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Markov Chain Modelling for Prediction on Future Market Price of Potatoes with Special Reference to Nagaon District

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Abstract: *Like many fields, the Markov Chain Model can be very effectively applied to the prediction of market prices of agricultural products. In this paper, attempts have been made to study and predict the future market price of potatoes with the data collected from Lanka Regulated Market in the Nagaon District, Assam. By applying this model, the data related to the market price of potatoes from 4th June 2014 to 21st April 2017 i.e. for 478 days were collected to predict the future price interval for fifteen consecutive days. Seven distinct and non-overlapping intervals of market price were constructed and the transitions from one interval to the other were counted to derive the transition probability matrix for Markov Chain model. Using the transition probability matrix and initial state vector the prediction for short period were made. The results obtained from the analysis were indistinguishable from real situation. Furthermore, considering the three possible stages of a particular day's price status in comparison to the previous day's price as 'increase', 'decrease' and 'remain same', the three-state transition matrix has been calculated and attempted to find out the long term behaviour of the market price of potatoes.*

Keywords: *- Markov Chain, Transition Probability Matrix, Steady State Probability*

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I. Introduction

Agriculture forms the backbone of the economy of Assam. Thus price of agricultural commodities plays an important role in an agricultural economy like Assam.. Most of the working population in rural area of Assam are directly involved in agricultural activities. The physiographic conditions, soil quality and the climatic pattern of the region are remarkably favourable for the production of different crops, vegetables and fruits, essential for livelihood. There are many factors, which act in different directions, which affect the agricultural production. Most of the farmers mainly depend on nature to produce their agricultural commodities. Again, some commodities are produced in a particular season. Thus, factors like availability of machine power, accessibility of good quality seeds and planting materials, post harvest technology, marketing facility and infrastructure influence the price of the commodities produced. Marketing for produced commodities and unorganized marketing system are other major problems in this region that creates a wide gap between the producer and the consumer. The transportation facilities of goods from their production regions to the other parts of the state or the country are insufficient. High rainfall and annual flood also affect the production of crops as well as the price of the goods. The demand for a particular commodity and insufficient supply of that commodity may cause the fluctuation of price. The continuous increase in the price of the products creates an adverse effect in the day-to-day life of common people.

Nagaon District is the one of the largest districts in Assam, situated in the central part of the state covering an area of 3735 sq km and the cultivated area is approximately 2712.85 sq km, which is about 72.64% of geographical area. Agriculture is the major source of occupation in rural areas and most of the people are engaged in producing different agricultural commodities. The mighty Brahmaputra and other tributaries like Kalong, Kapili help to increase the productivity of the cultivated areas. The modern method of cultivation like power tiller, irrigation, chemical fertilizers etc are used to increase the agricultural productivity.

To control the price of agricultural commodities, the Regulated Market Scheme of Agricultural Produce was introduced in 1976, under the Assam Agricultural Produce Market Act 1972 in different places of Assam. The main objectives of the Regulated Market Scheme are to regulate the buying and selling of agricultural commodities, eradication of mal- practices and the role of intermediaries, which prevent the trade in urban, semi-urban and rural markets. Under this mechanism, there is a provision for establishing modern market yard with scientific godown for storage, place for open auction, display yards, traders' shop etc. This system has contributed greatly in enabling the grower to get reasonable price for their production and the buyers to get fair deals in trading (http: //www. efreshglobal. com/eFresh /Content/ eFresh.aspx?u=a). The Regulated

Market Committees of Nagaon District under Assam State Agricultural Marketing Board are constituted in Dhing and Lanka and are known as Dhing Regulated Market Committee and Lanka Regulated Market Committee. Dhing Regulated Market under the Dhing mauza was established in 1979. The distance of Nagaon town to the market is about 35 kilometres and which is well linked by road and railway transportation. Excluding Kampur and Lanka revenue circle, the entire Nagaon District is covered by Dhing Regulated Market committee. According to the average annual revenue receipts, the committees are classified as class A, class B and Class C status. The Dhing Regulated Market Committee is classified as the Class A, owing to the fact that the committee has average annual revenue receipts of more than 1.5 million. The Lanka regulated Market Committee was established by converting the principal market yard of Lanka and Nilbagan in 1981 which falls under the Hojai subdivision.

