Spatio-Temporal Changes in Cropping Pattern in the State of Rajasthan

ABSTRACT

This study was conducted in the state of Rajasthan. Four major crop groups viz; cereals (pearlmillet, maize and wheat), pulses (moong bean, moth bean, kharif pulses and gram), oilseeds (soyabean and rapeseed and mustard) and others (cotton and clusterbean) were selected for analysis. All the crops in the above groups having five per cent or more area under cultivation in a district were selected. The districts were selected on the basis of last five years average (2005-06 to 2009-10 Secondary data were collected from published records and reports of the Directorate of Economics and Statistics, Government of Rajasthan, Jaipur and official website of Rajasthan Agriculture Department www.krishi.rajasthan.gov.in.

The study period encompassed a duration of 58 years starting from; 1956-57 to 2014-15. The data were also analyzed for twelve different periods by using Markov chain analysis technique for studying the change in cropping pattern.

The study results revealed that the bajra crop was almost stable and cotton crop (except during-2000 to2005) highly unstable with no retention of their previous area over the periods in the state of Rajasthan, but acreage of the crops was continuously shifting from one crop to another crop throughout the period. However, crops like kharif pulses, wheat, clusterbean, soyabean and mustard had more retention as compared to gram, cotton and maize during-1956- 57 to 2014-15 indicating its stability in the state.

Key words - Spatio-temporal, cropping pattern, retention, stability etc.

1. INTRODCTION

Agricultural development of India has been agitating the minds of Indian politicians, the policy makers, the planners, the agricultural

scientists and farmers since independence. A number of agricultural development plans gave rise to institutional and technological changes in the foodgrains production in the country. There are many empirical studies witnessing that the area under some crops increased over time while under some others it either decreased and /or remained stagnant. Despite a technological breakthrough in agriculture, the Indian agriculture is still a gamble of monsoon. This leads to high degree of risks and uncertainty in production, prices and farm incomes because the farmers are often not sure about the outcomes from agriculture due to weather and market induced risks. In spite of the impressive achievements, the Indian agricultural sector continues to face poor infrastructure conditions. As a result, the productivity levels of many major crops in India are not comparable with the yields obtained in agriculturally advanced countries. The country's agriculture has gained in strength and resilience since independence, although growth in agriculture is highly skewed over regions and crops.

Agriculture has also been an important sector in the state of Rajasthan due to large dependencies of the population on it. It contributes around 21 per cent (2007-08 to 2011-12) in State GSDP at constant prices (2004-05). Though the share of agriculture sector has been declining or stagnant over time, it still remains a predominant sector in respect of labour absorption. The sector, therefore, deserved to be assigned due importance for its sustainable and balanced development at the state level too. Therefore, different development programmes were initiated in every Five Year Plan covering different aspects of agricultural development.

Agricultural development was not uniform throughout the state. A number of empirical studies conducted at the state/regional level have shown that the area, production and productivity of some crops have increased over time whereas some other registered a decline while a few have stagnated over time and space. The increase in area might be

due to bringing in new area under cultivation and/or shifting of area from one crop to another. This phenomenon may better be understood by studying the growth and cropping pattern of various crops of a region in question. Likewise, the diversion of productive resources affects the productivity of crops. Those crops which are comparatively more profitable attract productive resource from less profitable crops. However, the extent of diversion depends on a number of factors like level of technology for crop production, domestic requirements, degree of risks arising due to fluctuating prices, weather conditions etc. How and to what extent has the improved crop production technology helped grow, shift and diversify the crops in the state at regional level is not known. This study is an attempt to generate such types of information that will help the researchers, scientists and the policy makers to develop crop specific plans for higher and balanced agricultural production in the state.

Most of the past studies relating to the performance of agriculture in Rajasthan is of macro level. The districts level study would be useful to formulate micro-level agricultural policies. It would also envisage understanding the changes in cropping pattern over the years.

2. RESEARCH METHODOLOGY

The study period encompassed a duration of 58 years starting from; 1956-57 to 2014-15. For the purpose of drawing meaningfull conclusions, the data were also analyzed for studying spatio-temporal changes in cropping pattern for twelve different periods corresponding to five year plans *Viz*; Period-I (1956 to 1960), Period-II (1961 to 1965), Period-III (1966 to 1970), Period-IV (1971 to 1975), Period-V (1976 to 1980), Period-VI (1981 to 1985), Period-VII (1986 to 1990), Period-VIII (1991 to 1995), Period-IX (1996 to 2000), Period-X (2001 to 2005), Period-XI (2006 to 2010) and Period-XII (2011 to 2014) by using Markov chain analysis technique.

