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DYNAMICS OF CROPPING PATTERN IN GUJARAT STATE: A MARKOV CHAIN APPROACH

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ABSTRACT

The assessment of shift in cropping pattern in different regions is crucial for a better insight into the agricultural development process. The present study was undertaken with a view to examine the dynamics of cropping pattern in Gujarat. The data on area of different crops for the period from 1990-91 to 2007-08 were collected from the Directorate of Agriculture, Government of Gujarat, Gandhinagar and analyzed for four different periods by using Markov chain. The major findings emerged from the study revealed that any single crop did not retain its area in Gujarat, but the acreage of the crops was continuously shifting from one crop to another crop throughout the period. However, other crops like cumin, tur, rape & mustard, onion, garlic etc. had more retention as compared to groundnut, cotton, bajra, jowar and wheat during the study period indicating its stability in the state. The groundnut remained more stable while the loss of area from major crops towards other crops like maize, castor sesamum, tur, etc. indicated that the cropping pattern of the region moves towards diversification in Saurashtra region. The paddy and maize lost more area to cotton, wheat and other crops like tur, cumin, potato, etc. in Middle Gujarat. The castor crop had more retention of its area as compared to other crops in North Gujarat. In South Gujarat, the decreasing trend of area under groundnut was observed. There is greater scope for decision making in the selection of crops to put the agriculture on the pedestal of sustainable growth which needs to be considered in research and extension programmes.

Introduction

Gujarat has predominantly a non food crop economy with preponderance of cotton, groundnut and tobacco. In the recent decades, commercial orientation is more associated with oilseeds, sugarcane, vegetables, spices *etc.* and the area under cereals such as rice, bajra and jowar has decreased. The rise in the share of superior cereals of rice and wheat has been only marginal upto early 80s, thereafter, these are witnessing steady decline in the area. The growth performance of production and area under the major foodgrain crops has become weak in the state during 1981-96 as compared to previous two decades due to shift in cropping pattern towards non-food grain crops during 1949-96 (Anonymous, 2004).

The gradual decline in foodgrain production is not only raising doubts about the food security but also indicating structural transformation of the state agriculture. A notable feature of cropping pattern changes in recent times is the enhanced share of other crops, occupying more than a quarter of gross cropped area (GCA). The area operated remains almost same, just marginally decreased from 100.00 lakh hectares in 1970-71 to 98.77 lakh hectares in 2003-04.

The information at national or state level on shift in cropping pattern offer no sufficient clue for effective human efforts because the regions differ with respect to their needs and resource availabilities. Therefore, the present study was undertaken with the following specific objectives.

1. To study the change in the cropping pattern of different regions of Gujarat
2. To understand the nature of crop substitution.

Methodology

Markov Chain Analysis is an application of dynamic programming to the solution of a stochastic decision process. A finite Markov process is a stochastic process whereby the outcome of a given trial 't' (t = 1, 2,T) depends only on the outcome a preceding trial (t-1) and this dependence is the same at all stages of the sequence of trials (Lee *et al.*, 1965). Consistent with this definition, let the S_i represent i^{th} state or possible outcomes; $i = 1, 2, \dots, r$, W_{it} represent the probability that state S_i occurs on trial t or proportion observed in trial 't', in alternative outcome state i of a multinomial population based on sample size n, i.e. $P_r(S_{it})$. P_{ij} represent the transitional probability which denotes the probability that if for any time t the process is in state S_i , it moves on next trial to state S_j ,

$$\text{i.e. } P_r(S_j, t+1 / S_{it}) = P_{ij}$$

$P_r = (P_{ij})$ represent transitional probability matrix which denotes transitional probability for every pair of states (i, j = 1, 2,, r) and has the following properties;

$$0 \leq P_{ij} \leq 1 \quad \dots\dots\dots(1)$$

$$\sum_{j=1}^n P_{ij} = 1 \quad \dots\dots\dots(2)$$

Given this set of notations and definitions for a first order Markov chain, the probability of particular sequence S_i on trial t and S_j on trial $t + 1$ may be represented by

$$P_r(S_{it}, S_{j,t+1}) = P_r(S_{it}) P_r(S_{j,t+1} / S_{it}) = W_{it} P_{ij} \quad \dots (3)$$

and the probability of being in state j at trial $t + 1$ may be represented by $P_r(S_{j,t+1}) =$

$$\sum_i W_{it} P_{ij} \quad \text{or, } W_{j,t+1} = \sum_i W_{it} P_{ij} \quad \dots\dots\dots (4)$$

