A MARKOV CHAIN MODEL FOR MAIZE PRODUCTION IN TAMILNADU

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ABSTRACT

Maize (Zea mays L) is a cercal grain, also known as Queen of Cereals due to its diverse usages. Maize is one of the important coarse cereal crops grown in different agro-climatic conditions of India. In this Paper was studied about to use Markov chain Model to assess the Maize Production trend since markov chain would consider only the characteristics of the past Behaviour of the data set. The time series data on maize production for the period of 1963-1964 to 2016-17 grown in Tamilnadu have been collected from the Season and crop report 2016-17 published by Department of Economics and statistics, Government of Tamilnadu. To Predict the the production of maize for the year 2018, 2019, 2020 using three state Markov chain Model.

Key Worde: Maize production , Tamil Nadu , Markov chain Model , Transition Matrix , Chapman –kolmogorov equation .

1. Introduction

The word 'Agriculture is derived from the Latin word 'Ager' means Land or field and 'Culture' means cultivation. It means the science and Art of producing crops and livestock for economic purpose. Agriculture is an art of raising plant life from the soil for the use of mankind. Agriculture is the mile stone in the history of human civilization, due to agriculture man settled at particular place. Agriculture is one of the oldest and prime activities of the human being. It has remained an important source of land. In spite of growing industrialization and urbanization in the world, nearly fifty percent working population still engaged in agriculture. Agriculture is a backbone of Indian economy. In India about sixty four percent of the total population is dependent on agriculture for their live food. The study of land and agriculture from the geographical point of view gained more importance after 1950. At the beginning of 1970 and later on the green Revolution brought of remarkable change in the field of agriculture, due to this

India become not only self sufficient in food grains but it could also expert a small quality of it. Maize (Zea mays L) is a cercal grain, also known as Queen of Cereals due to its diverse usages. In India, it is cultivated in most of the State throughout all the seasons, depending on the regions and socio-economic conditions of the population, the maize-grain is used for various purposes including food, feed, fodder, green cobs, sweet corn, baby corn, popcorn, starch and several industrial products. According to the fourth advance estimates of the Ministry of Agriculture. Government of India, maize in India occupied about 8.7 million hectares (M ha) of the area and produced about 22.2 million tonnes (Mt) of maize grain during 2012-13. It is about 15 percent and 5 percent to total maize-area , while 8 percent and 2.4 percent to total production in Asia and the world, respectively [FAOSTAT (2013)].

Maize is one of the important coarse cereal crops grown in different agro-climatic conditions of India. Maize ranks third next to Wheat and Rice in the world with respect to area, while its productivity surpasses all other cereal crops. Maize is grown in 70 countries of the world. The major Maize growing countries are USA, China, Brazil, Mexico, Indonesia, India, France and Argentina. In some parts of the world, Maize is used as food grain for human consumption. It is being used for manufacturing industrial products like starch, syrup, alcohol, acetic and lactic acids, glucose, paper, rayon, plastic, textile, adhesive, dyes, synthetic materials, rubber etc. In USA more than 90 per cent of the people use Maize oil for consumption purpose and around 25% of Crop land area is occupied by Maize. India is at 6th position in Maize production and 15th position in its productivity in the World. In India Maize is grown all over the country. In India the major producing states are Karnataka, Andhra Pradesh, Madhya Pradesh, Bihar, Rajasthan, Tamil Nadu, Telangana and Uttar Pradesh.

Hanson et al.(2004),Holton et al.(2003), Jones et al.(1984),Martin et.al.(2000),Mureithi et al.(2003), Pradeep Kumar Kanjeer et.al.(2018),Pawan Kumar Sharma et.al.(2018),Ranjith Kumar et.al.(2014),Rathod(2018),Manatsa et.al.(2011), Habib(2013), are authors who studied about the area, production and yield about the Maize crop. In this Paper was studied about to use Markov chain Model to assess the Maize Production trend since Markov chain would consider only the characteristics of the past Behavior of the data set. The time series data on maize production for the period of 1963-1964 to 2016-17 grown in Tamilnadu have been collected from the Season and crop report 2016-17 published by Department of Economics and statistics, Government of Tamilnadu.