2.1 Markov Chain Analysis

Markov Chain Analysis is an application of dynamic programming to the solution of a stochastic decision process that can be described by a finite number of states. The Markov process was used to study the shifts in the cropping pattern and thereby gain an understanding about the dynamics of the changes.

2.1.1 The Markov Probability Model

Any sequence of trial (experiments) that can be subjected to probabilistic analysis is called a stochastic process. For a stochastic process, it is assumed that the movements (transitions) of objects from one state (possible outcome) to another are governed by probabilistic mechanism or system. 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 of 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,...,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 transition 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,

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

Pr = (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;

$0 \leq P_{ij} \leq 1$ ..... (1)

$$\sum_{j=1}^{n} P_{ij} = 1 \text{ ..... (2)}$$

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

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

and the probability of being in state j at trial t + 1 may be represented by

$$P_r (S_{j\,t-1}) = \sum_i W_{it} P_j \text{ or, } W_j, t+1 = \sum_i W_{it} P_{ij} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

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. 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 j 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.

2.1.2 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,

$$W_{it} = W_{it} W_i , t - 1\ P_{ij} + U_{jt} \ldots\ldots\ldots (5)$$

or in matrix form it can be written as,

$$Y_j = X_j P_j + U_j \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where ,

Y = (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

U_j = vectors of random disturbances estimator. If we employ this method in obtaining estimates of the transitional probabilities, our problem may be specified as follows;

Y- XP ' E .....(7)

Subject to;

Y = XP + U .....(8)

RP = e ----------(9)

$P \geq 0$ ----------(10)

Where, E is a unit vector of order (rT * 1). In order to solve the above LP problem, non negative variables are introduced for U such that

$U = \theta - \beta$ ……(11)

Where,

$\theta = (\theta_{jt}) \geq 0$ .....(12)

$\beta = (\beta_{jt}) \geq 0$ .....(13)

By redefining U in this way, the LP problem may be transformed to the following form;

To minimize,

$(\theta + \beta)$ ' E .....(14)

Subject to;

Y = XP + U .....(15)

RP = e ----------(16)

$P , \theta, \beta \geq 0$ .....(17)

3. RESULTS AND DISCUSSION

The markov chain analysis was carried out by using data on the cropping pattern of Rajasthan state. This technique was employed separately for twelve different periods viz. Period-I (1956 to 1960), Period-II (1961 to 1965), Period-III (1966 to 1970), Period-IV (1971 to

1975), Period-V (1976 to 1980), Period-VI (1981 to 1985), Period-VII (1986 to 1990), Period-VIII (1991 to 1995), Period-IX (1996 to 2000), Period-X (2001 to 2005), Period-XI (2006 to 2010) and Period-XII (2011 to 2014).

The stability of the acreage share of crops and their direction of change over a period of time was captured by transition probability matrix (TPM). As the diagonal element approach zero, the crop becomes less stable and is approaches one, they become more stable over a period of time. The elements in the i^{th} row give the proportions of previous periods acreage of i^{th} crop which is likely to loose to other crops in the current period. The elements of i^{th} column give the proportion of area of i^{th} crop which is likely to gain in the current period. The results of the transition probability matrix and actual and estimated proportions of area under major fields crops viz., Pearlmillet, maize, wheat, kharif pulses, gram, soyabean, mustard, cotton and Clusterbean are presented in table- 1 to12.

Table- 1 depicts the results of transitional probability matrix for major field crops in the state of Rajasthan during the quinquenium - 1956-60. It is evident from the table that kharif pulses, gram, soyabean, cotton and clusterbean crops remained highly unstable with no retention of its previous area while pearlmillet crop was somewhat stable with 38 per cent retention during this period. Pearlmillet crop gained cent per cent from clusterbean, 92 per cent from gram, 84 per cent from kharif pulses and 71 per cent from maize. Wheat gained 24 per cent of area from pearlmillet and kharif pulses gained 67 per cent from wheat and 24 per cent from mustard crop. Soyabean and cotton lost 100 per cent, mustard 46 per cent and pearlmillet 25 per cent to gram crop. Cotton crop gained 20 per cent from mustard and 14 per cent from wheat during the same period.