Some of the crops produced in the areas are seasonal and some are cultivated throughout the year, using modern methods. The large number of agricultural commodities produced in the Nagaon district constitutes crops, fruits, vegetables, spices, nut-crops, pulses, oilseeds etc. However, not all these commodities fall under this Regulated Markets scheme. The Assam State Government controls the inflow of goods in to the market, and agricultural commodities notified by the Government arrive from time to time. For instance, the Dhing Regulated Market, deals in agricultural commodities like areca nut, green chilli, jute, mustard seeds, rice, sesame etc. while, the Lanka Regulated Market, handles commodities like brinjal, green chilli, mustard oil, onion, potato and rice. Thus, the present study endeavours to model the price movements of different agricultural commodities produced in the district using Markov Chain Model.

II. Literature Review

In many recent studies, Markov Chain has been used to model many economic and social problems like brand loyalty, stock market prediction, land use pattern and vegetable market prediction etc. Zhang et al. (2009) used Markov Chain Model to forecast the stock market trend of China's stock market and achieve a satisfactory result. Otieno et al. (2015) studied the trend of Kenya's stock exchange using Markov Chain Model and predict the share price accurately. Zhu and Xu (2012) analysed and predicted the fluctuation cycle of vegetable price of China using Markov Chain Model. Taking the average of five days and ten days data, they predicted the price interval accurately and confirmed that it was feasible to predict the price of the vegetable using Markov Chain Model.

In his study, "A Markov Chain Model for Vegetable Price Movement in Jaffna", Jasin Than et al. (2015) studied the daily price data of vegetables at Thirunele Valley market of Sri Lanka. The collected data was classified according to the price change on two successive days. Using two different models, the price movement of different vegetables were analysed and the steady state probabilities and mean recurrence time were obtained.

III. Objective Of The Study

The objectives of the study are to use first order Markov Chain model;

a. To predict the arrival market price movement of agricultural commodities in near future

b. To estimate the transition probability matrix for the commodities and to find the long term price behaviour

Research Methodology:

For the purpose of the study, the Markov Chain Model has been applied as a base. The study has been conducted based on secondary data collected from Agricultural Marketing Information Network (AGMARKNET), which was launched by the Union Ministry of Agriculture in the year 2000. The AGMARKNET website (http://www.agmarketnet.nic.in) provides information of commodity and variety wise daily prices, arrival date, daily maximum price, minimum price from all the wholesale markets of India. In this study the daily arrival price of potatoes were taken from Lanka Regulated Market provided by AGMARKNET. For the present study, the arrival market price, related to the agricultural product, potatoes have been collected from Lanka Regulated Market.

The Markov Chain Model:-

Markov Chain is a special type of stochastic model of random phenomenon, which evolves with time in a probabilistic manner.

The stochastic process $\{X_n\}$, n=0, 1, 2... with discrete state space, **S** is a Markov Chain if it satisfies the Markov property.

That is for any $i, j, i_1, i_2 \dots i_{n-1} \in$ **S**

$$P_r\{x_{n+1}=j \mid x_n = i, x_{n-1} = i_{n-1} \dots, x_1 = i, x_0 = i_0\}$$
$$= P_r\{x_{n+1} = j \mid x_n = i\}$$

Let $p_{ij} = P_r\{X_{n+1} = j \mid X_n = i\}$, then it is the transition probability of moving from state i in n^{th} step, to the state j in $(n+1)^{th}$ step. These probabilities are one-step transition probabilities of Markov Chain. If the one-step transition probabilities are irrelevant of time n then the chain is time homogeneous or stationary Markov Chain. The transition probabilities represented in a matrix form known as transition probability matrix and written as

$$\mathbf{P} = [p_{ij}]_{n \times n} \quad , \quad 0<p_{ij}<1$$

All the possible states of the Markov Chain are used as rows and columns, so transition probability matrix is always a square matrix and the row sum is always one.