2. Methods

The Markov Chains has been introduced by the Russian mathematician, Andrey Andreyevich Markov, in 1970. After this date numbers of researchers have been employing this technique in different fields. For the Markov process, the probability of the given condition in the given moment may be deduced from information about the preceding conditions. A Markov chain represents a system of elements moving from one state to another over time. The order of the chain gives the number of time steps in the past influencing the probability distribution of the present state, which can be greater than one. Many natural processes are considered as Markov processes. In fact, the probability transition matrix is a tool for describing the Markov chains behavior. Each element of the matrix represents probability of passage from a specific condition to a next state. Although it is very complicated to transform agricultural production problems in to mathematical equations, Markov Chains Method comes out as the primary and most powerful technique in making decision and predicting.

2.1. Markov process

If {X(t),t∈ T}is a stochastic process such that, given the value X(s)the values of X(s),t>s, do not depend on the values of X(u),u<s, then the process is said to be a Markov process. A process is, $t_1 < t_2 < \cdots < t_n < t$.

$$\Pr\left\{a \le X(t) \le \frac{b}{X(t_1)} = x_1 \dots \dots X(t_n) = x_n\right\} = Pr\left\{a \le X(t) \le \frac{b}{X(t_n)} = x_n\right\}$$

The process $\{X(t), t \in T\}$ is a Markov process.

2.2. Markov chain

A discrete parameter Markov process is known as a Markov chain. The stochastic process $\{X_n$, n=0, 1, 2...} is called a Markov chain, if, for j , k ,$j_1 \dots . j_{n-1} \in N$,

$$Pr\left\{X_n = \frac{k}{X_{n-1}} = j, X_{n-2} = j_1 \dots . X_0 = j_{n-1}\right\} = Pr\left\{X_n = \frac{k}{X_{n-1}} = j\right\} = P_{ij}$$

The states of the Markov chain X_n has the outcome j, the process is said to be at state j at n^{th} occurrence. To a pair of states (j, k) at the two successive occurrence are associated conditional probability ij is independent of n, the Markov chain is said to be stationary transition probabilities. If the chain is said to be non-homogeneous, so confine to homogeneous chains.

The transition probability P_{jk} refers to the states (j,k) , the transition is one –step and P_{jk} is called unit step transition probability. In the general case are concerned with the pair of states (j,k),the state j at the n^{th} occurrence and state k at the $(n + m)^{th}$ occurrence. The consistent transition probability is then called m-step transition probability and is denoted by $P_{jk}^{(m)}$, i.e. $P_{jk}^{(m)} = Pr\left\{X_{n+m} = \frac{k}{X_n} = j\right\}$.

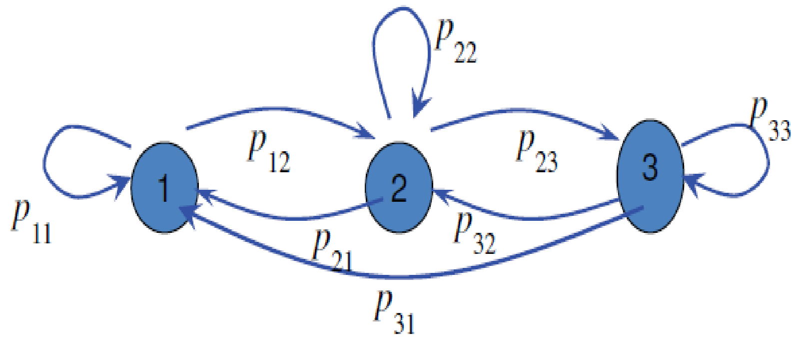

Figure -1. Transition Graph of Markov Chain

2.3. Transition Matrix

The transition probabilities P_{jk} satisfy the condition that $P_{jk} \geq 0, \sum_k P_{jk}$ =1 for all j.These probability may be written in the matrix form

$$P=\begin{bmatrix} P_{1.1} & P_{1.2} \dots \dots P_{1.k} \\ P_{2.1} & P_{2.2} \dots \dots P_{2.k} \\ . & . \quad\quad . \\ . & . \quad\quad . \\ P_{j.1} & P_{j.2} \dots \dots P_{j.k} \end{bmatrix}$$