Table: 1 Transitional probability matrix for major field crops in the state of Rajasthan during-1956 to 1960

1956-60	Pearlmillet	Maize	Wheat	Kharif pulses	Gram	Soyabean	Mustard	Cotton	Clusterbean
Pearlmillet	0.3847	0.0000	0.2380	0.1210	0.2544	0.0000	0.0000	0.0018	0.0000
Maize	0.7095	0.2905	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wheat	0.0000	0.0000	0.0264	0.6677	0.0000	0.0000	0.1623	0.1435	0.0000
Kharif pulses	0.8368	0.1632	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Gram	0.9242	0.0758	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Soyabean	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
Mustard	0.0000	0.0000	0.0000	0.2423	0.4556	0.0000	0.0976	0.2046	0.0000
Cotton	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
Clusterbean	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

It is evident from table- 2 (during- 1961 to 1965) that wheat, soyabean, mustard, cotton and clusterbean were highly unstable crops with zero retention of its previous area. Pearlmillet, kharif pulses and gram were almost stable with approximately 91, 79 and 13 per cent retention of area during this period. Pearlmillet crop gained hundred per cent of area from maize, soyabean and clusterbean; maize grained 21 per cent of area from kharif puses and wheat gained 65 per cent of area from gram crop. Cotton lost cent per cent of area to kharif pulses and wheat and mustard to gram crop and gram lost 13 per cent of area to mustard and 9 per cent to cotton crop during the same period.

The results of transitional probability matrix of major field crops during period- 1966 to 1970 are presented in table- 3. It is observed from the table that maize, kharif pulses, gram, soyabean, cotton and clusterbean were highly unstable crops with zero retention of its previous area. The retention in area under pearlmillet and wheat was estimated at 41 and 50 per cent during the period. Pearlmillet gained cent per cent of area from gram and clusterbean, 94 per cent from mustard and over 93 per cent from kharif pulses and wheat gained hundred per cent of area from soyabean and 75 per cent from cotton crop. Pearlmillet lost approximately 31 per cent of area to kharif puses and maize lost hundred per cent, wheat 34 per cent and cotton 25 per cent to gram crop during this period.

Table- 4 depicts the results of TPM of crops in the state of Rajasthan during- 1971 to 1975. It is evident from the table that pearlmillet and clusterbean crops were more stable with 85 and 100 per cent retention of area during this period. Remaining crops were highly unstable with zero retention of their previous area under cultivation. Pearlmillet and maize gained 59 and 17 per cent of area from gram and wheat gained cent per cent of area from maize and cotton and 15 per cent from kharif pulses. Wheat lost 91 per cent, soyabean 100 per cent and mustard 95 per cent of their area to kharif pulses; kharif pulses lost 85 per cent of its area to gram crop and gram crop lost 20 per cent of its area to cotton crop during the same period.

Table: 2 Transitional probability matrix for major field crops in the state of Rajasthan during-1961 to 1966

1961-66	Pearlmillet	Maize	Wheat	Kharif pulses	Gram	Soyabean	Mustard	Cotton	Clusterbean
Pearlmillet	0.9140	0.0551	0.0000	0.0083	0.0000	0.0000	0.0000	0.0226	0.0000
Maize	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wheat	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
Kharif pulses	0.0000	0.2096	0.0000	0.7904	0.0000	0.0000	0.0000	0.0000	0.0000
Gram	0.0000	0.0000	0.6511	0.0000	0.1286	0.0000	0.1339	0.0864	0.0000
Soyabean	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mustard	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
Cotton	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Clusterbean	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table: 3 Transitional probability matrix for major field crops in the state of Rajasthan during-1966 to 1970