The data for study are the proportion of area under crops. The proportion changes from year to year as a result of factors like weather, technology, price and institutional changes *etc.* It is reasonable to assume that the combined influence of these individually systemic forces approximates to a stochastic process and propensity of farmers to move from one crop to another differs according to the crop state involved. The process of cropping pattern change may be described in form of matrix P of first order transition probabilities. The element P_{ij} indicates the probability of a crop state i in one period will move to crop state j during the following period. The diagonal element P_{ij} measures the probability that the proportion share of i^{th} category of crop will be retained.

Estimation of Transitional Probability Matrix

Equation (4) can be used as a basis for specifying the statistical model for estimating transitional probabilities. If errors are incorporated in equation (4), it becomes,

$$W_{it} = \sum_i W_{i,t-1} P_{ij} + U_{jt} \quad \dots\dots\dots(5)$$

or in matrix form it can be written as,

$$Y_j = X_j P_j + U_j \quad \dots\dots\dots(6)$$

Where $Y_j = (T * 1)$ vectors of observations reflecting the proportions in cropping pattern j in time t , $X_j = (T * r)$ matrix of realized values of the proportions in cropping pattern in time $t - 1$, $P_j = (r * 1)$ vectors of unknown transition parameters to be estimated and $U_j =$ vectors of random disturbances.

The data from the period 1985-86 to 2007-08 were collected and compiled from the various reports published by Bureau of Economics and Statistics, Directorates of Agriculture, Government of Gujarat, Gandhinagar and analyzed for five different periods *Viz*; Period-I(1990-91 to 1994-95), Period-II (1995-96 to 1999-00), Period-III (2000-01 to 2004-05), and Period-IV (2005-06 to 2007-08) by using Markov chain analysis technique. The rationale

behind dividing study period into blocks of five years considers the agricultural census conducted at an interval of five years and to divide it into blocks of 10 year is too long to capture the effect of shift in cropping pattern within the period of 10 years. While to analyze the data by dividing the study period into blocks of 2 or 3 years becomes the whole task too bulky and difficult. The analysis was also carried out for four different regions as well as the state as a whole.

Results and Discussion

The stability of the acreage share of crop and their direction of change over a period of time was captured by transition probability matrix. As the diagonal elements approaches zero, the crops become less and less stable and as they approaches one, they become more and more stable over a period of time. The elements in the i^{th} row (Table 1-3) give the proportions of previous period's acreage of i^{th} crop which is likely to loose to other crops in the current period. The element of i^{th} column gives the proportion of area of i^{th} crop which is likely to gain in the current period.

The results of Transition Probability Matrix (TPM) for groundnut, bajra, jowar, cotton, wheat and other crops (includes maize, castor, sesamum, tur, gram, cumin, onion and garlic) in Saurashtra region and Middle Gujarat region are presented in Table 1. Actual shift in area of Saurashtra region under the crop is calculated by multiplying the TPM and actual area under the crop which is presented in Appendix-I. Jowar and other crops were stable with 43 and 13 per cent retention during Period-I while bajra retained 79 per cent area during Period-II in Saurashtra region. The highest retention of groundnut was observed during Period-IV, followed by its 78 per cent retention, during Period-III. Cotton was found highly unstable crop which had retention of 53 per cent of its area only during Period-IV. As being a dominant crop of the Saurashtra region, groundnut remained more stable with more than 70 per cent retention during last two periods. The lost of area from major crops towards other crops indicated that the cropping pattern of the region moves towards diversification. Khandare *et al.* (2005) also observed, by using Markov chain that the kharif groundnut was more stable in acreage in Vidarbha region of Maharashtra during 1990-91 to 1998-99.

