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A MATHEMATICAL MODELING STUDY OF THE ADOPTION OF TECHNOLOGY BY THE FARMERS OF RANCHI DISTRICT

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Abstract

In this paper, we proposed a simple mathematical model for farmers in the Ranchi district to adopt and implement agricultural technologies. We used the Fisher-Pry model, which is a very effective model in the study of technological adoption. The model's output is a Sigmoid curve, or S-shaped curve, that develops exponentially at first, then approximately linearly, and lastly asymptotically. We have studied the models of technology spread using a basic case study and brought in a real-world situation. Mathematically, it is possible to predict that adoption will rise to the number m/2 implies when 50% of the farmers have adopted the technology, after which it will slow down. In a real-life situation, the point of inflection might occur before or after m/2.

We also collected data on some of the food crops of Ranchi district from 2011 to 2017, as well as rainfall for each year, and evaluated it graphically/mathematically. In comparison to the other years in the research, we found that rainfall was lower in 2015-2016. As a result, production per unit area fell. If the farmers in Ranchi had employed the available irrigation technology, this crisis would not have arisen.
Keywords: Agriculture, Technology, Adoption, Mathematical Modeling.

Introduction

Agriculture is the main source of income in Jharkhand, accounting for 60-75 percent of the population. Farmers in this region are uninformed of and uninterested in newer and better agricultural technology, resulting in low production. As a result, they have become underprivileged.

New agricultural technology has the potential to increase the production and quality of agricultural goods, as well as improve people's economic conditions. Farmers using new information to cultivation methods and other agricultural activities in order to increase production and quality. By replacing the old style of farming with a new and more effective method of agriculture, the region may benefit from technological innovation.

The following were some of the main obstacles in the way of farmers in the research area adopting new agricultural technology:

1. Agricultural activities are frequently delayed due to a lack of appropriate and timely assured irrigation facilities.
2. To increase productivity, the technical input has got to be reoriented and reinforced.

3. Due to its growing preference for nuclear families and young migration to urban areas for the glamorous city life, there is a shortage of manpower in the household.
4. For a good price, there were insufficient marketing facilities.
5. The region's educated young, in particular, have lost interest in agriculture.

The elements of technology diffusion comprise of innovation, strategies to commercialize technologies is propagation, time, and units of social system[3]
In view of this, we investigated a mathematical model for predicting new agricultural technology adoption among farmers of the Ranchi district in this paper. Here, we have predicted that the adoption process of agricultural technologies as S-shaped curve or sigmoid pattern growth, the adoption goes through phases which includes initial exponential phase, an approximately linear phase and finally an asymptotic phase.

MATHEMATICAL MODELING

Let us suppose that m be the total number of farmers. Also, let $y(t)$ be number of farmers who have adopted the new technologies in time t. Also a farmer will adopt the new technology only after a farmer who already uses it told him about it.
Let us suppose that δy farmers adopt the new technologies in time δt.
At any time t, let $y(t)$ be the number of farmers who are using technology and $\{m - y(t)\}$ be the number of farmers who are not using technology.
Therefore,
$\delta y \propto y(t)$
$\delta y \propto \{m - y(t)\}$
Thus we can write
$\delta y = Cy(t)\{m - y(t)\}\delta t$
Where, C is the positive constant.

If the number of successful adopters, who can communicate the new innovation in efficient manner, is large, the greater will be the number who can possibly adopt it and larger will be the rate of change $y(t)$. So that we assume [1]

$$\frac{dy}{dt} = Cy(t)\{m - y(t)\} \quad 1$$

This gives the first mathematical model.
On solving, we have

$$log\left|\frac{y}{m-y}\right| = mCt + A$$

Where,
A is the integration constant which can be calculated after taking initial conditions.
If at $t = 0; m = m_0$ & $y = y_0$
Then we can write

