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# Application of Markov Chain process in forcasting the adoption of an Oil Palm seed technology in Nigeria

By

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Abstract

Attempts have been made in this study to project the future adoption trends of an improved oil palm seed variety in Nigeria, using a first order Markov chain process. Farmers were classified into six different adoption categories based on the percentage of their total cultivated land under the improved seed variety during the 1982 and 1983 planting seasons.

The results show that the adoption rate will be 48 percent in 1985 and involve 14,906 farmers in varying degrees. By 1995, the adoption index is predicted to reach 70.6 percent and will involve 20,474 farmers.

## Introduction

Adoption can be viewed as the mental process which an individual passes through in deciding to use an innovation. For conceptual purpose, the adoption precess is broken down into five stages viz. awareness, interest, trial, evaluation and adoption (Rogers, 1962). Innovations themselves have characteristics which aid or militate against their adoption such as relative advantage, compatibility, complexity, divisibility and communicability (Grilliches, 1957).

Rogers (1962) classified all individuals in a social system into five categories of innovateness according to their time position when they first began using an innovation. These are innovators (4 per cent), early adopters (12 per cent), early majority (34 per cent) late majority (34 per cent and laggards (16 per cent). He also deduced that innovateness is correlated with such socio-economic variables as personal characteristics, communication behaviours, and social relationships of the individual.

Nigeria is currently searching for the most appropriate policy instruments to stimulate the adoption of modern agricultural inputs, especially high yielding varieties of seeds like oil palm. The determination of the adoption rates of these inputs will be very useful in guiding their multiplication and procurement.

There is evidence that Nigerian farmers are receptive to technological change. However, except for a few studies such as Falusi (1976), most previous studies on adoption in Nigeria have been conducted by extension specialists and sociologists who have attempted to explain adoption rates by highly qualitative methods without actually attempting to predict future trends in the adoption of these innovations. As rightly noted by Feder and Silberman (1981), most adoptions cannot be categorised

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simply as 'adoption' or 'non-adoption' since adoption takes place by degree. For example, farmers using a high yielding seed variety may devote different proportions of their land, ranging from 0 to 100 per cent, to the crop so that adoption/non-adoption does not provide much information about the farmers' behaviour. Similarly, a farmer may be applying small or large amounts of fertilizer per hectare. Infact, major technological issues relate to the extent and intensity of use at the individual farm level, rather than to the initial decision to adopt a new practice. The implication is that adoption cannot be adequately represented by a dichotomous qualitative variable in most cases.

The objective of this paper is to analyse the extent of adoption of oil palm seed technology by Nigerian small holder farmers with a view to predicting future adoption trends, using the Markov chain process. The Markov chain process employed here is the first-order analytical model based on the assumption of inter-temporal constancy of the transition probability matrix.

## The Methodology

### 2.1 *The Model:*

Let

ij = 1,2,3,. . . .k represent the different stages of adoption or adoption groups.

$t_0t_1t_2$,. . . tm be the m years or periods under consideration,

$N^0$ = the total number of farmers belonging to the k different stages of adoption at the initial period to; and

$n^0{}_{i.}$ (i = 1,2,. . .k) the number of farmers belonging to the i-th adoption group at the initial period, to, such that $\sum_{i=1}^{k} n_i{}^0. = N^0$ (1)

The adoption groups here are defined in terms of the proportion of their total cultivated area under high yielding oil palm seed variet.