The results of TPM for cotton, paddy, wheat, bajra, maize and other crops (includes jowar, groundnut, sesamum, gram, potato, tobacco, sugarcane and tur) in Middle Gujarat indicated that cotton showed more stability with more than 50 per cent retention during Period-III. The paddy crop was found to remain stable only during Period-IV with 68 per cent retention while wheat retained 61 and 55 per cent area during Period-III and IV, respectively. The maize crop gained 76 per cent from bajra during Period-III. Other crops

gained 100 per cent area from maize during Period-III and IV. Paddy crop lost nearly 50 per cent area to other crops during Period-III and about 30 per cent during Period-I and IV. Wheat crop remained more stable in recent periods as it gained area from cotton, where as cotton is substituting other crops. It is also observed that maize lost its cent per cent area to other crops during the last two periods. This calls for policy attention for middle Gujarat.

The results of TPM for bajra, cotton, jowar, wheat, castor and other crops (includes cumin, potato, groundnut, sesamum, rape & mustard, maize, paddy and gram) in North and South Gujarat region are presented in Table 2. Wheat lost its cent per cent area to bajra followed by 74 per cent loss of castor area to jowar during the Period-I in North Gujarat. Other crops, jowar, castor, bajra and wheat retained 68, 24, 22, 10 and 8 per cent, respectively during Period-I. Castor lost 78 per cent of its previous acreage to wheat during Period-I. Only other crops and jowar were able to retain 69 and 43 per cent area, respectively while castor lost its 89 per cent area to wheat during Period-II. Other higher loser crops were wheat (73 %) and cotton (60 %) while castor and other crops were gainers during Period-II. During the period from 2000-01 to 2004-05, the other crops remained stable with the highest retention of 60 per cent while bajra, cotton, and jowar were unstable crops which had no retention. Higher loss of area from cotton (100 %), jowar (97 %) and wheat (83 %) to bajra was observed during this period. Castor and other crops showed stability in acreage with 48 per cent and 60 per cent retention of area while bajra, cotton and jowar remained highly unstable with no retention during Period-IV. Wheat, jowar and cotton crops lost, respectively its 100, 99 and 51 per cent area to other crops during Period-IV. It can be concluded that castor crop had more retention of its area as compared to other crops. Higher loss of area by major crops to other crops during recent period shows diversification of the cropping pattern in the region.

The results of TPM for cotton, paddy, groundnut, wheat and other crops (sugarcane, maize, onion, gram, castor, tur, onion and sesamum) in South Gujarat region indicated that the other crops retained 62 per cent while jowar, groundnut and wheat had no retention during Period-I. Jowar lost 95 per cent of its previous acreage to paddy while wheat lost 90 per cent to other crops during Period-I. Other crops, cotton, jowar and paddy were able to retain 56, 40, 30 and 25 per cent area, respectively while wheat lost its 70 per cent area to paddy during Period-II. Other losers were paddy (37 %) and jowar (37 %). Contrary to this, cotton and paddy were gainers, respectively during Period-II. Marvar *et al.* (2002) also observed shift in area under different crops by using Markov chain analysis. They observed that the paddy and cotton were most stable crops of Vidarbha region in Maharashtra during

1990-99. Wheat crop was the highest retainer (100 %) while groundnut and jowar had no retention. Higher lost of area from groundnut (100 %), and jowar (83 %) to paddy and cotton, respectively was observed during Period-III. Paddy and other crops showed stability in acreage with 84 and 53 per cent retention of area, respectively while cotton, jowar, groundnut and wheat remained highly unstable with no retention during Period-IV. Jowar and groundnut crops lost its cent per cent area to cotton crop while wheat lost its cent per cent area to other crops during Period-IV. Retention of area by other crops ranging from 44 to 62 per cent during last five periods indicated the diversified cropping pattern of the region.