The probability

$$p_{ij}^{(k)} = \Pr\{X_{n+k} = j \mid X_n = i\} \; \forall\, k>0\; n \geq 0,\; i\; j \in \mathbf{S}$$

is the k step transition probability of state i to state j in k steps. In the matrix form it is represented as

$$\mathbf{P}^{(k)} = [p_{ij}^{(k)}]_{i,j \in S} \;\; \forall\, k>0.$$

That is the k step transition matrix is the one step transition matrix raised to the power k and the $p_{ij}^{(k)}$ is the $(i, j)^{th}$ element of the matrix $\mathbf{P}^{(k)}$. If the chain is time homogeneous, then it is independent of n and

$$p_{ij}^{(k)} = \Pr\{X_k = j \mid X_0 = i\} \;\; \forall\, k>0,\;\; i\; j \in \mathbf{S}$$

$$p_{ij}^{(1)} = p_{ij} \qquad \text{and} \qquad \mathbf{P}^{(1)} = [p_{ij}^{(1)}] = P \text{ and}$$

$$\mathbf{P}^{(k)} = \mathbf{P}^{k} \qquad \text{for all k,}$$

The probability $p_{ij}^{(k)} = \Pr\{X_{n+k} = j \mid X_n = i\} \; \forall\, k>0\; n \geq 0,\; i\; j \in \mathbf{S}$ is the k step transition probability of state i to state j in k steps. In the matrix form it is represented as

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That is the k step transition matrix is the one step transition matrix raised to the power k and the $p_{ij}^{(k)}$ is the $(i, j)^{th}$ element of the matrix $\mathbf{P}^{(k)}$. If the chain is time homogeneous, then it is independent of n and

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$$p_{ij}^{(1)} = p_{ij} \qquad \text{and} \qquad \mathbf{P}^{(1)} = [p_{ij}^{(1)}] = P \text{ and}$$

$$\mathbf{P}^{(k)} = \mathbf{P}^{k} \qquad \text{for all k}$$

The initial distribution of Markov chain at time 0 is defined as

$$\pi^{(0)} = [P_r\{X_0 = i\}]_{i \in \mathbf{S}} \text{ and}$$

$\pi^{(n)} = [P_r\{X_n = i\}]_{i \in \mathbf{S}} = [\pi_i^{(n)}]_{i \in \mathbf{S}}$, which is the row vector of probabilities at time n. This initial distribution is needed along with transition probability matrix to understand the chain fully.

Now $\pi^{(n)} = \pi^{(n-1)}\mathbf{P} = \pi^{(n-2)}\mathbf{PP} = \pi^{(n-2)}\mathbf{P}^2$

or $\pi^{(n)} = \pi^{(0)}\mathbf{P}^n \;\; \forall\, n \geq 0.$

The elements of □□ □ □ □ are the elements of unique solution $\pi = \pi\mathbf{P}$ and $\sum \pi_i = 1$

IV. Model development

For the development of the model, the price of the commodity under study was divided in to several intervals, using frequency distribution, which helps to find out the frequencies of its interval constructed. These intervals are distinct and non-overlapping and regarded as the different states of Markov Chain. The daily arrival price of the commodity was marked accordingly, as it is included in the interval. To formulate the transition matrix, the number of transitions from one interval to other interval was counted. This transition frequency matrix provides the transition probability matrix of Markov Chain. The transition probability matrix can be constructed by dividing each class frequency by its total class frequency. The initial state vector is derived by observing the last day's price and using the vector it was possible to find out the highest probability of next day's price.

V. Results and Analysis

Initially the date wise market price of potato from the Lanka Regulated Market was considered for the analysis of the model. The daily arrival price of potatoes from 4th June 2014 to 21st April 2017 i.e. for 478 days was taken for the study. During this period, the price of potatoes per quintal ranges between rupees 550 to 2600. The frequency distribution table with class interval 50 was constructed to establish the intervals that represent the states of Markov Chain. The frequency distribution table is represented in table 1.

