-0.30	0.012	0.015	0.04	-1.24
	TMO (I)	0.80	1.90	-0.03	0.044***	0.006	0.76	4.56
	TMO (II)	1.10	0.30	0.82	-0.085**	0.025	0.45	-8.23
	TMO Total	0.80	0.30	0.49	-0.016	0.008	0.11	-1.67
	Overall Period	1.60	0.30	-0.09	0.007*	0.004	0.45	0.71
Tamil Nadu	Pre TMO	0.10	0.20	-1.92	0.031	0.015	0.24	3.21
	TMO (I)	0.20	0.10	-1.63	0.008	0.027	0.005	0.80
	TMO (II)	0.10	0.10	-2.53	0.044	0.030	0.13	4.50
	TMO Total	0.20	0.10	-1.51	-0.021	0.011	0.10	-2.09
	Overall Period	0.10	0.10	-1.52	-0.010	0.005	0.08	-1.09
Uttar Pradesh +	Pre TMO	1313.50	658.90	7.11	-0.026**	0.009	0.36	-2.62
Uttarakhand	TMO (I)	594.60	845.40	6.72	0.014*	0.011	0.63	1.43
	TMO (II)	759.10	945.20	6.74	0.008*	0.008	0.60	-0.83
	TMO Total	594.60	945.20	6.87	0.007*	0.003	0.56	-0.71
	Overall Period	1313.50	945.20	6.97	-0.006**	0.002	0.42	-0.68
Rajasthan	Pre TMO	1975.30	2680.50	7.32	0.032**	0.009	0.45	3.28
	TMO (I)	2604.70	5082.60	8.24	0.028**	0.010	0.31	2.84
	TMO (II)	3879.80	8429.80	8.68	0.019*	0.009	0.45	1.93
	TMO Total	2604.70	8429.80	8.29	0.022***	0.003	0.58	2.30
	Overall Period	1975.30	8429.80	7.39	0.037***	0.002	0.84	3.82
Madhya Pradesh +	Pre TMO	1536.03	1763.03	6.36	0.034***	0.002	0.75	3.45
Chhattisgarh	TMO (I)	1796.36	5632.03	7.03	0.056***	0.001	0.74	5.75
	TMO (II)	5697.36	9617.33	7.63	0.059***	0.004	0.86	6.07
	TMO Total	1796.36	9617.33	8.96	0.067***	0.006	0.89	6.92
	Overall Period	1536.03	9617.33	8.43	0.071***	0.007	0.91	7.35
India	Pre TMO	6532.03	7563.66	8.45	0.035***	0.003	0.67	3.56
	TMO (I)	7769.31	13496.96	8.96	0.044***	0.002	0.71	4.49
	TMO (II)	13659.75	23154.39	7.91	0.059***	0.001	0.80	6.07
	TMO Total	7769.31	23154.39	8.06	0.053***	0.003	0.89	5.44
	Overall Period	6532.03	23154.39	8.75	0.069***	0.007	0.94	7.14

***, ** and * shows significant at 1, 5 and 10 per cent levels of probability.

Table 4: Compound annual growth in productivity (kg/ha) of rapeseed and mustard during different periods