$$A = log\left|\frac{y_0}{m_0 - y_0}\right|$$

Now, putting the value in the above equation we have

$$log\left|\frac{y}{m-y}\right| = mCt + log\left|\frac{y_0}{m_0 - y_0}\right|$$

But if $y_0 = 1$, we have

$$y = \frac{me^{mCt}}{m_0 - 1 + e^{mCt}}$$

Let $\frac{y(t)}{m} = f(t)$

Then (1) reduces to

$\frac{df(t)}{dt} = C_1 f(t)[1 - f(t)]$ 2

We investigate this model

Since $y(t) \leq m, f(t) \leq 1, \frac{df(t)}{dt} \geq 0$

$$\frac{d^2f}{dt^2} = C_1\{1 - 2f(t)\}\frac{df(t)}{dt}$$

Now,

$\frac{d^2f}{dt^2} > 0 \ for\ f(t) < \frac{1}{2}$

$\frac{d^2f}{dt^2} = 0 \ for\ f(t) = \frac{1}{2}$

$\frac{d^2f}{dt^2} < 0 \ for\ f(t) > \frac{1}{2}$

Also, $\frac{df(t)}{dt}$ increases when $f < \frac{1}{2}$ and decreases when $f > \frac{1}{2}$

$f(t)$ or $y(t)$ increases at increasing rate when $y(t) < \frac{m}{2}$ and it increases but at decreasing rate $y(t) > \frac{m}{2}$.

There is a point of inflexion when $f(t) = \frac{1}{2}\ or\ y(t) = \frac{m}{2}$

On solving (2),

$$f(t)\{1 - f_0\} = f_0\{1 - f(t)\}e^{C_1 t}$$

$$f(t) = \frac{1}{1 + \frac{1 - f_0}{f_0}e^{-C_1 t}}$$

Where f_0 is the value of $f(t)$ at $t = 0$.

Thus $f(t) \leq 1$ and $f(t) \to 1$, when $t \to \infty$

$y(t) \to m$ when $t \to \infty$

That is the technology will have to wait a long time for all farmers to adopt it. In today's continuously emerging technology age, adopters have the ability to adopt new technologies at any time, therefore previous ones will not be adopted by all farmers.

The model (2) is called Fisher-Pry model [2] and is a very successful model for explaining how, why, and how quickly new ideas and technologies spread.

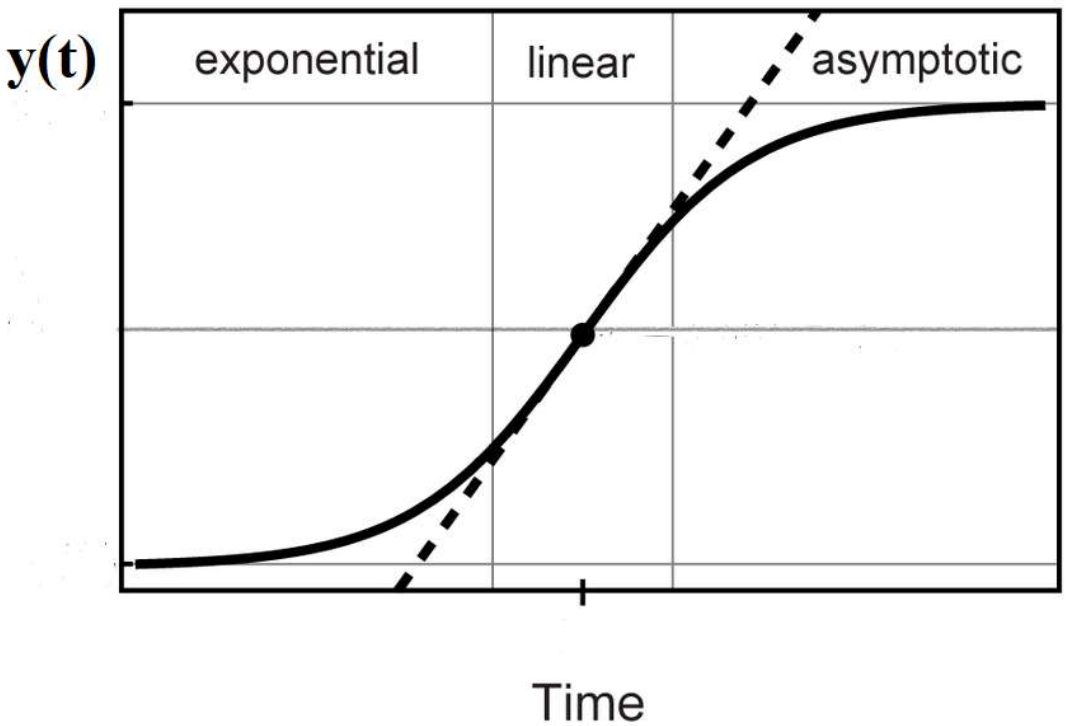

Figure: 1

Table 1: Yield in Tonnes/Hectare of some of the food crops in Ranchi Jharkhand

Year	**Wheat**	**Rice**	**Maize**
2011-2012	2.04	1.73	2.34
2012-2013	2.06	1.67	3.09
2013-2014	2.31	1.56	2.91
2014-2015	2.09	1.74	2.77
2015-2016	1.74	0.53	1.36
2016-2017	2.24	2.43	3.42

Source: Directorate of Economics and Statistics.