The results of transitional probability matrix for groundnut, cotton, bajra, jowar, wheat and other crops (includes paddy, maize, castor, sesamum, rape & mustard, tur, gram, sugarcane, cumin, onion and potato) in Gujarat state (Table 3) indicated that wheat lost its 100 per cent area to cotton, followed by 99 per cent lost of bajra area to other crops during the same period. Reddy and Achoth (2000) also observed, by using Markov chain that area under oilseeds and other commercial crops has increased in 1980s at the cost of area under food grain crops in Karnataka. Groundnut retained 32 per cent while cotton, bajra, jowar and wheat had no retention during Period-I. Wheat and bajra lost 100 per cent of its previous acreage to other crops while jowar lost 53 per cent to bajra crop during Period-I. Jowar, cotton, and other crops were able to retain 61, 34, and 17 per cent area, respectively while groundnut, bajra and wheat had no retention during Period-II. Groundnut lost its 80 per cent area to other crops during Period-II. Other losers were bajra (77 %), wheat (58 %) and other crops (42 %), whereas other crops and groundnut were gainers, respectively during Period-II. Other crops were the highest retainers (29 %) while groundnut, jowar and wheat had no retention. Cent per cent loss of area from wheat and jowar to cotton and bajra, respectively was observed during Period-III. Cotton showed stability in acreage with 45 per cent and retention of area whereas groundnut, bajra, jowar and wheat remained highly unstable with no retention during Period-IV. Bajra and groundnut crops lost its 99 and 91 per cent area to other crops while wheat lost its cent per cent area to jowar during Period-IV. Jowar had lost its area to cotton, groundnut, pulses, oilseeds *etc.* Rao and Parwez (2005) also stated that the area under sorghum crop replaced considerably by competing cotton crop in Gujarat at the state and district level.

Conclusions and policy Implications

The groundnut remained more stable while the loss of area from major crops towards other crops like maize, castor sesamum, tur, *etc.* indicated that the cropping pattern move towards diversification in Saurashtra region. The paddy and maize lost more area to cotton,

wheat and other crops like tur, cumin, potato, *etc.* in Middle Gujarat region. The castor crop had more retention of its area as compared to other crops in North Gujarat region. The decreasing trend of area under groundnut was observed in South Gujarat region. Any single crop did not retain its area throughout the period in Gujarat, but the acreage of the crops was continuously shifting from one crop to another crop throughout the period. However, other crops like cumin, tur, rape & mustard, onion, garlic *etc.* had more retention as compared to groundnut, cotton, bajra, jowar and wheat during the study period indicating its stability in Gujarat state. There is greater scope for decision making in the selection of crops especially in diversified regions to put the agriculture on the pedestal of sustainable growth which need to be considered in research and extension programmes.