1966-70	Pearlmillet	Maize	Wheat	Kharif pulses	Gram	Soyabean	Mustard	Cotton	Clusterbean
Pearlmillet	0.4063	0.0770	0.0841	0.3073	0.0621	0.0000	0.0145	0.0487	0.0000
Maize	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
Wheat	0.0000	0.0754	0.5000	0.0000	0.3443	0.0000	0.0804	0.0000	0.0000
Kharif pulses	0.9326	0.0674	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Gram	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Soyabean	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mustard	0.9353	0.0000	0.0000	0.0000	0.0000	0.0000	0.0647	0.0000	0.0000
Cotton	0.0000	0.0000	0.7503	0.0000	0.2497	0.0000	0.0000	0.0000	0.0000
Clusterbean	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table: 4 Transitional probability matrix for major field crops in the state of Rajasthan during-1971 to 1975

1971-75	Pearlmillet	Maize	Wheat	Kharif pulses	Gram	Soyabean	Mustard	Cotton	Clusterbean
Pearlmillet	0.8460	0.0650	0.0300	0.0000	0.0000	0.0000	0.0500	0.0080	0.0000
Maize	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wheat	0.0000	0.0000	0.0000	0.9130	0.0870	0.0000	0.0000	0.0000	0.0000
Kharif pulses	0.0000	0.0000	0.1540	0.0000	0.8460	0.0000	0.0000	0.0000	0.0000
Gram	0.5870	0.1740	0.0000	0.0000	0.0350	0.0000	0.0000	0.2040	0.0000
Soyabean	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mustard	0.0000	0.0000	0.0000	0.9520	0.0000	0.0000	0.0000	0.0000	0.0480
Cotton	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Clusterbean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000

It is evident from table- 5 (during- 1976 to 1980) that all the crops except pearlmillet were highly unstable with zero retention of their previous area. Pearlmillet was almost stable with approximately 80 per cent retention of area during this period. Pearlmillet crop gained 41 per cent of area from wheat and 23 per cent from clusterbean; maize gained 13 per cent of area from wheat and hundred per cent of area from soyabean crop and wheat gained 82 per cent of area from gram crop. Kharif pulses gained 100 per cent of area from maize and 42 per cent from clusterbean crop. Wheat, kharif pulses and clusterbean lost 23, 33 and 25 per cent of area to the gram crop; wheat lost 12 per cent of area to the mustard crop and mustard and cotton lost cent per cent, kharif pulses 67 per cent and wheat 11 per cent of area to clusterbean crop during the period.

Table- 6 depicts the results of TPM for major field crops in the state during- 1981 to 1985. It is observed from the table that maize, kharif pulses, gram, cotton and clusterbean crops remained highly unstable with no retention of their previous area while pearlmillet, wheat, soyabean and mustard were somewhat stable with 53, 33, 28 and 12 per cent retention during this period. Pearlmillet crop gained cent per cent area from kharif pulses, 27 per cent from maize and 30 per cent from clusterbean. Maize gained 11 per cent area from clusterbean, 9 per cent from mustard and 8 per cent from pearlmillet; wheat gained 41 per cent from gram, 7 per cent from pearlmillet and kharif pulses gained 72 per cent area from soyabean, 30 per cent from clusterbean, 27 per cent from mustard and 13 per cent from pearlmillet crop. Gram gained 73 per cent area from maize, 46 per cent from mustard and 19 per cent from pearlmillet crop. Clusterbean lost 26 per cent area to mustard crop; gram lost 26 per cent area to cotton crop and cotton lost 100 per cent, gram 33 per cent and wheat 67 per cent area to clusterbean crop during this period.

Table: 5 Transitional probability matrix for major field crops in the state of Rajasthan during-1976 to 1980

1976-80	Pearlmillet	Maize	Wheat	Kharif pulses	Gram	Soyabean	Mustard	Cotton	Clusterbean
Pearlmillet	0.8025	0.0715	0.0657	0.0000	0.0000	0.0000	0.0032	0.0571	0.0000
Maize	0.0000	0.0000	0.0000	0.9988	0.0012	0.0000	0.0000	0.0000	0.0000
Wheat	0.4130	0.1340	0.0000	0.0000	0.2255	0.0000	0.1209	0.0000	0.1066
Kharif pulses	0.0000	0.0000	0.0000	0.0000	0.3316	0.0000	0.0000	0.0000	0.6684
Gram	0.0000	0.0000	0.8205	0.0000	0.0000	0.0000	0.0000	0.0802	0.0992
Soyabean	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mustard	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
Cotton	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
Clusterbean	0.2329	0.0338	0.0000	0.4170	0.2542	0.0000	0.0377	0.0245	0.0000