This is called the transition probability matrix or matrix of the Markov chain is a stochastic matrix i.e .a square matrix with non-negative element and row sums.

2.4. Chapman –kolmogorov equation

Considered unit-step probabilities, the probability of X_n given X_{n-1} and the probability of the outcome at the n^{th} step,P_{jk} gives the probability of unit-step transition from the state j at a occurrence to the state k at the next following occurrence. The m-step transition probability is denoted by

$$Pr\left\{X_{m+n} = \frac{k}{X_n} = j\right\}=P_{jk}^{(m)}$$

$P_{jk}^{(m)}$ gives the probability that from the state j at n^{th}occurrence, the state k is reached at $(m+n)^{th}$ occurrence in m steps,the probability of transition from the state j to the state k in exactly m steps. The number n does not occur and the chain is homogeneous. The one-step transition probabilities $P_{jk}^{(1)}$ are denoted by P_{jk}.

3. Results and Discussion

Markov chain stochastic model has been applied to the maize production data. When analyzing and forecasting process by Markov Chain, one should carry out the step viz.,(i)construction of state and to determine the corresponding state probabilities;(ii)to write a state transition probability matrix by the probabilities. The results obtained are discussed in detail in the following sections.

3.1. Empirical analysis based on three-state Markov Chain

The 54 years India's Maize production data from reference, were divided into three different states namely decrease, no change and increase with each state having a fixed interval length, say 2600 was considered for analysis and forecasting purposes. The maximum and minimum production values are 8224 and 646 respectively.

The decrease state was formed with an interval size of 2600 ranging from 600 to 8400 , other two states namely no change and increase were formed similarly and hence the different states are viz.,

Decrease = x_1 = [600, 3200],

no change = x_2 =[3200, 5800] and

Increase = x_3 = [5800, 8400].

For the year 1963 the production value is 1110 and hence it falls in the no change state; for 1964 the value is 1098 and it fell in the no change state.

Similarly rest of the year's production data are classified into their respective states and summarized in Table 1

Table-1. Classification of maize production data into the three different states

year	1963	1964	1965	1966	1967	1968	1969	1970	1971
state	decrease	decrease	decrease	decrease	decrease	decrease	decrease	decrease	Decrease
year	1972	1973	1974	1975	1976	1977	1978	1979	1980
state	decrease	decrease	decrease	decrease	decrease	decrease	decrease	decrease	Decrease
year	1981	1982	1983	1984	1985	1986	1987	1989	1990
state	decrease	decrease	decrease	decrease	decrease	decrease	decrease	decrease	Decrease
year	1991	1992	1993	1994	1995	1996	1997	1998	1999
state	decrease	decrease	decrease	decrease	decrease	decrease	decrease	decrease	Decrease
year	2000	2001	2002	2003	2004	2005	2006	2007	2008
state	decrease	decrease	decrease	decrease	decrease	decrease	decrease	No change	No change
year	2009	2010	2011	2012	2013	2014	2015	2016	2017
state	No change	No change	No change	increase	No change	increase	increase	increase	Decrease

3.2. Formation of initial state vector

In order to determine the initial state probability vector, the maize production data was divided into three states viz.,decrease, no change and increase and let $x_1 =$ decrease, x_2 =no change and x_3 = increase then the state space is E(x_1, x_2, x_3), and state probability is total number of data in a single state, State vector is denoted by $\eta_{(i)} = (P_1, P_2, \dots P_n)$ Where i=1,2,…..n,Where P_j is probability of x_j j=1,2,….n.There is 54 year maize production data in table 1 ,where decrease $x_1 = 44$. no change x_2 = 6 and increase x_3 =4, so the probability of each state are as follows: $P_1 = \frac{44}{54} = 0.8148$, P_2 =6/54= 0.1111 , P_3 =4/54=0.0740 and the state vector $\eta_{(o)}$ =(0.8148, 0.1111,,0.0703) is called initial state vector.

