International Journal of Trends in Mathematics Education Research
Vol. 5, No. 4 (2022), pp. 417~421
ISSN 2621-8488 (online)
DOI: https://doi.org/10.33122/ijtmer.v5i4.203

SAINTIS publishing

Research Article

Implementation of markov chain in predicting regeneration agricultural in Pasuruan district

Abdul Wahid✉**, Ayik Pusakaningwati, M. Imron Masud**

Program of Study Industrial Engineering, Universitas Yudharta Pasuruan, Indonesia, 67162
✉Corresponding Author: wahid@yudharta.ac.id

Received: 28 August 2022 *Revised: 26 October 2022* *Accepted: 20 November 2022* *Available online: 30 December 2022*

ABSTRACT

The Industrial Era 5.0 has made many positive and negative changes in various sectors, one of the negative impacts is the agricultural sector related to the lower portion of young farmers so that it must be a serious concern for the government in future agricultural development programs, especially in agricultural base areas such as in Pasuruan Regency. This situation encourages the importance of finding solutions to realize the regeneration of farmers. This study aims to analyze the transformation between generations of agricultural workers in Pasuruan Regency through the Marcov Chain model approach. The final result of this study is the analysis of transformations between generations of agricultural workers in Pasuruan Regency so that it can be used as a basis for formulating future policies for better future generations of agriculture.

Keywords: markov chain; farmer regeneration; transformation

1. INTRODUCTION

Indonesia is a country that has abundant natural resources, so it is necessary to optimize one of them in the agricultural sector so that adequate and qualified human resources (HR) are needed. One of the problems of agricultural development in Indonesia today is related to the adequacy of human resources. The interest of the younger generation to engage in agriculture is decreasing. The tendency of young farmers to leave the agricultural sector is influenced by the rate of urbanization and migration (Anwarudin et al., 2020). The push factor (push factor) is the mobility of young farmers from rural to urban areas and prefers to become workers abroad due to weak socio-economic living conditions and limited education (Arvianti & et al., 2015)(Fikriman, 2017).

Families are unable to fulfill their daily needs, so there is a tendency to migrate to cities and become migrant workers. This resulted in the shift of work of young farmers to the non-agricultural sector (factory workers or service sector workers). Disinterest in the world of agriculture which can hinder economic development due to higher and more certain income than working in the agricultural sector (Susilowati, 2016).

The Industrial Period 5.0, which was marked by the development of technology, fascinated people so that not a few left their farming jobs and turned to industries that were considered promising and even sold many of their fields, people thought that the agricultural world was no longer promising, resulting in reduced supply of agricultural products resulting in imports. and the high cost of agricultural products, with this phenomenon there is a need for research related to the transformation between generations of agricultural workers in Pasuruan Regency as an effort to analyze the transformation between generations of agricultural workers so that the results of this research can be used as a basis for formulating future policies for better future generations of agriculture (Yodfiatfinda, 2018)(Adisel, 2015).

Markov Chains

Markov Chains is a mathematical technique commonly used for modeling various systems and business processes (Holmes et al., 2022). This technique can be used to predict future changes in dynamic variables on the basis of changes in these dynamic variables in the past. This technique can also be used to analyze future events mathematically (Rens et al., 2022)(Vourdas, 2022). The Markovm Chain Model was invented by a Russian expert named A.A. Markov in 1906 (Mas'ud, 2019).

The Markov process is a stochastic process $\{X_t, t = 0, 1, 2, \ldots\}$. Possible value of X_t is finite or countable. If $X_t = i$, then the process is said to be at state-i. When the process is at state-i then it will move to state-j with opportunity Pij, when Pij does not depend on t. In other words, if:

$$P\{X_{t+1} = j \mid X_t = i, X_{t-1} = i_{t-1}, \ldots, X_1 = i_1, X_0 = i_0\}$$
$$= P\{X_{t+1} = j \mid X_t = i\} = P_{ij} \quad (1)$$

For all *state* $i_0, i_1, \ldots, i_{t-1}, i, j$, and all $t \geq 0$, Then the stochastic process is called *Stasioner Markov Chain*. From Equation (1) it can be interpreted that: for a Markov chain, the probability of future events X_{t+1}, just depends on what's happening now X_t. This is called a Markovian trait. This Markovian trait states that the probability of a future "state", provided the past "state", and *state* at the moment $X_t = i$, is *independent* to events in the past and only depends on the current state (Yakovyna & Symets, 2021)(Sánchez-Barroso et al., 2021).