Table: 6 Transitional probability matrix for major field crops in the state of Rajasthan during-1981to 1985

1981-85	Pearlmillet	Maize	Wheat	Kharif pulses	Gram	Soybean	Mustard	Cotton	Clusterbean
Pearlmillet	0.5310	0.0830	0.0730	0.1270	0.1860	0.0000	0.0000	0.0000	0.0000
Maize	0.2740	0.0000	0.0000	0.0000	0.7260	0.0000	0.0000	0.0000	0.0000
Wheat	0.0000	0.0000	0.3340	0.0000	0.0000	0.0000	0.0000	0.0000	0.6660
Kharif pulses	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Gram	0.0000	0.0000	0.4130	0.0000	0.0000	0.0000	0.0000	0.2560	0.3320
Soybean	0.0000	0.0000	0.0000	0.7170	0.0000	0.2830	0.0000	0.0000	0.0000
Mustard	0.0680	0.0930	0.0000	0.2650	0.4580	0.0000	0.1160	0.0000	0.0000
Cotton	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
Clusterbean	0.3010	0.1140	0.0170	0.3020	0.0000	0.0100	0.2560	0.0000	0.0000

It is evident from table- 7 that maize, kharif pulses, gram, soyabean, mustard, cotton and clusterbean crops remained highly unstable with no retention of their previous area during - 1986 to 1990. Pearlmillet and wheat were almost stable with 56 and 10 per cent retention of area during this period. Pearlmillet gained 90, 31 and 59 per cent area from wheat, gram and cotton; maize gained 27 per cent area from kharif pulses and 12 per cent from clusterbean and wheat gained 67 per cent area from maize and 69 per cent area from gram crop. Kharif pulses gained 39 per cent area from mustard and 28 per cent area from clusterbean crop. Soyabean, mustard, cotton and clusterbean crops lost 100, 38, 36 and 23 per cent area to gram crop; maize, kharif pulses and clusterbean lost 18, 73 and 11 per cent area to mustard crop and maize lost 15 per cent and clusterbean lost 22 per cent area to cotton crop. Pearlmillet and mustard lost 34 and 23 per cent of area to clusterbean crop during this period.

Table- 8 depicts the results of TPM for major field crops in Rajasthan state during- 1991 to 1996. It is observed from the table that maize, wheat, kharif pulses, gram, soyabean, mustard and cotton crops remained highly unstable with no retention of their previous area while pearlmillet and clusterbean crops were somewhat stable with 19 and 44 per cent retention during this period. Pearlmillet gained hundred per cent area from maize and cotton, 93 per cent from mustard and 46 per cent from kharif pulses. Maize gained 27 per cent area from gram, 6 per cent from pearlmillet and 5 per cent from clusterbean crop; wheat gained 23 per cent area from pearlmillet, 43 per cent from kharif pulses and 71 per cent from soyabean and kharif pulses gained 54 per cent area from wheat, 10 per cent from gram and 23 per cent from clusterbean crop. Gram gained 20, 11 and 7 per cent area from pearlmillet, kharif pulses and mustard crop. Wheat lost 13 per cent and clusterbean lost 7 per cent area to soyabean crop. Pearlmillet, wheat , soyabean and clusterbean lost 16, 23, 27 and 22 per cent area to mustard crop; pearlmillet, wheat and gram lost 5, 10 and 14 per cent area to cotton crop and pearlmillet and gram lost 11 and 49 per cent area to clusterbean crop during this period.

Table: 7 Transitional probability matrix for major field crops in the state of Rajasthan during-1986 to 1990

1986-90	Pearlmillet	Maize	Wheat	Kharif pulses	Gram	Soyabean	Mustard	Cotton	Clusterbean
Pearlmillet	0.5607	0.0405	0.0000	0.0431	0.0000	0.0148	0.0000	0.0000	0.3409
Maize	0.0000	0.0000	0.6681	0.0000	0.0000	0.0000	0.1842	0.1477	0.0000
Wheat	0.8951	0.0000	0.1049	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Kharif pulses	0.0000	0.2723	0.0000	0.0000	0.0000	0.0000	0.7277	0.0000	0.0000
Gram	0.3099	0.0000	0.6901	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Soyabean	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
Mustard	0.0000	0.0000	0.0000	0.3861	0.3841	0.0000	0.0000	0.0000	0.2298
Cotton	0.5862	0.0000	0.0000	0.0498	0.3640	0.0000	0.0000	0.0000	0.0000
Clusterbean	0.0000	0.1222	0.0000	0.2782	0.2301	0.0332	0.1121	0.2242	0.0000