Table1. Frequency distribution table

Sl No		BINS	Frequencies
1	Below	550	1
2	„	600	3
3	„	650	1
4	„	700	7
5	„	750	36
6	„	800	21
7	„	850	25
8	„	900	41
9	„	950	49
10	„	1000	22
11	„	1050	10
12	„	1100	17
13	„	1150	0
14	„	1200	1
15	„	1250	0
16	„	1300	0
17	„	1350	1
18	„	1400	12
19	„	1450	4
20	„	1500	22
21	„	1550	0
22	„	1600	8
23	„	1650	4
24	„	1700	26
25	„	1750	8
26	„	1800	13
27	„	1850	2
28	„	1900	34
29	„	1950	0
30	„	2000	9
31	„	2050	2
32	„	2100	61
33	„	2150	0
34	„	2200	10
35	„	2250	1
36	„	2300	10
37	„	2350	0
38	„	2400	15
39	„	2450	0
40	„	2500	0
41	„	2550	0
42	„	2600	4

The seven states of Markov Chain are defined as follows:
C1: the price of potatoes per quintal less than equal to 800 i.e. price<= 800
C2: 800<price<=1100, **C3**: 1100<price<=1400, **C4**: 1400<price<=1700
C5: 1700<price<=2000, **C6**: 2000<price<=2300, **C7**: 2300<price<=2600
The transition frequencies for the price of the potatoes were counted for each interval and represented in Table2.

Table2. Transition Frequency Matrix for Potatoes

	C1	C2	C3	C4	C5	C6	C7	Total
C1	**62**	**4**	**0**	**0**	**0**	**0**	**0**	**66**
C2	**6**	**157**	**1**	**0**	**1**	**0**	**0**	**165**
C3	**0**	**2**	**9**	**3**	**0**	**0**	**0**	**14**
C4	**0**	**1**	**3**	**54**	**6**	**0**	**0**	**64**
C5	**0**	**0**	**0**	**7**	**57**	**2**	**0**	**66**
C6	**0**	**0**	**0**	**0**	**2**	**77**	**4**	**83**
C7	**0**	**0**	**0**	**0**	**0**	**5**	**15**	**20**
								478

The transition probability matrix is constructed by dividing each class frequency by each total class frequency. Thus p_{11} = 62/66=0.09394, p_{12}=4/66=0.0606 and so on. The transition probability matrix for the arrival market price of potatoes is represented in Table3.

Table 3 Transition Probability Matrix

P=		**G1**	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**
	G1	**0.9394**	**0.0606**	**0**	**0**	**0**	**0**	**0**
	G2	**0.0364**	**0.9515**	**0.0061**	**0**	**0.0061**	**0**	**0**
	G3	**0**	**0.1429**	**0.6429**	**0.2143**	**0**	**0**	**0**
	G4	**0**	**0.0156**	**0.0469**	**0.8438**	**0.0938**	**0**	**0**
	G5	**0**	**0**	**0**	**0.1061**	**0.8636**	**0.0303**	**0**
	G6	**0**	**0**	**0**	**0**	**0.0241**	**0.9277**	**0.0482**
	G7	**0**	**0**	**0**	**0**	**0**	**0.2500**	**0.7500**

From the raw data, it was observed that the last day i.e. 478th day's price included in the first interval C1. Thus, the initial probability vector was constructed as

$\pi_{(0)}$= (1 0 0 0 0 0 0)

Now the prediction for 479th -day price by Markov Chain as

$\pi_{(1)} = \pi_{(0)}$*P = (0.9384 0.0606 0 0 0 0 0).