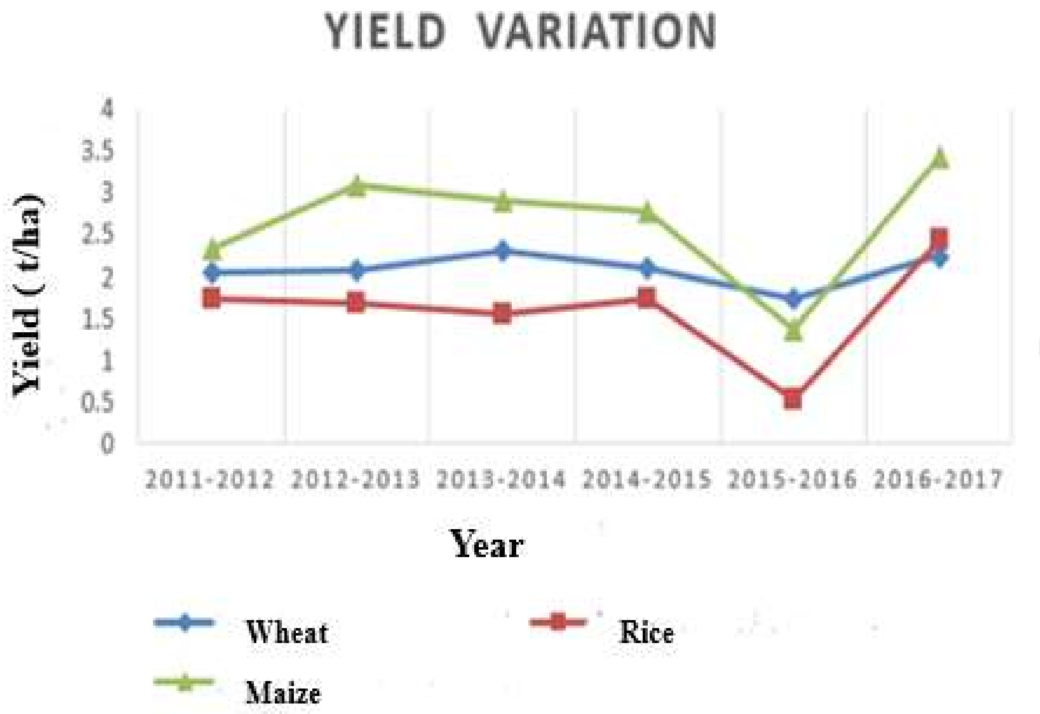

Figure:2

Observations from the graph

In Figure (2) of yield that is production per unit area of some of the food crops (Wheat, Rice and Maize), we observed that the growth of the curve was not so rapid, it was approximately linear except for the year 2015-2016.

We also observed that, according to statistics from the Department of Water Resources, rainfall in 2015-16 was 990.6mm, which was lower than the other years in the research.

Results

We have studied the models of technology spread using a basic case study and brought in real-world situation. Mathematically, it is possible to predict that adoption will rise up to the number m/2 implies, when 50% of the farmers have adopted the technology, after which it will slow down. In all situations of agricultural innovation, the most typical pattern found under generally stable conditions is a "sigmoid" pattern, in which this variable continuously passes through stages that appear to be exponential, then linear, and ultimately asymptotic to some upper limit. The point of inflexion is $y(t) = \frac{m}{2}$ while in real life situation it can occur before or after $\frac{m}{2}$.

The above-mentioned graph in support of the yield of various food crops (Table No. 1) clearly shows that the growth rate is roughly linear, but that the growth curve decreases in the years 2015-16 due to lesser rainfall.

The role of information technology and the media must be promoted in order to support the adoption of modern irrigation methods so that production per unit area always displays a development curve, even if there isn't enough rain in certain years. The media may play an important role in rapidly spreading agricultural technologies.

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