MARKOV CHAIN ANALYSIS FOR LAND SHIFTING IN INDIA AND MAHARASHTRA

Abstract:

Dynamics of Agriculture resembles the history of agriculture in India which examines the emphasizing significance to the nation's legacy, culture and civilization. India's agriculture changed after independence from a food-scarce nation to one that exports food this comes true primarily due to the result of scientific advancements. The present study is based on the secondary data with the use of Markov Chain analysis to ascertain land-shifting patterns in Indiaand Maharashtra state. Changes in land use brought on by agriculture, urbanization and environmental factors significantly impact resource management and sustainability. We build a Markov Chain model with secondary land utilization data from government reports to measure the transition probabilities between various land use categories over time. This study reveals important trends in land conversion, most notably the growth of urban areas at the expense of forested and agricultural areas. Thepredictive abilities of model highlight the significance of well-informed policy-making for sustainable land management by offering insights into potential future land use scenarios.

Keywords:

Land shifting, Markov chain analysis, stochastic model,Transition Probability Matrix

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1. Introduction:

One of the most important components of environmental and economic changes in any region is the dynamic shifting of land cover and use over time, also known as land shifting(Patel et al., 2019). For sustainable development and efficient land management in India, a country known for its wide range of landscapes, particularly in Maharashtra, a notable state with sizable agricultural and urban sectors, an understanding of these transitions is essential.The rapid urbanization, industrialization, and agricultural transformation that both Maharashtra and India are experiencing calls for a more accurate analysis and prediction of land use changes. While traditional land use analysis methods are often inadequate in capturing the probabilistic nature of these transitions, Markov Chain analysis proves to be invaluable in this regard (Mirkatouli J*et al.*, (2015). The Markov Chain model, grounded in probability theory, provides a strong framework for examining and projecting the likelihood of transitions between various land use states over time.

This study examines land shifting patterns in India and Maharashtra using Markov Chain analysis. This study attempts to provide a thorough understanding of how land use categories evolve, the probabilities associated with these changes, and their implications for future land management by using past land use data and applying Markov Chain models.The findings of this study are anticipated to make a substantial contribution to the areas of urbanization and land management, providing valuable information to researchers, planners, and policymakers who are interested in the sustainable development of Maharashtra and India.

2. Data Sources and Methodology:

The annual secondary data on Land Utilization for the period from 2011 to 2022 for India and Maharashtra were used for Markov Chain Analysis.

The steps involved in conducting a Markov Chain analysis, such as creating transition matrices and estimating state probabilities, are explained in detail in the following sections. The study will also go over the findings, emphasizing significant trends and patterns in land use transitions.

2.1<u>Markov Chain Analysis</u>:

According to Russian mathematician Andrey Markov, A Markov chain or Markov process is a stochastic model describing a sequence of possible events in which the probability of each event depends only on the state attained in the previous event.

P_{ij}= P [X_{m+1}= j | X_m = i]

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P_{ij}^{n} = P [X_{n+m} = j | X_m = i]

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This will give us the **Transition Probability Matrix** as a result.

2.2Transition Probability Matrix:

A matrix is said to be a Transition Probability Matrix if it satisfies the following two conditions:

1) All elements of the matrix must lie between 0 to 1.
2) Each row sum of the matrix must be 1.

3. Result and discussion:

3.1 Land shifting in India:

Table 1.Transition Probability Matrix of Land Shifting in India

	Forest	Uncultivable	Fallow	Excluding Fallow	Net Sown	Sown more than once	Total Cropped	Cultivable	Cultivated
Forest	0.57	0.21	0.22	0	0	0	0	0	0
Uncultivable	0.14	0.57	0	0	0.29	0	0	0	0
Fallow	0	0	0	0	0	0	0	1	0
Excluding Fallow	0.12	0.7	0	0.8	0	0.03	0	0	0
Net Sown	0	0	0	0	0.76	0	0	0.24	0
Sown more than once	0	0	0	0	0	0.83	0.17	0	0
Total Cropped	0	0	0	0	0	0.05	0.95	0	0
Cultivable	0.12	0	0.05	0.05	0.11	0	0	0.67	0
Cultivated	0	0	0	0	0	0	0	0	1

Table 1 shows that cultivated land shows 100 per cent of area retention in Land shifting in India, indicating that all cultivated land remains within its category with no changes in its area share.The total cropped area has 95 per cent of area retention showing stability in its proportion and lost 5 per cent share of the area to sown more than once area, reflecting a shift towards more intensive cropping practices.The area sown more than once retained 83 per cent share of the area means this category holds a significant share and lost 17 per cent to the total cropped area, suggesting that while multiple cropping areas are significant, there's also a substantial integration or overlap with the total cropped area.