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Table 1: Transitional Probability Matrix (TPM) for shift in cropping pattern													
Saurashtra region							Middle Gujarat region						
TPM for 1990-91 to 1994-95 (Period-I)							TPM for 1990-91 to 1994-95 (Period-I)						
Crops	Groundnut	Bajra	Jowar	Cotton	Wheat	Other Crops	Crops	Cotton	Paddy	Wheat	Bajra	Maize	Other Crops
Groundnut	0.0000	0.0000	0.0000	0.2237	0.0084	0.7679	Cotton	0.0000	0.0000	0.0000	0.0000	0.2575	0.7425
Bajra	0.5110	0.0000	0.0000	0.0000	0.3108	0.1782	Paddy	0.0000	0.0000	0.4579	0.1491	0.0424	0.3505
Jowar	0.0492	0.4757	0.4317	0.0434	0.0000	0.0000	Wheat	0.0000	0.0000	0.0439	0.0000	0.0000	0.9561
Cotton	0.1863	0.7230	0.0644	0.0000	0.0264	0.0000	Bajra	0.5010	0.0000	0.0000	0.0000	0.4990	0.0000
Wheat	0.7489	0.0000	0.0000	0.2372	0.0000	0.0139	Maize	0.0000	0.7060	0.0594	0.0000	0.0654	0.1692
Other Crops	0.7513	0.0000	0.0000	0.1236	0.0000	0.1252	Other Crops	0.2243	0.2249	0.0000	0.1888	0.0137	0.3483
TPM for 1995-96 to 1999-00 (Period-II)							TPM for 1995-96 to 1999-00 (Period-II)						
Crops	Groundnut	Bajra	Jowar	Cotton	Wheat	Other Crops	Crops	Cotton	Paddy	Wheat	Bajra	Maize	Other Crops
Groundnut	0.3054	0.0000	0.0000	0.0000	0.0268	0.6678	Cotton	0.2901	0.0000	0.0000	0.0000	0.4308	0.2790
Bajra	0.0000	0.7919	0.1791	0.0000	0.0000	0.0290	Paddy	0.1017	0.2162	0.3174	0.0000	0.2782	0.0865
Jowar	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	Wheat	0.7461	0.0000	0.2539	0.0000	0.0000	0.0000
Cotton	0.4778	0.0000	0.0000	0.0000	0.0609	0.4613	Bajra	0.2669	0.0000	0.2828	0.4503	0.0000	0.0000
Wheat	0.5131	0.0000	0.0000	0.4869	0.0000	0.0000	Maize	0.0000	0.0000	0.0000	0.0000	0.0379	0.9621
Other Crops	0.4326	0.0512	0.0000	0.5162	0.0000	0.0000	Other Crops	0.0000	0.3315	0.0000	0.1282	0.0000	0.5402
TPM for 2000-01 to 2004-05 (Period-III)							TPM for 2000-01 to 2004-05 (Period-III)						
Crops	Groundnut	Bajra	Jowar	Cotton	Wheat	Other Crops	Crops	Cotton	Paddy	Wheat	Bajra	Maize	Other Crops
Groundnut	0.7678	0.0000	0.0307	0.0000	0.0357	0.1658	Cotton	0.7184	0.0000	0.2816	0.0000	0.0000	0.0000
Bajra	0.0516	0.6307	0.0000	0.3176	0.0000	0.0000	Paddy	0.0000	0.0000	0.0000	0.3735	0.1530	0.4736
Jowar	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	Wheat	0.3830	0.0000	0.6170	0.0000	0.0000	0.0000
Cotton	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	Bajra	0.0000	0.0000	0.0000	0.2394	0.7606	0.0000
Wheat	0.0000	0.1985	0.0000	0.3436	0.4579	0.0000	Maize	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
Other Crops	0.2535	0.0648	0.0000	0.5134	0.0000	0.1682	Other Crops	0.1303	0.6141	0.0000	0.0000	0.1409	0.1147
TPM for 2005-06-to 2007-08 (Period-IV)							TPM for 2005-06-to 2007-08 (Period-IV)						
Crops	Groundnut	Bajra	Jowar	Cotton	Wheat	Other Crops	Crops	Cotton	Paddy	Wheat	Bajra	Maize	Other Crops
Groundnut	0.8140	0.1439	0.0000	0.0000	0.0421	0.0000	Cotton	0.2040	0.2887	0.3302	0.0147	0.1622	0.0000
Bajra	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	Paddy	0.0000	0.6759	0.0000	0.0000	0.0000	0.3241
Jowar	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	Wheat	0.0000	0.0000	0.5547	0.0000	0.0000	0.4453
Cotton	0.1531	0.0207	0.0178	0.5324	0.2760	0.0000	Bajra	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Wheat	0.0000	0.0000	0.0000	0.6045	0.0000	0.3955	Maize	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
Other Crops	0.0464	0.0000	0.0000	0.5409	0.0000	0.4127	Other Crops	0.5482	0.0000	0.0000	0.1522	0.2996	0.0000