3.3. Formation of state transition probability matrix

Since the state of the last year decrease while there is no state transition in **table ,** the decrease in state total number should be recorded as 44-1=43 points,where the number of states from decrease to decrease transition occurs 43 times. so transition probability for decrease to decrease P_{11} =43/44=0.9772.The number of transition from decrease to no-change is 1,so the corresponding transition probability i.e . P_{12} =1/43=0.2325. Since the number of transition from decrease to increase is 0,so it's corresponding transition probability is $P_{13} = 0$. Since the number of transitions from no change to decrease is and the total number of no change data points are 0,so the corresponding transition probability from no change to decrease is P_{21} =0, .similarly , one can obtain $P_{22} = \frac{5}{6} = 0.8333$ P_{23} =1/4=0.25 , P_{31} =1/44=0.0227, $P_{32} = \frac{1}{6} = 0.1667$ P_{33}=3/4=0.75

The state transition probabilities are summarized in **table**

$$P=\begin{bmatrix} 0.9772 & 0.0232 & 0 \\ 0 & 0.8333 & 0.25 \\ 00227 & 0.1667 & 0.75 \end{bmatrix}$$

Table-2.Transition probabilities of maize crop production data into the three states

Production state \ change	Decrease	no change	Increase
Decrease	0.9772	0.0232	0
no change	0	0.8333	0.25
Increase	0.227	o.1667	0.75

3.4. Prediction based on three –state Markov Chain

According to Markov process,the state probability in different periods are denoted by $\eta_{(i)}$, here $\eta_{(i+1)}$=$\eta_{(i)}$*P ,Where p is state transition probability matrix.As per the perusal of table ,the final production value lies in the decrese state and there is no further follow decrease information, Thus the initial state vector is $\eta_{(0)}$ = (1,0,0).By virtue of the initial state vector and state transition probability matrix of the final year ,one can obtain the state probability vector of year following final year.

Hence the state probability vector for the year 2018, 2019 and 2020 are

$\eta_{(1)}$ = $\eta_{(0)}$*P =(0.9772 0.0232, 0)

$\eta_{(2)}$ =$\eta_{(1)}$*p=(0.9345 0.081 0.002)

$\eta_{(3)}$ = $\eta_{(2)}$*p=(0.9764 0.0674 0.0342) respectively.

This iteration continues until the state probability vector values converge, which gives us a final forecasted state vector of the Maize production in year in future.

3.5. Stable condition of three –state Markov chain

In an actual situation the outcome of prediction is consistent, it is only then the production will be considered in near future .The calculation of derivation using the above recursive method is larger to predict the final production. According to system stable condition equations of Markov chain, one can step method to predict the state probability value of India's maize production.

Under stable conditions of Markov chain system:

$$\begin{cases} \eta * P = \eta \\ \sum_{i=1}^{n} x_i = 1 \end{cases} \quad \text{.................................... (1)}$$

Where $\eta = (x_1, x_2, \dots x_n)$ and $P = \begin{bmatrix} P_{11} & P_{12} \dots & P_{1n} \\ \dots & \dots . & \dots \\ P_{n1} & P_{n2} \dots . & P_{nn} \end{bmatrix}$

By taking the initial state vector and state transition matrix

$$P=\begin{bmatrix} 0.9772 & 0.0232 & 0 \\ 0 & 0.8333 & 0.25 \\ 0.0227 & 0.1667 & 0.75 \end{bmatrix}$$