If this same $N^0$ group of farmers is observed during another time period, $t_1$, it will be seen that in the time interval between the two periods, some farmers who originally belonged to a particular adoption group during the initial period might have moved to higher adoption groups, reamined in the same group or moved to lower groups. The possible pattern of movement between the two time periods is shown in table 1. In the table, nij refers to farmers in the i-th adoption group at the initial period, to, who have moved to the i-th group during the next period, $t_1$. Thus $n_{11}$ refers to farmers in the first adoption group at the initial period, to, who still remained in that group during the next period $t_1$; $n_{12}$

TABLE 1: NUMBER OF FARMERS IN DIFFERENT ADOPTION GROUPS

| Adoption Groups in Period $t_0$ | Adoption Groups in Period $t_1$ 1 2 3 . . . j . . . k | Total Proportionate Share |
|---|---|---|
| 1 | $n_{11}\ n_{12}\ n_{13}\ n_{1j}\ n_{1k}$ | |
| 2 | $n_{21}\ n_{22}\ n_{23}\ n_{2j}\ n_{2k}$ | |
| 3 | $n_{31}\ n_{32}\ n_{33}\ n_{3j}\ n_{ik}$ | |
| i | $n_{i1}\ n_{i2}\ n_{i3}\ n_{ij}\ n_{ik}$ | |
| k | $n_{ki}\ n_{k2}\ n_{k3}\ n_{kl}\ n_{kk}$ | |
| Total | | N 1.000 |
| Proportionate | | 1.000 |

refers to farmers in the first adoption group in period to, who have moved to the second (higher) group in period $t_1$, while $n_{21}$ refers to farmers in the second adoption group in period to, who have moved to the first (lower) adoption group in period $t_1$, and so on. The sum of the i-th row ( ) of the table represents the number of farmers belonging to the i-th adoption group during the initial period, to, while the sum of the j-th column ($n^1.j$) indicates the number of farmers belonging to the j-th adoption group during the next period, $t_1$. Similarly, represents the proportion of the $N^o$ farmers in the i-th adoption group at the initial period, while shows the proportion of the same $N^o$ farmers in the j-th adoption group during the next period. The probability ($P_{ij}$) that a farmer belonging to the i-th adoption group during the initial period, to, moves to the j-th adoption group in the next period, $t_1$, is given by $P_{ij} = n_{ij}/$ . (i,j = 1,2,3, . . . k) (2)

These $P_{ij}$ are called transitional probabilities and indicate the probability of the system being in state j in the next period or step, given that at present it is in state i. Since the $P_{ij}$ are probabilities,

$$\sum_{j=1} P_{ij} = 1 \text{ for all i} \qquad (3)$$

A matrix of these transitional probabilities is a transition matrix (P) and it gives the probabilities associated with all possible levels of movement (see table 2). It is a stochastic matrix whose rows represent retention and losses, while the columns represent retention and gains.

TABLE 2: TRANSITION MATRIX

| Adoption Groups in period to | Adoption Groups in Period $t_1$ 1 | 2 | 3 | j | k |
|---|---|---|---|---|---|
| 1 | $P_{11}$ | $P_{12}$ | $P_{13}$ | $P_{ij}$ | $P_{1k}$ |
| 2 | $P_{21}$ | $P_{22}$ | $P_{23}$ | $P_{2j}$ | $P_{2k}$ |
| 3 | $P_{31}$ | $P_{32}$ | $P_{33}$ | $P_{3j}$ | $P_{3k}$ |
| 4 | $P_{i1}$ | $P_{i2}$ | $P_{i3}$ | $P_{ij}$ | $P_{ik}$ |
| k | $P_{k1}$ | $P_{k2}$ | $P_{k3}$ | $P_{kj}$ | $P_{kk}$ |

The matrix of transitional probabilities can be used to forecast the distribution of farmers. Recall from table 1 that the proportionate distribution of farmers in the different adoption groups during period $t_1$ was given as , The product of this vector and the j-th column of the transition matrix gives the probability distribution of farmers in the j-th adoption group in period $t_2$.

In general, if we denote = ( ) as the vector of initial distribution of farmers in the different adoption groups at the initial period, to, and P as the transition matrix, then gives the probability distribution ( (see table 1) of farmers in the different adoption categories in the next period, $t_1$.