Table 2: Transitional Probability Matrix (TPM) for shift in cropping pattern

North Gujarat region							South Gujarat region						
TPM for 1990-91 to 1994-95 (Period-I)							TPM for 1990-91 to 1994-95 (Period-I)						
Crops	Bajra	Cotton	Jowar	Wheat	Castor	Other Crops	Crops	Cotton	Paddy	Jowar	Groundnut	Wheat	Other Crops
Bajra	0.0000	0.0000	0.0000	0.0773	0.1349	0.7878	Cotton	0.1361	0.2565	0.4015	0.0000	0.0192	0.1867
Cotton	0.0288	0.1489	0.4484	0.0000	0.3394	0.0345	Paddy	0.2817	0.0455	0.0000	0.1765	0.1463	0.3500
Jowar	0.0000	0.7858	0.0000	0.0000	0.0000	0.2142	Jowar	0.0448	0.9552	0.0000	0.0000	0.0000	0.0000
Wheat	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	Groundnut	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
Castor	0.0000	0.0000	0.7360	0.0000	0.1218	0.1422	Wheat	0.0000	0.0000	0.0994	0.0000	0.0000	0.9006
Other Crops	0.3497	0.0000	0.0000	0.0872	0.0000	0.5630	Other Crops	0.0000	0.1527	0.2307	0.0000	0.0000	0.6166
TPM for 1995-96 to 1999-00 (Period-II)							TPM for 1995-96 to 1999-00 (Period-II)						
Crops	Bajra	Cotton	Jowar	Wheat	Castor	Other Crops	Crops	Cotton	Paddy	Jowar	Groundnut	Wheat	Other Crops
Bajra	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	Cotton	0.4007	0.0000	0.0000	0.1418	0.0000	0.4575
Cotton	0.0000	0.0000	0.0000	0.0000	0.3955	0.6045	Paddy	0.3733	0.2483	0.0000	0.0104	0.0000	0.3679
Jowar	0.0000	0.0558	0.4325	0.0000	0.3282	0.1835	Jowar	0.0000	0.3725	0.2997	0.0000	0.2389	0.0889
Wheat	0.2674	0.0000	0.0000	0.0000	0.7326	0.0000	Groundnut	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
Castor	0.1143	0.0000	0.0000	0.8857	0.0000	0.0000	Wheat	0.0000	0.7020	0.0000	0.0000	0.0000	0.2980
Other Crops	0.2117	0.1027	0.0000	0.0000	0.0000	0.6855	Other Crops	0.0000	0.2598	0.1520	0.0315	0.0000	0.5567
TPM for 2000-01 to 2004-05 (Period-III)							TPM for 2000-01 to 2004-05 (Period-III)						
Crops	Bajra	Cotton	Jowar	Wheat	Castor	Other Crops	Crops	Cotton	Paddy	Jowar	Groundnut	Wheat	Other Crops
Bajra	0.0000	0.0000	0.0000	0.0000	0.1622	0.8378	Cotton	0.4809	0.0000	0.4896	0.0295	0.0000	0.0000
Cotton	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	Paddy	0.0000	0.0431	0.0000	0.0000	0.0000	0.9569
Jowar	0.9661	0.0000	0.0339	0.0000	0.0000	0.0000	Jowar	0.8626	0.0000	0.0000	0.0000	0.0974	0.0400
Wheat	0.8322	0.1678	0.0000	0.0000	0.0000	0.0000	Groundnut	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
Castor	0.0000	0.0000	0.0000	0.0000	0.2060	0.7940	Wheat	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
Other Crops	0.0904	0.1146	0.0022	0.1395	0.0502	0.6031	Other Crops	0.0493	0.4628	0.0000	0.0481	0.0000	0.4398
TPM for 2005-06 to 2007-08 (Period-IV)							TPM for 2005-06 to 2007-08 (Period-IV)						
Crops	Bajra	Cotton	Jowar	Wheat	Castor	Other Crops	Crops	Cotton	Paddy	Jowar	Groundnut	Wheat	Other Crops
Bajra	0.0000	0.3216	0.0219	0.4661	0.1905	0.0000	Cotton	0.0000	0.2269	0.0000	0.0000	0.0000	0.7731
Cotton	0.0000	0.0000	0.0000	0.4899	0.0000	0.5101	Paddy	0.0000	0.8306	0.0000	0.0000	0.1694	0.0000
Jowar	0.0149	0.0000	0.0000	0.0000	0.0000	0.9851	Jowar	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wheat	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	Groundnut	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Castor	0.0000	0.3363	0.1298	0.0000	0.4832	0.0506	Wheat	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
Other Crops	0.3966	0.0000	0.0000	0.0055	0.0000	0.5978	Other Crops	0.1828	0.0000	0.2140	0.0739	0.0000	0.5293

Table 3: Transitional Probability Matrix (TPM) for shift in cropping pattern in Gujarat state