Table: 8 Transitional probability matrix for major field crops in the state of Rajasthan during-1991 to 1996

1991-96	Pearlmillet	Maize	Wheat	Kharif pulses	Gram	Soyabean	Mustard	Cotton	Clusterbean
Pearlmillet	0.1909	0.0615	0.2288	0.0000	0.1963	0.0000	0.1591	0.0503	0.1129
Maize	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wheat	0.0000	0.0000	0.0000	0.5429	0.0000	0.1257	0.2337	0.0978	0.0000
Kharif pulses	0.4570	0.0000	0.4330	0.0000	0.1100	0.0000	0.0000	0.0000	0.0000
Gram	0.0000	0.2685	0.0000	0.1049	0.0000	0.0000	0.0000	0.1369	0.4897
Soyabean	0.0000	0.0000	0.7073	0.0000	0.0000	0.0207	0.2720	0.0000	0.0000
Mustard	0.9275	0.0000	0.0000	0.0000	0.0725	0.0000	0.0000	0.0000	0.0000
Cotton	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Clusterbean	0.0000	0.0505	0.0000	0.2251	0.0000	0.0715	0.2152	0.0000	0.4376

Table- 9 depicts the results of transitional probability matrix of major field crops in the state during- 1996 to 2000. It is evident from the table that pearlmillet and clusterbean crops were almost stable with approximately 52 and 43 per cent retention of area during this period. Remaining crops were highly unstable with zero retention of their previous area under cultivation. Pearlmillet gained 14 per cent of area from maize, 77 per cent from wheat, 13 per cent from gram and 8 per cent of area from cotton crop. Maize gained 24 per cent of area from wheat and 23 per cent of area from cotton; wheat gained 36 per cent of area from pearlmillet, 15 per cent from gram and 21 per cent of area from mustard crop and kharif pulses gained 34 per cent of area from mustard and 53 per cent from clusterbean crop. Kharif pulses lost 84 per cent of area to gram; mustard 22 per cent soyabean and soyabean lost hundred per cent, gram 36 per cent, kharif pulses 17 per cent and pearlmillet 12 per cent of area to mustard crop. Gram and mustard lost 12 and 24 per cent area to cotton crop and maize, gram and cotton lost 87, 21 and 69 per cent of area to clusterbean crop during the same period.

The resuls of TPM of crops in Rajasthan state during- 2000 to 2005 are presented in table- 10. It is observed from the table that maize, gram, soyabean and clusterbean were highly unstable crops with no retention of their previous area. The retention in area under pearlmillet, wheat, kharif pulses, mustard and cotton was estimated at 59, 45, 26, 59 and 31 per cent during the period. Pearlmillet gained 45, 66, 18, 69 and 18 per cent of area from wheat, soyabean, mustard, cotton and clusterbean crop. Maize gained 10 per cent of area from pearlmillet and 34 per cent from soyabean; wheat gained 54 per cent of area from gram and 20 per cent of area from clusterbean and kharif pulses gained 21 and 48 per cent of area from pearlmillet and maize crop during the period. Pearlmillet and mustard lost 10 and 11 per cent of area to gram crop and wheat and clusterbean lost 10 and 14 per cent of area to soyabean crop. Gram lost 39 per cent and clusterbean 31 per cent of area to mustard crop; gram lost 7 per cent and clusterbean 12 per cent of area to cotton crop and miaze, kharif pulses and mustard lost 52, 73 and 11 per cent of its area to clusterbean crop during the same period.

