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Peter Adebayo Idowu

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Information Technology Infusion Model for Agricultural Sector in Nigeria

Egejuru, N.C., Mhambe, P.D., Balogun, J.A., Asahiah, F.O. & *Idowu, P.A
Department of Computer Science & Engineering
Obafemi Awolowo University
Ile-Ife, Nigeria.

paidowu@oauife.edu.ng

ABSTRACT

In this paper, we identified Information & Communication Technology (ICT) devices used in the Nigerian agricultural sector and formulate infusion models for each identified ICT device. 200 structured questionnaires were used to collect information regarding the use of the ICT devices used among respondents of six (6) agricultural research and academic institutes selected from south-western Nigeria. Different ICT devices identified consisted of smartphones, Short Message Services (SMS), e-mail, computers, office hardware, wireless media technologies, global position satellites, geographical information systems, radio-frequency identification technology and automated systems. The results showed that majority of the respondents that adopted ICT were married males within the age groups of 31 – 50 years with less than 10 years of working experience using ICT devices at both work and on the field. The results of the study further showed that the earliest adopted ICT devices were computer and office hardware in 1994, e-mails in 1995, SMS and wireless technologies in 1998 and smartphones in 1999 - all adopted before the 21st century. The most adopted technology by more than 50% of the respondents were the computer, smartphones, SMS, e-mails, office hardware and wireless technologies in the discharge of their respective duties. Polynomial functions of degree m were used to formulate the infusion model for each ICT devices identified based on the yearly cumulative distribution of the number of users. The infusion models formulated can be used to estimate the number of users of ICT devices for any given year from the year of adoption of the ICT device.

Keywords: Information and Communications Technology, devices in use, infusion modeling, agricultural institutes.

1. INTRODUCTION

ICT devices are used for sending-out, storing and receiving information [1]. Information and communications technology is an umbrella that involves any communication application or device, encompassing, television, radio, satellite systems, cellular phones, computer hardware and software. In recent years, there is an incredible swift and dynamic execution of ICT which has turned the world into a global village [2]; [3]. Nations have also enjoyed an unparalleled increase in productivity as well as sustainable economic growth and development due to this evolving trend. However, this laudable development has not been evenly spread. It is no longer news that Information and Communication Technology (ICT) is arguably the most rapidly growing segment of the world ecosystem [4]. The development in the sector permeates every human activity: social, economic, cultural, religious, political etc. [5]. Investments in ICT have become crucial organizational strategies for survival and competitive advantage, especially in agricultural sector.

Agricultural extension services include transferring knowledge to farmers, advising and educating farmers in their decision making, enabling farmers to clarify their own goals and possibilities, and stimulating desirable agricultural developments [6]. Traditional public-sector extension services use different extension programmes to overcome barriers to technological adoption without much success [7]. In many agriculturally based local economies, the low availability of timely and needed information is skewed in favour of more networked individuals or organizations, which often force disadvantaged farmers to sell their harvests below fair value [8]. The uneven spread of infrastructure – market, finance, administrative (e.g., government services) and physical (roads, etc.) – is equally problematic in developed and developing nations, leading to significant differences in the ability to leverage individual and regional strengths. Insufficient extension services and poor access to information widen the gap in the adoption of new technologies, which can lead to lower long-term productivity [9].

According to Information and Communication Technology Agency – ICTA [10], although farmers have the real need to access market information, land records and services, accounting and farm management information, management of pests and diseases and rural development programmes. ICT could help accessing these services. However, ICT projects dealing with such services are extremely limited [11, 12]. The most common sources are still TV, radio, newspapers, other farmers, government agricultural extension services, traders, input dealers, seed companies and relatives. However, the quality and relevance of the information provided by these sources can be highly relative. Most farmers in developing countries therefore lack access to consistent, reliable information for many of their needs and often rely on a combination of these varied but inconsistent sources which includes traditional knowledge, experience and estimates, when making decisions [6, 13]. Another constraint is that even when correct and timely market price information is available, farmers are often unable to exploit any potential pricing benefits that exist between markets because of their inability to transport their produce to the markets with higher prices.

African countries have been characterized by decades of unfruitful attempts to shift from the agricultural sector. Based on western experience, less-developed countries were being pushed to strive for economic emancipation through the transformation of their economies with a decreased reliance on the primary sector [14]. The share of agriculture in GDP in many African countries is much smaller, often 30% or less indicating low productivity levels in the sector. Despite the role played by agriculture in development of Africa, agricultural production and yields have lagged far behind those in developed countries over the past few years. This poor sector performance, to a greater extent, has been attributed to the underutilization of improved agricultural technologies in developing countries since the 1970s [15].

Although agriculture and natural resources are deemed to continue being the key drivers of Africa's economic growth, the application of modern technologies have significant impact on the growth trajectories of most African economies. These, being the case, countries have identified ICT as an important component in moving the countries' subsistence-based economy to a service-sector driven high-value added information and technology based economy, which can compete effectively on the global market [16]. Therefore, there is a need to propose an ICT infusion model which can be used to measure the level of adoption of ICT into the agricultural sector of Nigeria, hence this study.

2. RELATED WORKS

Adekunjo *et al.* [17] performed a descriptive survey research design in order to investigate the impact of ICT on research output of scientists in selected research institutes in Edo State. The study population comprised of the scientist in two Nigerian Research Institutes (The Nigerian Institute for Oil Palm Research and Rubber Research Institute of Nigeria, Edo State of Nigeria). The study showed that the usage of computer, television, GSM, Internet and the printer ranked highest among the ICT tools in the institutes, majority of the scientists parade very high level of proficiency in the use of ICT in rendering research activities in the Institutes, the positive influence of ICT and staff training on research outputs of the scientists was very high. The study therefore recommends among others, that sufficient funds should be made available for acquisition of standard ICT facilities in the institutes, and that training and re-training of scientists should be intensified for the purpose of skill acquisition that will result in productivity.