Transition Opportunity Matrix

One of the main characteristics of the Markov chain is its transition opportunities. The transition probability describes the probability of moving from one state to another (Khadijat et al., 2021). In other words, it describes the probability of a process being in one state if the state of the process is known at one time in advance (Jia et al., 2021)(Sylvester, 2022). Mathematically, the probability of the transition can be written as follows:

$$P^{t,t+1}\{X_{t+1} = j \mid X_t = i\}, \quad n \geq 0, \quad i, j \geq 0 \quad (2)$$

The conditional probability of Equation (2) is said to be the transition probability. With *i* and *j* each represents the current state of the process *t* and *t*+1. If a Markov chain is known $\{X_t = t = 0, 1, \ldots\}$ with space *state* $\{0, 1, \ldots, s\}$, then the probability of the system is in *state-i* on a *state-j* in the previous observation is denoted by P_{ij} and is called the probability of the transition from *state-i* to *state-j*. Matrix $P = [P_{ij}]$ is called the Markov chain transition probability matrix. *State space* of the Markov chain is usually expressed as a non-negative integer $\{0, 1, 2, \ldots\}$. The probability that X_{t+1} It is in *state-j* if known X_t it is in *state-i* then it is called the transition probability 1 steps, denoted by $P^{t,t+1}$. The 1-step transition probability is independent of the time variable *n* is called the stationary 1-step transition probability denoted by P_{ij}. For each *s* usually the transition probability P_{ij} can be written in the form of a transition matrix *P*:

$$P = \begin{array}{c} \\ 0 \\ 1 \\ \vdots \\ s \end{array} \begin{array}{c} \begin{array}{cccc} 0 & 1 & \ldots & s \end{array} \\ \begin{bmatrix} P_{00} & P_{01} & \cdots & P_{0s} \\ P_{10} & P_{11} & \cdots & P_{1s} \\ \vdots & \vdots & \ddots & \vdots \\ P_{s0} & P_{s1} & \cdots & P_{ss} \end{bmatrix} \end{array}$$

P = [Pij] is called the transition probability matrix of a stationary process. If the number of states is finite, then the transition probability matrix is square and is called the transition probability matrix of a homogeneous Markov chain. The elements of the transition probability matrix satisfy:

1. $P_{ij} \geq 0$, for $i, j = 0, 1, 2, \ldots$
2. $\sum_{j=0}^{\infty} P_{ij} = 1$, for $i = 0, 1, 2, \ldots$

The Chapman-Kolmogorov Equation

According to Ross (2007), the Chapman-Kolmogorov Equation provides a way to calculate the n-step displacement probability (transition probability). Suppose Pij states the probability that the n-step transition of a process in state i will be in state -*j*.

$$P_{ij}^n = P\,(X_{n+m} = j \mid X_m = i), \qquad n \geq 0;\ i, j \geq 0$$

The Chapman-Kolmogorov equation is a tool for calculating the probability of an n-step transition:

$$\begin{aligned} P_{ij}^n &= P\{\, X_{n+m} = j \mid X_m = i\} \\ &= \sum_{k=0}^{\infty} P\{X_{n+m} = j, X_{m+1} = k \mid X_m = i\} \qquad (3) \\ &= \sum_{k=0}^{\infty} P\{X_{m+1} = k \mid X_m = i\}\, P\{X_{n+m} = j \mid X_{m+1} = k, X_m = i\} \\ &= \sum_{k=0}^{\infty} P\{X_{m+1} = k \mid X_m = i\}\, P\{X_{n+m} = j \mid X_{m+1} = k\} \\ &= \sum_{k=0}^{\infty} P_{ik}\, P_{kj}^{n-1} \end{aligned}$$

It appears that Equation (3) is a product of two matrices. If P^n mark matrix P_{ij}^n transition opportunities *n*- steps, then Equation (3) state that:

$$P^{(n)} = P^{(n-1)} \cdot P \qquad (4)$$

Steady State

The long-term behavior of a Markov process is characterized by its independence from initial state from the system. In this case, the system is said to have reached a steady state. Steady state conditions are conditions at a certain period in which the transition probability matrix has reached a steady state (equilibrium). If the transition probability matrix changes due to some changes on the part of the company or other reasons, then we must use a new transition probability matrix and calculate a new equilibrium market share matrix (Siswanto, 2007).