Table: 9 Transitional probability matrix for major field crops in the state of Rajasthan during-1996 to 2000

1996-2000	Pearlmillet	Maize	Wheat	Kharif pulses	Gram	Soyabean	Mustard	Cotton	Clusterbean
Pearlmillet	0.5230	0.0000	0.3560	0.0000	0.0000	0.0000	0.1220	0.0000	0.0000
Maize	0.1350	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.8650
Wheat	0.7650	0.2350	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Kharif pulses	0.0000	0.0000	0.0000	0.0000	0.8350	0.0000	0.1650	0.0000	0.0000
Gram	0.1300	0.0300	0.1520	0.0000	0.0000	0.0000	0.3610	0.1210	0.2050
Soyabean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
Mustard	0.0000	0.0000	0.2050	0.3360	0.0000	0.2230	0.0000	0.2360	0.0000
Cotton	0.0790	0.2290	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6930
Clusterbean	0.0000	0.0000	0.0000	0.5280	0.0000	0.0190	0.0000	0.0000	0.4530

Table: 10 Transitional probability matrix for major field crops in the state of Rajasthan during-2000 to 2005

2000-05	Pearlmillet	Maize	Wheat	Kharif pulses	Gram	Soyabean	Mustard	Cotton	Clusterbean
Pearlmillet	0.5934	0.0999	0.0000	0.2086	0.0981	0.0000	0.0000	0.0000	0.0000
Maize	0.0000	0.0000	0.0000	0.4770	0.0050	0.0000	0.0000	0.0000	0.5179
Wheat	0.4480	0.0000	0.4536	0.0000	0.0000	0.0984	0.0000	0.0000	0.0000
Kharif pulses	0.0000	0.0000	0.0000	0.2618	0.0116	0.0000	0.0000	0.0000	0.7265
Gram	0.0000	0.0000	0.5429	0.0000	0.0000	0.0000	0.3906	0.0664	0.0000
Soyabean	0.6611	0.3389	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mustard	0.1751	0.0000	0.0000	0.0000	0.1107	0.0171	0.5909	0.0000	0.1062
Cotton	0.6868	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3132	0.0000
Clusterbean	0.1823	0.0342	0.2043	0.0000	0.0000	0.1413	0.3132	0.1248	0.0000

The results of TPM of major field crops in the state of Rajasthan during- 2006 to 2010 are presented in table- 11. It is observed from the table that maize, wheat, kharif pulses, gram, mustard, cotton and clusterbean were highly unstable crops with no retention of their previous area. The retention in area under pearlmillet and soyabean was estimated at 33 and 17 per cent during the period. Pearlmillet gained 35, 53, 46 and 75 per cent of area from wheat, gram, soyabean and clusterbean crop. Maize gained 15 per cent of area from clusterbean and 6 per cent of area from mustard; wheat gained 20 per cent of area from pearlmillet, 57 per cent from maize and 21 per cent from mustard and kharif pulses gained 39 per cent of area from pearlmillet and 6 per cent of area from mustard crop. Cotton lost cent per cent , maize 43 per cent and pearlmillet 5 per cent of area to gram crop; wheat lost 13 per cent and clusterbean 9 per cent of area to soyabean crop and wheat, kharif pulses and gram lost 53, 34 and 25 per cent of area to mustard crop. Mustard lost 14 per cent of area to cotton crop and kharif pulses, gram soyabean and mustard lost 66, 22, 37 and 51 per cent of area to clusterbean crop during this period.

Table- 12 depicts the results of transitional probability matrix of major field crops during- 2011 to 2015. It is evident from the table that pearlmillet, kharif pulses, gram and mustard crops were almost stable with 45, 31, 34 and 27 per cent retention of area during this period. Remaining crops were highly unstable with zero retention of their previous area under cultivation. Pearlmillet gained 11 per cent of area from kharif pulses and 51 per cent of area from clusterbean; maize gained 12 per cent of area from pearlmillet crop and wheat gained 30, 41, and 15 per cent of area from pearlmillet, gram and clusterbean crops. Kharif pulses gained 30 per cent of area from wheat and 11 per cent of area from clusterbean crop. Clusterbean lost 22 per cent of area

Table: 11 Transitional probability matrix for major field crops in the state of Rajasthan during-2006 to 2010