Using the about equation (1)

$$\begin{cases} (x_1, x_2, x_3) \begin{bmatrix} 0.9772 & 0.0232 & 0 \\ 0 & 0.8333 & 0.25 \\ 0.0227 & 0.1667 & 0.75 \end{bmatrix} \\ x_1 + x_2 + x_3 \end{cases}$$

$$\text{And Hence} \begin{cases} 0.9772x_1 + 0.0232x_2 = x_1 \\ 0.8332x_2 + 0.25x_3 = x_2 \\ 0.0227x_1 + 0.1667x_2 + 0.75x_3 = x_3 \end{cases}$$

$$\text{In the above equation, one can get the following:} \begin{cases} x_1 \; = 0.440 \approx 0.440 \\ x_2 = 0.690 \approx 0.700 \\ x_3 = 0.187 \approx 0.187 \end{cases}$$

It is clear that the state probability value of the production computed under the steady-state is the same as conclusion derived by recursive formula.

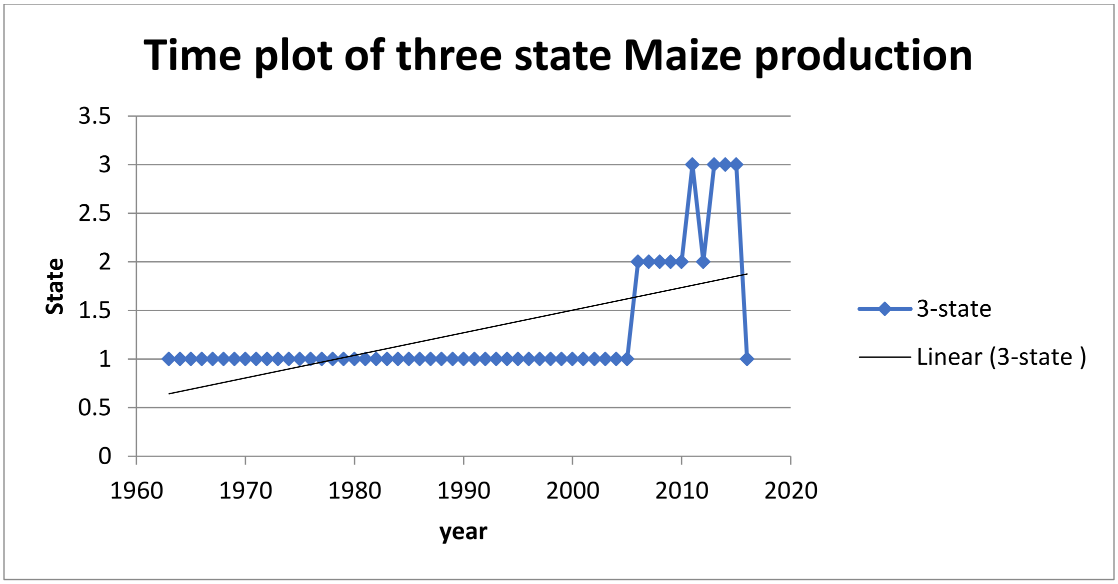

Figure 2- Time plot of three State Maize Production

Table-3. Forecasting of Tamilnadu Maize Production based on Markov Chain Model

Linguistic Values	**Percentage**	**Inteval**	**R^2 (%)**
Decrease	82	[600, 3200]	
No change	11	[3200, 5800]	**69**
Increase	07	[5800, 8400]	

After the calculation, we know that the production state interval after each year predicted by the above formula is basically consistent with the actual situation. The result given in table3 revealed that the R-square and linguistic prediction accuracy is high.

4. Conclusion

The Maize production of tamilnadu eventually was found to be the increase state in 82 percent; No change state about 11 percent and decrease state about 7 percent with 69 percent of R-square in three state markov chain Model. So the possibility of increase in Maize production has been observed.

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