According to Ross (2007), in a Markov chain with finite state space, at least one state is recurrent. Consequently, if state-i is recurrent and i communicates with j, then state-j is also recurrent. As a result, all irreducible states in the Markov chain with finite state space are recurrent. In addition, all recurrent states in a Markov chain with finite state space are positive recurrent.For irreducible, positive recurrent and aperiodic Markov chains ($\lim_{n\to\infty} P_{ij}^n$ exists and is independent of *i*), $\pi_j = \lim_{n\to\infty} P_{ij}^n$ is the unique non-negative solution of $\pi_j = \sum_{i=0}^{\infty} \pi_i P_{ij}$, $j \geq 0$ when $\sum_{j=0}^{\infty} \pi_j = 1$. Steady state conditions occur if the Markov process lasts a long time, i.e. when $\lim_{n\to\infty} P_{ij}^n = \pi_j$, when π_j is the limiting probability distribution $\pi = (\pi_1, \pi_2, \ldots, \pi_s)$ when $\pi_j > 0$ for $j = 0,1,2,\ldots,s$ and $\sum_{j=1}^{s} \pi_j = 1$. A Markov process is in state-j at time *n*, $P\{X_n = j\}$, which if decomposed into:

$$
\begin{aligned}
P\{X_n = j\} &= \sum_{i=0}^{\infty} P\{X_n = j, X_0 = i\} \\
&= \sum_{i=0}^{\infty} P\{X_n = j \mid X_0 = i\}\, P\{X_0 = i\} \\
&= \sum_{i=0}^{\infty} P_{ij}^n\, P\{X_0 = i\}
\end{aligned}
$$

In general, for a regular transition probability matrix *P*, then there is convergence and the above equation becomes Equation 5. Convergence means that for a long period of time $(n \to \infty)$, The probability of obtaining a Markov chain is at staten-*j* is π_j regardless of the initial state that is when 0.

$$
\begin{aligned}
\lim_{n\to\infty} P\{X_n = j\} &= \lim_{n\to\infty} \sum_{i=0}^{\infty} P_{ij}^n\, P\{X_0 = i\} \\
&= \sum_{i=0}^{\infty} \lim_{n\to\infty} P_{ij}^n\, P\{X_0 = i\} \qquad (5) \\
&= \sum_{i=0}^{\infty} \pi_j\, P\{X_0 = i\} \\
&= \pi_j \sum_{i=0}^{\infty} P\{X_0 = i\} \\
&= \pi_j \,.\, 1 \\
&= \pi_j
\end{aligned}
$$

State Vector

According to Howard and Rorres (2005), *state vector* for an observation on a Markov chain having *k* state is a line vector $\boldsymbol{w}$ where is componen-*i*, that is $\boldsymbol{w}_i$ is the probability that the system is in state -*i* at the time. *State* on the Markov chain which is written in the form of a vector called the state vector. The state vector for an observation on a Markov chain with $\boldsymbol{w}(t)$ *state* is the row vector $\boldsymbol{w}$. Can be written:

$$\boldsymbol{w} = [w_1, w_2, \ldots, w_i]$$

If *P* is a Markov chain transition matrix and $\boldsymbol{w}^{(t)}$ is the state vector at the th observation -*t*, so:

$$\boldsymbol{w}^{(t+1)} = P\ \boldsymbol{w}^{(t)} \qquad (6)$$

and in general:

$$\boldsymbol{w}^{(1)} = P\ \boldsymbol{w}^{(0)}$$

$$\boldsymbol{w}^{(2)} = P^2\ \boldsymbol{w}^{(0)} = P\, \boldsymbol{w}^{(1)}$$

$$\boldsymbol{w}^{(3)} = P^3\ \boldsymbol{w}^{(0)} = P\, \boldsymbol{w}^{(2)}$$

$$\boldsymbol{w}^{(t)} = P^t\ \boldsymbol{w}^{(0)} = P\, \boldsymbol{w}^{(t-1)}$$

From Equation 6, initial state vector $\boldsymbol{w}^0$ and the transition matrix *P* will determine $\boldsymbol{w}^{(t)}$

2. RESEARCH METHOD

This research was conducted on a generation of agricultural workers in Pasuruan Regency who are engaged in agriculture. The location selection is purposive with the consideration that farming is one of the economic business units of the Pasuruan Regency community, but it still hasn't shown positive developments that are better from year to year and even generations tend to decline who switch to the industrial world.