Forest land retained 57 per cent of the share of an area even though it lost 21 per cent share of the area to Uncultivable land and 22 per cent of the share of the area to Fallow land. Also, it gains 14 per cent of the share of area from uncultivable land and 12 per cent each from area excluding fallow land and cultivable land.This reflects a complex interaction where forest land loses a considerable portion to other land categories but also sees gains from various sources, indicating a dynamic equilibrium.

Uncultivable land retained 57 per cent share of the area and lost 14 per cent and 29 per cent share of the area to Forest and Net sown area respectively.Suggesting that while a significant portion remains uncultivable, some of it transitions to other uses, particularly net sown area.Net sown area retained 76 per

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cent share of the area and lost 24 per cent to cultivable land.This indicates that a significant portion of the land previously categorized as net sown is being reallocated or reassigned to cultivable land.

3.2 Land shifting in Maharashtra:

Table 2. Transition Probability Matrix of Land Shifting in Maharashtra

	Forest	Uncultivable	Fallow	Excluding Fallow	Net Sown	Sown more than once	Total Cropped	Cultivable	Cultivated
Forest	0.71	0	0.29	0	0	0	0	0	0
Uncultivable	0	0.74	0	0	0	0.26	0	0	0
Fallow	0	0.18	0.42	0.40	0	0	0	0	0
Excluding Fallow	0	0.11	0	0.36	0	0	0.53	0	0
Net Sown	0	0	0	0	0	0	0	0.06	0.94
Sown more than once	0	0	0	0	0	0.87	0.13	0	0
Total Cropped	0.06	0.01	0	0.02	0	0	0.91	0	0
Cultivable	0.01	0	0	0	0	0	0	0.95	0.04
Cultivated	0	0	0	0	0.92	0	0	0	0.08

From Table 2 we can see that, Cultivable land has 95 per cent of area retention indicating a high degree of stability in land classified as cultivablein Land shifting in Maharashtra. Cultivable land retentionshows that most of the land classified as cropped remains stable while it lost a 4 per cent share of the area to cultivated land and a 1 per cent share of the area to forest land,indicating that some cultivable land is reclassified or repurposed, but the majority remains in this category.The total cropped area retained a 91 per cent share of the area and it lost 6 per cent, 2 per cent and 1 per cent share of the area to forest land, area excluding fallow land and uncultivable land respectively.Area sown more than once retained 87 per cent share of the area meaning a substantial portion of this land remains as multiple cropping zones while it lost 13 per cent share of the area to total cropped areareflecting a significant overlap or transition between these categories.

Forest land retained 71 per cent of the share of the area even though it lost 29 per cent of the area to Fallow land,suggesting that a significant portion of forest land is being converted or reclassified as fallow land, which might reflect a change in land use or natural processes affecting forest cover.

Uncultivable land retained 74 per cent share of the area and lost 26 per cent share of the area to Sown more than once areaindicating that some land previously categorized as uncultivable is now being utilized for multiple cropping, reflecting a shift in land use or improved land management practices.

4. Conclusion:

The analysis of land shifting in India and Maharashtra reveals notable stability across various land categories. In India, cultivated land retains 100 per cent of its area share in land shifting, while the total

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cropped area has 95 per cent retention indicating a trend towards more intensive cropping practices. The area sown more than once suggesting a significant overlap with the total cropped area. Forest land shows a complex interaction in which forest land experiences gains from multiple sources while also losing a significant amount to other land categories, pointing to a dynamic equilibrium. Some uncultivable land transitions to other uses, particularly net sown areas. The net sown area indicates a significant portion of land being reallocated to cultivable land. In Maharashtra, cultivable land has high stability. Most cropped land remains stable with a 4 per cent share lost to cultivated land and 1 per cent to forest land. Some cultivable land is reclassified but the majority remains in this category. The total cropped area retained 91 per cent. Area sown more than once with a significant portion remaining as multiple cropping zones. Forest land retained 71 per cent of the area, while a 29 per cent share was lost to fallow land. Uncultivable land indicates a shift in land use or improved management practices.

Overall, the findings reflect a stable agricultural environment in both India and Maharashtra with high retention rates and a trend toward more intensive cropping practices, with a noticeable ability for proper land use management. However, the dynamic interactions between forest land and agricultural areas require ongoing monitoring to balance agricultural development with environmental sustainability.

Disclaimer (Artificial Intelligence):

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of manuscripts.

5. References:

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