TPM for 1990-91 to 1994-95 (Period-I)							TPM for 2000-01 to 2004-05 (Period-III)						
Crops	Groundnut	Cotton	Bajra	Jowar	Wheat	Other Crops	Crops	Groundnut	Cotton	Bajra	Jowar	Wheat	Other Crops
Groundnut	0.3226	0.3542	0.0000	0.0000	0.0000	0.3232	Groundnut	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
Cotton	0.4934	0.0000	0.0000	0.4103	0.0963	0.0000	Cotton	0.4249	0.1080	0.1091	0.0000	0.0000	0.3580
Bajra	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	Bajra	0.1105	0.1534	0.0852	0.2452	0.2270	0.1787
Jowar	0.0000	0.0000	0.5314	0.0000	0.2362	0.2324	Jowar	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000
Wheat	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	Wheat	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
Other Crops	0.1190	0.2554	0.3047	0.1700	0.0142	0.1367	Other Crops	0.2878	0.1773	0.0000	0.1499	0.0957	0.2893
TPM for 1995-96 to 1999-00 (Period-II)							TPM for 2005-06 to 2007-08 (Period-IV)						
Crops	Groundnut	Cotton	Bajra	Jowar	Wheat	Other Crops	Crops	Groundnut	Cotton	Bajra	Jowar	Wheat	Other Crops
Groundnut	0.0000	0.1749	0.8251	0.0000	0.0000	0.0000	Groundnut	0.0000	0.0000	0.0000	0.0891	0.0000	0.9109
Cotton	0.0626	0.3416	0.1911	0.0000	0.0000	0.4047	Cotton	0.3243	0.4460	0.0000	0.0000	0.0000	0.2297
Bajra	0.0000	0.0000	0.0000	0.0000	0.2329	0.7671	Bajra	0.0081	0.0000	0.0000	0.0000	0.0000	0.9919
Jowar	0.0000	0.0000	0.0000	0.6089	0.1131	0.2780	Jowar	0.0000	0.0000	0.0211	0.0000	0.0000	0.9789
Wheat	0.4209	0.0000	0.0000	0.0000	0.0000	0.5791	Wheat	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
Other Crops	0.4252	0.2933	0.0000	0.1110	0.0000	0.1705	Other Crops	0.3559	0.1773	0.3007	0.0000	0.1413	0.0248

Appendix-I: Shift in cropping pattern of the Saurashtra region

Shift in area for 1990-91 to 1994-95 (Period-I)							Shift in area for 2000-01 to 2004-05 (Period-III)						
Crops	Groundnut	Bajra	Jowar	Cotton	Wheat	Other Crops	Crops	Groundnut	Bajra	Jowar	Cotton	Wheat	Other Crops
Groundnut	0	685	0	0	289	8793	Groundnut	7986	748	1920	0	170	0
Bajra	0	0	2348	517	99	6901	Bajra	0	0	0	0	0	13497
Jowar	16456	0	0	0	0	0	Jowar	0	0	0	0	0	13497
Cotton	0	0	1171	2304	0	5832	Cotton	0	0	5459	1518	0	0
Wheat	14466	780	0	0	0	0	Wheat	0	1126	0	0	762	2508
Other Crops	754	1040	1095	100	0	8490	Other Crops	3026	1768	451	115	0	6227
Shift in area for 1995-96 to 1999-00 (Period-II)							Shift in area for 2005-06 to 2007-08 (Period-IV)						

Crops	Groundnut	Bajra	Jowar	Cotton	Wheat	Other Crops	Crops	Groundnut	Bajra	Jowar	Cotton	Wheat	Other Crops
Groundnut	0	1885	0	0	0	9554	Groundnut	3254	4710	0	406	0	0
Bajra	6782	1021	0	0	0	5800	Bajra	1263	2734	566	0	505	0
Jowar	0	0	3265	854	490	0	Jowar	3699	0	5806	0	0	0
Cotton	0	0	3351	1807	274	0	Cotton	0	0	0	0	0	13497
Wheat	3129	5226	0	0	0	0	Wheat	1925	0	0	0	249	9095
Other Crops	3392	317	593	0	25	8703	Other Crops	2724	0	0	0	0	11263