Data was collected through interviews, direct observation/observation, and documentation. The data collected in this study consisted of two kinds, namely primary data and secondary data. Primary data is data obtained through direct interviews with generations of farmers based on a list of previously prepared questions. While secondary data which is supporting research data obtained from institutions or agencies related to research.

The data collected in the data collection stage needs to be processed first. The goal is to simplify all data collected and presented in a good and neat arrangement for later analysis. Data processing is needed to translate the figures obtained, then processed and analyzed using the Markov chain approach.

3. RESULTS AND DISCUSSION

Based on the questionnaires collected from the work of the Pasuruan district community as respondents that there are four groups of types of work that are mostly carried out by agriculture, entrepreneurs, factory workers, and others. This research involved 150 respondents with 3 missing data. In the first period of the study, 44 respondents chose to be farmers, 32 respondents chose to be entrepreneurs, 34 respondents chose to be factory workers, and 37 respondents chose to be other workers (other than farmers, entrepreneurs, and factory workers). In the second period, it showed the following changes, from farmer voters as much as 77% of farmer respondents still chose to become a farmer, 9% of farmer respondents wanted to change jobs to become an entrepreneur, 11% of farmer respondents wanted to change jobs to become factory workers, and 3% of respondents farmers want to change jobs to other jobs (besides farmers, entrepreneurs, and factory workers).

Meanwhile, from the voters of entrepreneurial workers, 4% of entrepreneurial respondents wanted to change jobs to become farmers, 73% of entrepreneurial respondents still chose to be an entrepreneur, 12% of entrepreneurial respondents wanted to change jobs to become factory workers, and 11% of entrepreneurial respondents wanted to change jobs to other jobs. (Besides farmers, entrepreneurs, and factory workers). Meanwhile, from the voters of factory workers as much as 14% of factory workers respondents of entrepreneurial respondents want to change jobs to become farmers, 27% of entrepreneurial factory workers respondents want to change jobs to become entrepreneurs, 53% of factory workers respondents still choose to become factory workers, and 6% of factory worker respondents want to change jobs to other jobs (besides farmers, entrepreneurs, and factory workers). Meanwhile, from the voters of other workers (besides farmers, entrepreneurs, and factory workers) as many as 3% of other worker respondents want to change jobs to become farmers, 22% of other worker respondents want to change jobs to become entrepreneurs, 9% of other worker respondents want to change jobs to become workers. factories, and 66% of other worker respondents still choose to become other workers (besides farmers, entrepreneurs, and factory workers), as shown in **Table 1**.

Table 1. Transition matrix

	Initial	Farmer	Entrepreneur	Factory Employee	Others
Farmer	0,30	0,77	0,09	0,11	0,03
Entrepreneur	0,22	0,04	0,73	0,12	0,11
Factory employee	0,23	0,14	0,27	0,53	0,06
Other	0,25	0,03	0,22	0,09	0,66

The results of the respondents were then entered in the POM software for windows 3 and the results were as shown in Figure 2, where in period 2 and period 3 there was a change in each state where the agricultural sector experienced a significant decline where in period 1 to period 2 it decreased by 16% and from period 2 to period 3 decreased by 11%.

(untitled) Solution

	State 1	State 2	State 3	State 4
End of Period 1				
Farmer	,77	,09	,11	,03
Entrepreneur	,04	,73	,12	,11
Factory employee	,14	,27	,53	,06
Other	,03	,22	,09	,66
End prob (given initial)	,28	,30	,20	,21
End of Period 2				
Farmer	,61	,17	,16	,06
Entrepreneur	,08	,59	,17	,16
Factory employee	,19	,37	,33	,11
Other	,06	,33	,14	,47
End prob (given initial)	,26	,35	,19	,19
End of Period 3				
Farmer	,50	,24	,18	,09
Entrepreneur	,11	,52	,18	,18
Factory employee	,21	,40	,25	,14
Other	,10	,39	,16	,35
End prob (given initial)	,25	,37	,19	,19

Figure 1. Multiplications

4. CONCLUSION

The results of the respondents were then entered in the POM software for windows 3 and the results were as shown in Figure 2, where in period 2 and period 3 there was a change in each state where the agricultural sector experienced a significant decline where in period 1 to period 2 it decreased by 16% and from period 2 to period 3 decreased by 11%.