Now, during the subsequent period, $t_2$, becomes the initial distribution and so on, so that the distribution of farmers in different adoption groups in each subsequent period can be predicted as follows:

As t tends to infinity we obtain another probability row vector $e = (e_1, e_2, e_3, \ldots e_k)$. On using this vector to multiply the transition matrix P such that

$$eP = e \tag{5}$$

and

(6)

we obtain the probability distribution of farmers in the different adoption groups in equilibrium. The row vector e is called the equilibrium, steady state or limiting state probability vector.

2.2 *The Data*

This study covers the Small Holder Oil Palm Project in Nigeria which is a tripartite agreement between the World Bank, the Federal and the State Governments of Nigeria. Under the scheme, which took off in 1975, it was envisaged that a total of 38,000 hectares of high yielding variety of oil palm seed would be developed by the end of 1985. The small holders involved under this arrangement are located in the major oil palm belts of the country as follows: Owerri, Imo State (10,000 hectares). The project was designed to involve 29,000 participating farm families or small holders who are the main focus of this study.

These small holders are managed by the small-holder Management Units attached to each state's Ministry of Agriculture under the supervision of the Federal Department of Agriculture and Rural Development. Under the scheme, rural small scale farmers are mobilised into cooperative societies for the planting of high yielding variety (HYV) of *tenera* specie developed at the Nigerian Institute for Oil Palm Research, (NIFOR) Benin, Bendel State in 1969. This HYV is a hybrid of the tall local African specie and the dwarf South American specie. It combines all the good qualities of both species such as:

1. short stem that remains within easy reach to farmers even after 25 years of growth;
2. bearing fruits between 3 and 4 years after planting as against 7 and 8 years for the local variety; and
3. very high yield of 16-18 fresh fruit bunches per hectare per year which is five times higher than the yield from the local variety.

Data were collected from the Monitoring and Evaluation Unit (M.E.U.), Benin, Bendel State of the Federal Department of Agriculture on the stages of adoption of the 29,000 farmers targeted to participate in the project for two planting seasons, 1982 and 1983. Farmers were regarded to have adopted the improved HYV of oil palm seed on the basis of their average farmland devoted to the crop in the 1982 and 1983 planting seasons, and the proportion of their total cultivated land under this improved variety during the two periods. From the area under HYV of oil palm seed, the percentage area under this variety for the two periods and for all the 29,000 participating farmers were calculated. The farmers were then grouped into six adoption categories based on the area under HYV.

**Empirical Analysis and results**

3.1 *Distribution of Farmers in different adoption groups*

Table 3 shows the distribution of farmers in the six different adoption groups during the 1982 and 1983 planting seasons. The table shows that in 1982, out of the 29,000 farmers targeted to participate in the scheme, 18,673 or 64.39 per cent were non-adopters of the HYV, while only 10,327 or 35.61 per cent were adopters in varying degrees; 4,011 or 13.83 per cent of the total number of farmers were laggards; 3,189 or 11.00 per cent were late majority; 593 or 2.04 per cent were early adopters and 121 or 0.42 per cent were innovators. However, by 1983, the non-adopters had declined to 17,381 farmers, or 59.93 per cent, while the adopters had increased to 11,619 farmers or 40.07 per cent, made up of 3,485 or 12.02 per cent Laggard, 4,056 or 13.99 per cent late majority, 3,115 or 10.7 per cent early majority, 821 or 2.83 per cent early adopters and 142 or 0.49 per cent innovators.

The probability vector (0.599, 0.120.0.140, 0.107, 0.028, 0.005) of the distribution of farmers in 1983 will be regarded as the vector of initial distribution for the purpose of further analysis.