According to this prediction, the probability of the arrival market price of potatoes belongs to the state C1 is highest i.e. there are 94.84% chance of the price of next arrival of potatoes lies in the interval, price<=800. From the raw data, the 479-day arrival price is 800, which is true. The 480-day prediction can be done by calculating

$\pi_{(2)} = \pi_{(1)}$*P = (0.8828 0.1145 0.0004 0 0.0004 0 0).

From this calculation, it is clear that the probability of arrival price of potatoes for the state C1 is the highest. Thus, it can be said that there are 88.28% chance that the next day's price is in the first state and from raw data it is seen that the price of 480th- day is 750. The Table 4 describe the probabilities of predicted interval of price and the actual price of potatoes for 15 arrival dates. From the table it is clear that Markov Chain can be used to predict the price interval of potatoes for short period.

Table 4 Predicted Intervals

Sl no	Arrival Day		Probabilities						Predicted interval	Actual price
		C1	C2	C3	C4	C5	C6	C7		
1	479	0.9384	0.0606	0.0000	0.0000	0.0000	0.0000	0.0000	C1	800
2	480	0.8828	0.1145	0.0004	0.0000	0.0004	0.0000	0.0000	C1	750
3	481	0.8326	0.1625	0.0009	0.0001	0.0010	0.0000	0.0000	C1	725
4	482	0.7872	0.2053	0.0016	0.0004	0.0019	0.0000	0.0000	C1	725
5	483	0.7462	0.2432	0.0023	0.0009	0.0029	0.0001	0.0000	C1	725
6	484	0.7090	0.2770	0.0030	0.0015	0.0041	0.0002	0.0000	C1	750
7	485	0.6754	0.3070	0.0037	0.0024	0.0053	0.0003	0.0000	C1	750
8	486	0.6450	0.3336	0.0043	0.0034	0.0067	0.0004	0.0000	C1	800
9	487	0.6174	0.3572	0.0050	0.0045	0.0081	0.0006	0.0000	C1	650

10	488	0.5923	0.3781	0.0056	0.0057	0.0096	0.0008	0.0001	C1	625
11	489	0.5696	0.3965	0.0061	0.0070	0.0112	0.0011	0.0001	C1	800
12	490	0.5489	0.4128	0.0067	0.0084	0.0127	0.0014	0.0001	C1	800
13	491	0.5301	0.4271	0.0072	0.0099	0.0143	0.0017	0.0002	C1	800
14	492	0.5130	0.4397	0.0077	0.0114	0.0159	0.0020	0.0002	C1	800
15	493	0.4974	0.4508	0.0081	0.0129	0.0175	0.0024	0.0002	C1	800

In comparison of the price of potatoes of the previous day, the price in any specific day may increase, decrease or remain the same. In other words, today's market price can be categorized in three distinct states 'increase', 'decrease' or 'remain same' as compared to yesterday's price. These three states are distinct and non-overlapping and occurrence of one particular day event mainly depends on the occurrence of previous day event. Now comparing today's price with that of the previous day, each arrival price of potatoes can be classified as 'increase', 'decrease', or 'remain same'. Then it is possible to derive a 3x3-transition probability matrix of

Markov Chain whose three states define as
S1: the price of potatoes for any specific day is less than the previous day's price
S2: the price of potatoes for any specific day is greater than the previous day's price
S3: the price of potatoes for any specific day is remain same as the previous day's price
The transition frequency matrix for the three states are presented in Table 5

Table 5 Transition Frequency Matrix

	S1	S2	S3	**Total**
S1	15	22	36	**73**
S2	15	9	35	**59**
S3	39	30	276	**345**
Total	**69**	**61**	**347**	**477**

The transition probabilities are calculated as p_{11}= 15/73= 0.2054, p_{12}= 22/73=0.3014 ... p_{33}=276/345=0.8000. The transition probability matrix is represented in Table 6