ACKNOWLEDGEMENTS

The researcher would like to thank the Universitas Yudharta Pasuruan and the Ministry of Education, Research and Technology of the Republic of Indonesia who have supported this research both from funds and others so that this research was carried out smoothly.

AUTHOR'S CONTRIBUTIONS

The authors discussed the results and contributed to from the start to final manuscript.

CONFLICT OF INTEREST

There are no conflicts of interest declared by the authors.

REFERENCES

Adisel. (2015). *Transformasi Masyarakat Petani Dari Tradisional ke Modern*.

Anwarudin, O., Sumardjo, S., Satria, A., & Fatchiya, A. (2020). Process and Approach to Farmer Regeneration Through Multi-strategy in Indonesia. *Jurnal Penelitian dan Pengembangan Pertanian*, *39*(2), 73. https://doi.org/10.21082/jp3.v39n2.2020.p73-85

Arvianti, E. Y., & et al. (2015). Minat Pemuda Tani Terhadap Transformasi Sektor Pertanian Di Kabupaten Ponorogo. *Journal Buana Sains*, *15*(2), 181–188.

Fikriman. (2017). Transformasi Pertanian dan Pembangunan Pedesaan. *urnal Agri Sains*, *1*(2), 1–12.

Holmes, B., McHale, I. G., & Żychaluk, K. (2022). A Markov chain model for forecasting results of mixed martial arts contests. *International Journal of Forecasting*, *xxxx*. https://doi.org/10.1016/j.ijforecast.2022.01.007

Jia, X., Wang, H., Xu, L., Wang, Q., Li, H., Hu, Z., Li, J., & Ouyang, M. (2021). Constructing representative driving cycle for heavy duty vehicle based on Markov chain method considering road slope. *Energy and AI*, *6*, 100115. https://doi.org/10.1016/j.egyai.2021.100115

Khadijat, A., Anthony, T., Ganiyu, O., & Bolarinwa, S. (2021). Forest cover change in Onigambari reserve, Ibadan, Nigeria: Application of vegetation index and Markov chain techniques. *Egyptian Journal of Remote Sensing and Space Science*, *24*(3), 983–990. https://doi.org/10.1016/j.ejrs.2021.08.004

Mas'ud, M. I. (2019). *Riset Operasi 1*. Yudharta Press.

Rens, M. T. H., Bea-Bragado, I., & Bea, J. A. (2022). Markov chain based non-linear fatigue damage accumulation model. *Probabilistic Engineering Mechanics*, *68*(February), 103250. https://doi.org/10.1016/j.probengmech.2022.103250

Sánchez-Barroso, G., González-Domínguez, J., García-Sanz-Calcedo, J., & Sanz, J. G. (2021). Markov chains estimation of the optimal periodicity for cleaning photovoltaic panels installed in the dehesa. *Renewable Energy*, *179*, 537–549. https://doi.org/10.1016/j.renene.2021.07.075

Susilowati, S. H. (2016). Fenomena Penuaan Petani dan Berkurangnya Tenaga Kerja Muda serta Implikasinya bagi Kebijakan Pembangunan Pertanian. *Forum penelitian Agro Ekonomi*, *34*(1), 35. https://doi.org/10.21082/fae.v34n1.2016.35-55

Sylvester, J. (2022). The cover time of a (multiple) Markov chain with rational transition probabilities is rational. *Statistics & Probability Letters*, *187*, 109534. https://doi.org/10.1016/j.spl.2022.109534

Vourdas, A. (2022). Markov chains with doubly stochastic transition matrices and application to a sequence of non-selective quantum measurements. *Physica A: Statistical Mechanics and its Applications*, *593*, 126911. https://doi.org/10.1016/j.physa.2022.126911

Yakovyna, V., & Symets, I. (2021). Reliability assessment of CubeSat nanosatellites flight software by high-order Markov chains. *Procedia Computer Science*, *192*, 447–456. https://doi.org/10.1016/j.procs.2021.08.046

Yodfiatfinda. (2018). Meningkatkan Minat Generasi Muda di Sektor Pertanian untuk Mewujudkan Ketahanan Pangan. *Lembaga Ketahanan Nasional Republik Indonesia*, 1–57. http://info.trilogi.ac.id/repository/assets/uploads/AGB/eeb6f-meningkatkan-minat-generasi-muda-di-sektor-pertanian-untuk-mewujudkan-ketahanan-pangan_b2.pdf