**TABLE 3: DISTRIBUTION OF FARMERS IN DIFFERENT ADOPTION GROUPS, 1982 AND 1983 PLANTING SEASONS**

| 1982 planting season: percentage of land under oil palm | 1983 planting season percentage of land under HYV oil palm | | | | | | Total | Share |
|---|---|---|---|---|---|---|---|---|
| | 0 | 1-20 | 21-40 | 41-60 | 61-80 | 81-100 | | |
| 0 | 17,103 | 920 | 471 | 179 | 0 | 0 | 18,673 | 0.644 |
| 1-20 | 216 | 1,921 | 866 | 714 | 294 | 0 | 4,011 | 0.138 |
| 21-40 | 52 | 313 | 2,411 | 310 | 103 | 0 | 3,189 | 0.110 |
| 41-60 | 10 | 292 | 212 | 1,809 | 82 | 8 | 2,413 | 0.083 |
| 61-80 | 0 | 39 | 96 | 103 | 338 | 17 | 593 | 0.021 |
| 81-100 | 0 | 0 | 0 | 0 | 4 | 117 | 121 | 0.004 |
| Total | 17,381 | 3,485 | 4,056 | 3,115 | 821 | 142 | 29,000 | 1.000 |
| Share: | 0.599 | 0.120 | 0.140 | 0.108 | 0.028 | 0.005 | 1.000 | |

*Source:* Computed from Data obtained from Monitoring and Evaluation Unit (MEN), Benin City, Bendel State

3.2 *Transitional Probabilities of Farmers' Distribution*

Based on the movement of farmers in the different adoption groups during the 1982 and 1983 planting seasons as shown in table 3, transitional probabilities were calculated for each state of the farmer. The matrix of these probabilities or the transition matrix is shown in table 4. The diagonal elements, represent the retention probabilities of the different adoption groups, while the off - diagonal element are the probabilities of losses and gains. It can be seen that the highest retention probabilities of 0.967 and 0.916 occurred among farmers devoting 81-100 per cent, and zero per cent, respectively, of their total cultivated lands to the HYV, while farmers cultivating 1-20 per cent and 61-80 per cent of their farm lands with the HYV had the lowest retention probabilities of 0.479 and 0.570, respectively.

**TABLE 4: MATRIX OF TRANSITIONAL PROBABILITIES**

| 1982 Planting season, Percentage of Land Under HYV | 1983 Planting Season, Percentage of Land Under HYV | | | | | Sum |
|---|---|---|---|---|---|---|
| | 0 | 1.20 | 21-40 | 41-60 | 61-80 | 81-00 |
| 0 | 0.916 | 0.049 | 0.025 | 0.010 | 0 | 1.000 0 |
| 1-20 | 0.054 | 0.479 | 0.216 | 0.178 | 0.073 | 1.000 0 |
| 21-40 | 0.016 | 0.098 | 0.756 | 0.097 | 0.032 | 1.000 0 |
| 41-60 | 0.004 | 0.121 | 0.088 | 0.750 | 0.034 | 1.0000.003 |
| 61-80 | 0 | 0.066 | 0.162 | 0.174 | 0.570 | 1.0000.029 |
| 81-100 | 0 | 0 | 0 | 0 | 0.033 | 1.0000.967 |

*Source:* Computed from Table 3

3.3. *Predicted Distribution of Farmers in Different Adoption Groups*

Using the probability vector of farmers' distribution in the six different adoption groups in 1983 and the transition matrix, we predicted the probability distribution of farmers in the different adoption categories for the period 1984-1995. This is shown in table 5. Based on these probabilities, the expected number of farmers in each adoption group was predicted for each subsequent period. This is given table 6, while the estimated adoption indices are contained in table 7. (An adoption index measures the proportion of adopters).

The table shows that by 1985, the target year when the first phase of the Small Holder Oil Palm Project is earmarked for completion, 14,094 farmers or 48.6 per cent of the targeted 29,000 Participating farmers would be non-adopters of the HYV, while 14,906 farmers or 51.4 per cent would be adopters in varying degrees -232 innovators, 1,218 early adopters, 4,524 early majority, 5,510 late majority and 3,422 Laggards. The adoption index in 1985 will be 7.9 per cent higher thanthat of 1983.