2006-10	Pearlmillet	Maize	Wheat	Kharif pulses	Gram	Soyabean	Mustard	Cotton	Clusterbean
Pearlmillet	0.3323	0.0319	0.1984	0.3855	0.0519	0.0000	0.0000	0.0000	0.0000
Maize	0.0000	0.0000	0.5684	0.0000	0.4316	0.0000	0.0000	0.0000	0.0000
Wheat	0.3476	0.0000	0.0000	0.0000	0.0000	0.1255	0.5268	0.0000	0.0000
Kharif pulses	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3443	0.0000	0.6557
Gram	0.5312	0.0000	0.0000	0.0000	0.0000	0.0000	0.2514	0.0000	0.2174
Soyabean	0.4580	0.0000	0.0000	0.0000	0.0000	0.1700	0.0000	0.0000	0.3720
Mustard	0.0234	0.0634	0.2093	0.0570	0.0000	0.0000	0.0000	0.1389	0.5080
Cotton	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
Clusterbean	0.7530	0.1453	0.0000	0.0000	0.0000	0.0901	0.0000	0.0116	0.0000

Table: 12 Transitional probability matrix for major field crops in the state of Rajasthan during-2011 to 2015

2011-15	Pearlmillet	Maize	Wheat	Kharif pulses	Gram	Soyabean	Mustard	Cotton	Clusterbean
Pearlmillet	0.4540	0.1190	0.2980	0.0000	0.0000	0.0000	0.1140	0.0000	0.0160
Maize	0.0000	0.0000	0.0000	0.0190	0.0000	0.0000	0.9810	0.0000	0.0000
Wheat	0.0000	0.0000	0.0000	0.2990	0.0000	0.1280	0.0000	0.0000	0.5730
Kharif pulses	0.1090	0.0000	0.0000	0.3100	0.0000	0.0000	0.1500	0.0530	0.3770
Gram	0.0000	0.0220	0.4100	0.0000	0.3350	0.0000	0.0000	0.2330	0.0000
Soyabean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
Mustard	0.0000	0.0000	0.0000	0.0000	0.0000	0.0170	0.2660	0.0000	0.7170
Cotton	0.0000	0.0000	0.0000	0.0000	0.0000	0.9200	0.0000	0.0000	0.0800
Clusterbean	0.5120	0.0140	0.1520	0.1050	0.2180	0.0000	0.0000	0.0000	0.0000

to gram; wheat lost 13 per cent and cotton lost 92 per cent of area to soyabean crop and pearlmillet lost 11 per cent, maize lost 98 per cent and kharif pulses lost 15 per cent of area to mustard crop. Kharif pulses and gram lost 5 per cent and 23 per cent of area to cotton crop and wheat, kharif pulses, soyabean, mustard and cotton lost approximately 57, 34, 100, 72 and 8 per cent of area to clusterbean crop during this period.

4. CONCLUSION

Spatio- temporal changes in cropping pattern as estimated through markov chain analysis revealed that pearlmillet crop was somewhat stable with 38 per cent retention during 1956-60. During 1961 to 1965, pearlmillet, kharif pulses and gram were almost stable. During 1966 to 1970 almost all crops except pearlmillet and wheat were highly unstable crops with zero retention of its previous area. Pearlmillet and clusterbean crops were more stable with 85 and 100 per cent retention of area during - 1971 to 1975. All the crops except pearlmillet were highly unstable during 1976 to 1980. During the quinquennial period ending 1985 pearlmillet, wheat and soyabean were somewhat stable. Maize, kharif pulses, gram, soyabean, mustard, cotton and clusterbean crops remained highly unstable during - 1986 to 1990. Pearlmillet and wheat were almost stable with 56 and 10 per cent retention of area. During - 1991 to 1996 pearlmillet and clusterbean crops were somewhat stable and same crops were almost stable during 1996 to 2000. The remaining crops were highly unstable with zero retention of their previous area under cultivation during the period. The retention in area under pearlmillet, wheat, kharif pulses, mustard and cotton was estimated at 59, 45, 26, 59 and 31 per cent during - 2000 to 2005. Maize, wheat, kharif pulses, gram, mustard, cotton and clusterbean were noted to be highly unstable crops during 2006 to 2010 with no retention of its previous area. The retention in area under pearlmillet and soyabean was estimated at 33 and 17 per cent during the same period. Pearlmillet, kharif pulses, gram and mustard crops were almost stable with 45, 31, 34 and 27 percent retention of area during - 2011 to 2014-15. Overall it may be concluded that the pearlmillet crop was

almost stable and cotton crop (except-2000 to 2005) highly unstable with no retention of its previous area over the periods.

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