States	Time period	Initial year observation	Final year observation	Constant	Trend coefficient	Standard error	R^2	CAGR (%)
Gujarat	Pre TMO	471.10	1085.80	5.78	0.068**	0.017	0.50	7.04
	TMO (I)	1292.80	1182.10	7.04	0.030*	0.007	0.0001	3.04
	TMO (II)	1071.50	1808.00	7.12	0.021**	0.005	0.48	2.16
	TMO Total	1292.80	1808.00	6.93	0.014***	0.002	0.52	1.50
	Overall Period	471.10	1808.00	6.18	0.029***	0.002	0.71	3.00
Maharashtra	Pre TMO	200.00	291.70	5.19	0.043***	0.006	0.76	4.43
	TMO (I)	551.00	250.00	6.03	-0.033**	0.013	0.39	0.03
	TMO (II)	250.00	285.70	5.79	-0.005	0.011	0.01	0.005
	TMO Total	551.00	285.70	5.82	-0.004*	0.004	0.35	-0.48
	Overall Period	200.00	285.70	5.56	0.005	0.002	0.07	0.51
West Bengal	Pre TMO	329.90	705.50	5.72	0.048***	0.005	0.84	4.97
	TMO (I)	600.00	766.40	6.65	0.002*	0.006	0.45	0.28
	TMO (II)	804.60	1175.00	6.69	0.020**	0.004	0.58	2.09
	TMO Total	600.00	1175.00	6.57	0.012***	0.002	0.52	1.22
	Overall Period	329.00	1175.00	5.99	0.023***	0.001	0.81	2.33
Karnataka	Pre TMO	285.70	234.00	5.67	-0.009	0.004	0.20	-0.93
	TMO (I)	186.00	267.60	5.44	0.011**	0.004	0.35	1.16
	TMO (II)	255.80	168.00	5.88	-0.019	0.020	0.06	-1.93
	TMO Total	186.00	168.00	5.51	-0.007*	0.005	0.35	-0.69
	Overall Period	285.00	168.00	5.55	-0.002*	0.002	0.45	-0.19
Tamil Nadu	Pre TMO	200.00	250.00	5.50	0.010	0.013	0.05	1.00
	TMO (I)	333.33	226.00	6.43	-0.046**	0.067	0.45	-4.49
	TMO (II)	200.00	232.00	5.51	0.002	0.011	0.02	0.20
	TMO Total	333.33	232.00	5.41	-0.004*	0.019	0.42	-0.41
	Overall Period	200.00	232.00	5.63	0.008	0.008	0.01	0.80
Uttar Pradesh +	Pre TMO	607.10	616.20	6.21	0.006	0.010	0.03	0.69
Uttarakhand	TMO (I)	610.80	998.20	6.60	0.019*	0.009	0.45	1.91
	TMO (II)	895.40	1392.00	6.89	0.012**	0.005	0.78	1.30
	TMO Total	610.80	1392.00	6.63	0.015***	0.002	0.51	1.55
	Overall Period	607.10	1392.00	6.15	0.021***	0.001	0.76	2.18
Rajasthan	Pre TMO	594.40	673.50	6.14	0.018**	0.008	0.35	1.90
	TMO (I)	700.50	1001.90	6.65	0.012*	0.006	0.43	1.25
	TMO (II)	853.80	1410.30	6.88	0.017**	0.004	0.53	1.76
	TMO Total	700.50	1410.30	6.62	0.016***	0.001	0.73	1.67
	Overall Period	594.50	1410.30	6.16	0.022***	0.001	0.85	2.23
Madhya Pradesh +	Pre TMO	623.12	695.66	6.23	0.013*	0.001	0.66	1.30
Chhattisgarh	TMO (I)	676.23	714.63	6.29	0.026**	0.002	0.70	2.63
	TMO (II)	759.33	948.06	6.17	0.029***	0.002	0.75	2.94
	TMO Total	676.23	948.06	6.71	0.033***	0.003	0.73	3.35
	Overall Period	623.12	948.06	6.09	0.037***	0.001	0.80	3.76
India	Pre TMO	1063.64	4362.03	5.96	0.036***	0.003	0.81	3.66
	TMO (I)	3632.03	5549.69	5.73	0.042***	0.001	0.86	4.28
	TMO (II)	5963.16	7692.30	6.01	0.049***	0.002	0.84	5.02
	TMO Total	3632.03	7692.30	6.23	0.051***	0.004	0.95	5.23
	Overall Period	1063.64	7692.30	6.14	0.059***	0.001	0.93	6.07

***, ** and * shows significant at 1, 5 and 10 per cent levels of probability.

Table 5: Instability indices in area of rapeseed and mustard in major rapeseed and mustard producing states and India

Particulars	Period				
	Pre TMO	TMO-I	TMO-II	TMO	Overall Period
Low instability	Gujarat (11.97)	Karnataka (9.41)	Madhya Pradesh+ Chhattisgarh (12.07)	Madhya Pradesh+ Chhattisgarh (13.80)	Madhya Pradesh+ Chhattisgarh (14.57)
	Maharashtra (8.86)	Uttar Pradesh+ Uttarakhand (10.87)	Rajasthan (12.11)	Rajasthan (13.65)	Rajasthan (13.50)
	Madhya Pradesh+ Chhattisgarh (6.90)	West Bengal (11.19)	Uttar Pradesh + Uttarakhand (10.25)	Uttar Pradesh + Uttarakhand (11.66)	Rajasthan (6.87)
	Rajasthan (6.87)		West Bengal (9.71)	West Bengal (12.21)	
	India (14.83)				
Medium instability		Maharashtra (27.36)	Karnataka (23.18)	Karnataka (24.37)	Gujarat (21.33)
	Uttar Pradesh + Uttarakhand (15.61)	Madhya Pradesh + Chhattisgarh (15.81)	Maharashtra (24.87)		Maharashtra (28.83)
	West Bengal (23.85)	India (23.83)	India (19.78)	Tamil Nadu (29.58)	
		Rajasthan (15.80)	Gujarat (23.29)		Uttar Pradesh + Uttarakhand (15.80)
		Tamil Nadu (25.07)			West Bengal (21.25)
		Gujarat (26.76)			
High instability	Karnataka (33.27)		Tamil Nadu (31.67)	Gujarat (45.97)	Karnataka (36.27)
	Tamil Nadu (33.06)			Maharashtra (30.26)	Tamil Nadu (33.38)
				India (41.34)	India (48.34)

Figures in parentheses indicate values of instability indices.