By 1990, an estimated 10,991 farmers or 37.9 per cent of the targeted farmers will still be non-adopters, while 18,009 farmers or 62.1 per cent will be adopters with innovators among them being 406. The adoption index of 62.1 per cent in 1990 shows an increase of 22 per cent over the 1983 figure. Finally, in 1995, only 8,520 farmers or 29.4 per cent will not adopt it with innovators among them rising to 696. The adoption rate for 1995 shows a substantial increase of 30.5 per cent over that of 1983.

**TABLE 5: PROBABILITY VECTORS OF FARMERS' DISTRIBUTION IN DIFFERENT ADOPTION GROUPS, 1984-1995**

| Period | Adoption Groups: Percentage of Land Under HYV | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1-20 | 21-40 | 41-60 | 61-80 | 81-100 |
| 1982 | 0.644 | 0.132 | 0.110 | 0.083 | 0.021 | 0.004 |
| 1983 | 0.599 | 0.120 | 0.140 | 0.108 | 0.028 | 0.005 |
| 1984 | 0.559 | 0.135 | 0.161 | 0.126 | 0.033 | 0.006 |
| 1985 | 0.520 | 0.116 | 0.177 | 0.143 | 0.037 | 0.007 |
| 1986 | 0.486 | 0.118 | 0.190 | 0.156 | 0.042 | 0.008 |
| 1987 | 0.456 | 0.121 | 0.202 | 0.168 | 0.044 | 0.009 |
| 1988 | 0.427 | 0.124 | 0.213 | 0.180 | 0.046 | 0.010 |
| 1989 | 0.402 | 0.125 | 0.222 | 0.190 | 0.049 | 0.012 |
| 1990 | 0.379 | 0.128 | 0.228 | 0.200 | 0.051 | 0.014 |
| 1991 | 0.359 | 0.130 | 0.236 | 0.206 | 0.053 | 0.016 |
| 1992 | 0.340 | 0.132 | 0.241 | 0.214 | 0.055 | 0.018 |
| 1993 | 0.323 | 0.133 | 0.247 | 0.220 | 0.057 | 0.020 |
| 1994 | 0.308 | 0.134 | 0.252 | 0.225 | 0.059 | 0.022 |
| 1995 | 0.294 | 0.135 | 0.257 | 0.230 | 0.060 | 0.024 |

*Actual Figures; *Source:* Computed from Table 4

**TABLE 6: PREDICTED DISTRIBUTION OF FARMERS IN DIFFERENT ADOPTION GROUPS, 1984-1995**

| Period | Adoption Groups | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | 0 | 1-20 | 21-40 | 41-60 | 61-80 | 81-100 | |
| 1982* | 18,673 | 4,011 | 3,189 | 2,413 | 593 | 121 | 29,000 |
| 1983 | 17,381 | 3,485 | 4,050 | 3,115 | 821 | 142 | 29,000 |
| 1984 | 16,211 | 3,335 | 4,669 | 3,654 | 957 | 174 | 29,000 |
| 1985 | 15,080 | 3,364 | 5,133 | 4,147 | 1,073 | 203 | 29,000 |
| 1986 | 14,094 | 3,422 | 5,510 | 4,524 | 1,218 | 232 | 29,000 |
| 1987 | 13,224 | 3,509 | 5,858 | 4,872 | 1,276 | 261 | 29,000 |
| 1988 | 11,383 | 3,596 | 6,177 | 5,220 | 1,334 | 290 | 29,000 |
| 1989 | 11,658 | 3,625 | 6,438 | 5,510 | 1,421 | 340 | 29,000 |
| 1990 | 10,991 | 3,712 | 6,612 | 5,900 | 1,479 | 406 | 29,000 |
| 1991 | 10,411 | 3,770 | 6,844 | 5,974 | 1,537 | 464 | 29,000 |
| 1992 | 9,860 | 3,828 | 6,989 | 6,206 | 1,595 | 522 | 29,000 |
| 1993 | 9,367 | 3,857 | 7,163 | 6,300 | 1,653 | 580 | 29,000 |
| 1994 | 8,932 | 3,806 | 7,308 | 6,525 | 1,711 | 638 | 29,000 |
| 1995 | 8,526 | 3,915 | 7,453 | 6,670 | 1,740 | 696 | 29,000 |