Table 6 Transition Probability Matrix

P=		S1	S2	S3
	S1	0.2054	0.3014	0.4932
	S2	0.2543	0.1525	0.5932
	S3	0.1130	0.0870	0.8000

The initial probability vector $\pi_{(0)}= (\pi_1, \pi_2, \pi_3)$ for price of the potatoes are derived as follows
π_1=69/477= 0.1447 π_2 = 61/477= 0.1279 π_3=347/477=0.7275
Now with the help of this probability vector, the next day's price of potatoes can be predicted. The probability vector for 479th day will be-
$\pi_{(1)}= \pi_{(0)}*P$ = (0.1444 0.1264 0.7292)

For 480 day the probability vector will be-
$\pi_{(2)}= \pi_{(1)}*P$ = (0.1442 0.1262 0.7295)

From the calculation, it is noticed that the state remain same (S3) has the highest probability for both the days, implies that the market price of potatoes will remain unchanged in these days i.e. there are 72.92% and 72.95% chance that the price of potatoes remain unchanged for 479 th and 480 th day respectively. This prediction of future price is almost indistinguishable with the real situations. The n-step transition probability matrix gives the idea of the long-term behaviour of the market price of potatoes. The elements of the probability matrix P^n give the probability of price, which is now in a particular state will be in another state after n-steps. The higher order transition probabilities are calculated by raising the power of the matrix P.

P^2=		S1	S2	S3	P^4=		S1	S2	S3

	S1	0.1746	0.1508	0.6747		S1	0.1459	0.1281	0.7261
	S2	0.1580	0.1515	0.6904		S2	0.1453	0.1275	0.7272
	S3	0.1357	0.1169	0.7473		S3	0.1436	0.1256	0.7308
P^5=		S1	S2	S3	P^6=		S1	S2	S3
	S1	0.1446	0.1267	0.7288		S1	0.1443	0.1263	0.7295
	S2	0.1444	0.1265	0.7291		S2	0.1442	0.1263	0.7295
	S3	0.1440	0.1260	0.7300		S3	0.1441	0.1261	0.7298
P^7=		S1	S2	S3	P^8=		S1	S2	S3
	S1	0.1442	0.1262	0.7296		S1	0.1442	0.1262	0.7297
	S2	0.1442	0.1262	0.7296		S2	0.1442	0.1262	0.7297
	S3	0.1441	0.1262	0.7297		S3	0.1441	0.1262	0.7297
P^9=		S1	S2	S3	P^{10}=		S1	S2	S3
	S1	0.1441	0.1262	0.7297		S1	0.1441	0.1262	0.7297
	S2	0.1441	0.1262	0.7297		S2	0.1441	0.1262	0.7297
	S3	0.1441	0.1262	0.7297		S3	0.1441	0.1262	0.7297

The above higher order transition probability matrices, makes it clear that when the power of the matrix increase the row elements of the matrix approach to some constant probabilities. After a period of 10 trading days, the matrix attains the state of equilibrium or a steady state position where each row of the matrix is identical. From this calculation, it can be concluded that if the market price of potatoes initially in any one of the state down (S1), up (S2) or remain same (S3) then it will attain the state down with probability 0.1441. If the market price of potatoes in any one of the three states then it will reach the state up (S2) with probability 0.1262, and similarly irrespective of initial state the market price will reach the state remain same (S3) with probability 0.7297. Thus, it can be said that there are approximately 14.41% chance of price of the potatoes will decrease, 12.62% chance of price increase and 72.97% chance of price remain same. This indicates that the market price of potatoes will be stable regardless of its present price.

VI. Conclusion

By applying Markov Chain model in the study, attempts have been made to predict the arrival market price interval of potatoes of Lanka Regulated market of Nagaon District. The forecasting was done for the short period of consecutive 15 days. The prediction made for the price interval by the model was identical to real situations. To study the long term behaviour of price of potatoes, the steady state probabilities for three different states ‘increase’, ‘decrease’ and ‘remain same’ were calculated and found that state ‘remain same’ had the highest probability. This implies that the price of potatoes remain unchanged in near future. In the real situation the fluctuation of price of potatoes influenced by many factors, therefore, the forecasting made for the future price by any one method may not be adequate but the results obtained by Markov Chain model was quite encouraging.

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