Table 6: Instability indices in production of rapeseed and mustard in major rapeseed and mustard producing states and India

Particulars	Period				
	Pre TMO	TMO-I	TMO-II	TMO	Overall Period
Low instability		Karnataka (11.51)	Madhya Pradesh + Chhattisgarh (15.00)		
			India (10.87)		
Medium instability	Maharashtra (17.25)	Gujarat (27.86)	Gujarat (26.07)	Madhya Pradesh + Chhattisgarh (16.61)	Gujarat (16.07)
	Madhya Pradesh+ Chhattisgarh (17.75)	Madhya Pradesh+ Chhattisgarh (17.93)			Madhya Pradesh + Chhattisgarh (19.11)
	Rajasthan (17.23)	Rajasthan (17.50)	Rajasthan (15.00)	Rajasthan (16.61)	Rajasthan (19.17)
	Uttar Pradesh + Uttarakhand (17.06)	Uttar Pradesh+ Uttarakhand (19.60)	Uttar Pradesh+ Uttarakhand (15.74)	Uttar Pradesh+ Uttarakhand (19.55)	Uttar Pradesh+ Uttarakhand (19.14)

	India (18.43)	West Bengal (18.64)	Tamil Nadu (25.80)	West Bengal (18.31)	West Bengal (27.45)
		India (18.05)	West Bengal (15.27)		
High instability	Gujarat (31.43)	Maharashtra (45.04)	Karnataka (36.34)	Gujarat (60.39)	Karnataka (40.60)
	Karnataka (32.84)		Maharashtra (32.46)	Karnataka (34.45)	Maharashtra (37.46)
		Tamil Nadu (60.89)		Maharashtra (38.51)	
	Tamil Nadu (32.63)			Tamil Nadu (46.13)	Tamil Nadu (45.10)
	West Bengal (31.38)			India (44.30)	India (33.99)

Figures in parentheses indicate values of instability indices.

Table 7: Instability indices in productivity of rapeseed and mustard in major rapeseed and mustard producing states and India

Particulars	Period				
	Pre TMO	TMO-I	TMO-II	TMO	Overall Period
Low instability	Karnataka (7.34)	Gujarat (14.19)	Gujarat (10.18)	Madhya Pradesh+ Chhattisgarh (9.36)	Madhya Pradesh + Chhattisgarh (11.83)
	Maharashtra (11.57)	Karnataka (6.93)	Madhya Pradesh + Chhattisgarh (7.76)		
	West Bengal (10.53)	Madhya Pradesh + Chhattisgarh (5.91)	India (14.60)	Rajasthan (9.30)	Rajasthan (11.82)
	India (11.47)	India (10.96)	Rajasthan (7.79)	Uttar Pradesh+ Uttarakhand (13.02)	West Bengal (14.03)
		Rajasthan (10.74)	Uttar Pradesh+ Uttarakhand (10.81)	West Bengal (10.92)	
		West Bengal (11.69)	West Bengal (8.43)		
Medium instability	Madhya Pradesh+ Chhattisgarh (15.66)	Maharashtra (25.69)	Maharashtra (20.44)	Gujarat (27.55)	Karnataka (26.30)
		Uttar Pradesh+ Uttarakhand (16.44)	Tamil Nadu (21.91)	Maharashtra (24.85)	Maharashtra (24.98)
	Rajasthan (15.66)			Tamil Nadu (27.43)	Uttar Pradesh+ Uttarakhand (15.65)
	Uttar Pradesh+ Uttarakhand (18.39)			India (26.48)	Tamil Nadu (19.31)
	Tamil Nadu (21.77)				India (19.78)
High instability	Gujarat (39.40)	Tamil Nadu (33.35)	Karnataka (36.10)	Karnataka (30.41)	

Figures in parentheses indicate values of instability indices.

During the entire period of study instability in the productivity of rapeseed and mustard in all the major states and country as a whole varied from 11.82 to 26.30 per cent wherein productivity in Madhya Pradesh (undivided), Rajasthan and West Bengal was comparatively more stable than the other major states.

CONCLUSION

The compound annual growth rate of rapeseed and mustard was positive during the pre TMO period in all the leading states except Karnataka and Uttar Pradesh (undivided). Maximum growth in the area was in the state of Gujarat. During the TMO period the area increased at a rate of 5.86 per cent in the whole country. It is observed that instability which was analysed using Cuddy Della Velle index showed that rapeseed and mustard was highly unstable in respect of area in the states of Karnataka (33.27) and Tamil Nadu (33.06) during the starting of the TMO period, whereas, production was also noticed as high unstable in Gujarat (31.43) followed by Karnataka (32.84) during the pre TMO period and if the whole study period of TMO is considered then the productivity of rapeseed and mustard was comparatively more stable in MP (undivided), Rajasthan, Uttar Pradesh (undivided), and West Bengal. In the recent past i.e. in the TMO – II period, no any significant change has been observed in this oilseed's productivity in the states of Maharashtra, Karnataka and Tamil Nadu though, their joint contribution in country's rapeseed and mustard production is around 6 per cent. The study suggests to conduct farm level studies in these states to identify the constraints operating in efficient execution of the Technology Mission on Oilseeds so that this mission may address the farmers' problems accordingly. Similar studies are also needed in the states wherein instabilities are found medium and high in area and productivity of this oilseed during recent past (TMO – II period) namely; Gujarat, Maharashtra, Tamil Nadu and Karnataka.

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