*Source:* Computed from Table 5

TABLE 7: PREDICTED ADOPTION RATES, AND THEIR GROWTH RATES' 1984-1995

| Period | Adoption Rate (%) | Percentage change with 1983 as base year |
|---|---|---|
| 1983 | 40.10 | |
| 1984 | 44.20 | 4.10 |
| 1985 | 48.00 | 7.90 |
| 1986 | 51.40 | 11.30 |
| 1987 | 54.50 | 14.40 |
| 1988 | 57.30 | 17.20 |
| 1989 | 59.80 | 19.70 |
| 1990 | 62.10 | 22.00 |
| 1991 | 64.10 | 24.00 |
| 1992 | 66.00 | 25.90 |
| 1993 | 67.70 | 27.60 |
| 1994 | 69.20 | 29.10 |
| 1995 | 70.60 | 30.50 |

*Source:* Computed from Table 6

*Summary and Conclusion*

We have used a Markov chain process to forcast future trends in both the adoption and the distribution of farmers into different adoption categories with respect to improved high yielding variety of oil palm seed in Nigeria.

If all factors currently influencing the adoption of improved high yielding oil palm seed technology in the country remain the same, the adoption rate is predicted to be 48 per cent by 1985 when the first phase of the Small Holder Oil Palm Projects are earmarked for completion. This figure represents an increase of 7.9 per cent over that of 1983. In the same year, the distribution of farmers in the six different adoption groups will be 14094 non-adopters, and 14,906 adopters in varying degrees; 3,422 laggards, 5,510 late majority, 4,524 early majority, 1,218 early adopters and 232 innovators.

Since the lifespan of most of these projects has been extended, the adoption index is predicted to reach 62.1 per cent by 1990, involving 18,009 small holders consisting of 406 innovators, 1479 early adopters, 5900 early majority, 6612 late majority and 3,712 laggards. The predicted adoption index for 1990 shows an increase of 22 per cent over that of 1983. Similarly, by 1995, the adoption index is predicted to be 70.6 per cent, involving 20,474 farmers with the innovators among them rising to 696. The predicted adoption index for 1995 shows a substantial increase of 30.5 per cent over the 1983 figure.

The relatively low adoption rates of the improved oil palm seed variety are due mainly to the fact that most of these projects did not take off on the scheduled date of March 1975 coupled with shortage of funds and improved seeds. There was glaring inability of NIFOR to meet the seed requirements of most of these projects. This

largely contributed to the poor response rate as farmers could not plant all their developed seed beds. Secondly, farmers aims and aspirations were not taken into consideration in the siting of some of the Small Holder Oil Palm Projects in the country. This fact accounted for poor or non-participation of formers in these projects, especially those sited in Ondo and Bendel states that are traditionally cocoa producing areas. This problem can be traced to poor project formulation and preparation. In addition, the Federal and some state governments failed to meet their financial obligations to the Small Older Oil Palm Projects. This resulted in the World Bank withdrawing from the scheme in Bendel and Ondo States in June 1982.

It is, therefore, recommended that all the Small Holder Oil Palm Projects in the country should be encouraged to establish their own seed multiplication centres so as to arrest the delay in the development of more hectares. Moreover, seed multiplication centres should be established by the various states and local governments in theoil palm belt. The Nigerian Institute for Oil Palm Research (NIFOR) should be more responsive to its duty in the area of seed multiplication and distribution.

In addition, more field offices should be established by the Small Holder Management Units. These offices should be managed by extension specialists who would explain the benefits derivable from the scheme to farmers. Demonstration plots should also be established at these centres together with seed multiplication centres andoil palm processing facilities. Lastly, Governments, state and Federal, should be more alive to their responsibilities by providing funds on time to these projects.

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