Williams and Agbo [18] performed an evaluation of the use of ICT in agricultural technology delivery to farmers in Ebonyi State, Nigeria. This study evaluated the use of ICT as a source of technology delivery among farmers in Ebonyi State of Nigeria. Multiple-stage random sampling technique was used to select 120 respondents. Primary data were collected using a structured questionnaire and interview schedule. Both descriptive and inferential statistics were employed in data analysis. Results obtained showed that 55% of the respondents were males whose age brackets fall within 30 – 39 years. About 30% had secondary education. Out of 45% of the respondents who were farmers, 41.7% were mainly crop farmers. 54.17% of the respondents had access to mobile phones whereas 57.50% had no access to computer. ICTs was used by 31.67% of the respondents to get information on new varieties, ICT was effective in information delivery in determining the quantity of farm inputs. A high co-efficient of multiple determination (R^2) of 76.6% was obtained. This means that 76.6% of the total variables in the dependent variables were caused by the changes in independent variables included in the regression model. Infrastructural, technical, institutional and financial constraints were identified by factor analysis. In conclusion, overcoming the problems of information dissemination and communication, language barriers and limited economic resources would increase the use of ICTs in the study area.

Lucky and Achebe [19] performed a study on ICT and Agricultural Information Dissemination using the Institute of Agricultural Research (IAR) located at the Ahmadu Bello University, Zaria as a case study. In the study, assessing the level of effort made by researcher at IAR as a foremost agricultural institution in passing on farm information to farmers using ICT channels were made. It involved engaging farmers and researchers alike through oral interview in an impact assessment with a view to devising better means of disseminating agricultural information to rural farmers. The finding shows the low level deployment of ICT in information dissemination in this very important segment of the economy and as such leaves a lot of room for improvement.

Iorliam *et al.* [20] performed a study on the adoption of ICT as a source of information on agricultural innovations among farm households in Nigeria. The study analyzed adoption of ICTs as source of information on agricultural innovations in Nigeria. Data was collected through a structured questionnaire administered to one hundred and twenty (120) Agricultural Development Programme (ADP) farmers sampled in Benue State. Results show that Radio (46.7%), Newspapers (45.8%), contact farmers (42.5%), and extension agents (41.7%) ranked first, second, third and fourth respectively in terms of adoption by farmers. Level of education and incomes were the significant ($P<0.05$) determinants of ICT adoption. Enabling policy environment that would encourage utilization of ICTs through deliberate programmes that expose farming communities to ICTs and support incomes such as highly subsidized ICT trainings and increased credit facilities to rural farmers would enhance adoption of ICTs in Nigeria.

Salau and Saingbe [21] worked on the access and utilization of ICT among agricultural researchers and extension workers in selected institutions in Nasarawa State of Nigeria. This study was conducted in three tertiary institutions and the ADP in Nasarawa State in 2006 to determine the accessibility and level of utilization of ICTs by agricultural scientists and extension workers. A sample of 45 Agricultural researchers and 45 extension workers was randomly selected for the study using a set of questionnaire. Data analysis was carried out through the use of descriptive statistics and linear regression model. The findings revealed that researchers had 87% access to ICT facilities while extension workers had 66% access. On the level of utilization of ICTs for agricultural communication, the researchers scored 84% while extension workers scored 70.3%. The regression analysis further revealed that level of education positively influenced the level of utilization of ICTs while years of working experience had negative influence. The key problems militating against the use of ICTs in the area were, poor access to ICT facilities, lack of computer knowledge, low income and poor power supply. It was recommended that agricultural organizations should install all necessary ICT facilities in their establishments and provide training opportunities for their staff. Constant power supply to both urban and rural communities should be considered a fundamental human right and treated as such.

3. MATERIALS AND METHODS

This study used structured questionnaire as the instrument of data collection from respondents of the selected location in Nigeria to elicit information about the ICT devices used among respondents working in Nigerian agricultural academic and research institutes. This study also considered respondents selected from five (5) major agricultural research and academic institutions located in Nigeria, namely:

i. Federal University of Agriculture, Abeokuta (UNAB);
ii. Federal University of Agriculture Agro-Allied Services (UNAB-AAS);
iii. Agro Services Co-operation (ASCO);
iv. Ministry of Agriculture, Kotopo (MOAK); and
v. Institute of Agricultural Research and Training (IART).

The instrument of data collection used to collect information from the respondents of the study included demographic information and ICT components used at each sites alongside the impact of the ICT components. Following the collection of data from the respondents, the data was analyzed using standard descriptive statistics tools: tables for data presentation and graphs for data presentation. The ICT infusion model was formulated using polynomial expressions of degree m estimated from cumulative total of users for each year from the year of infusion of each device. The study population identified for this study is the academic and research staffs of the agricultural academic and research institutes respectively. 200 questionnaires were distributed among the respondents with the necessary information provided.

This study incorporated the use of descriptive statistical techniques for the purpose of analyzing the data collected for this study from the respondents. The descriptive statistics methods used helped in the simplification of the data collected in a sensible way by the provision of descriptive summary using frequency tables and charts. The ICT infusion model was formulated using the Microsoft® Excel's built-in functionality for estimating the trend line of graphical tables and charts – which in this case is a polynomial function of degree *m*. For the purpose of this study, the IT infusion model was formulated as a function of the number of years; *x* from the base year, Y_0 up to a required year Y_x using a polynomial equation of degree *m* for each identified IT component. Equation 1 shows how to determine number of years, x that is required to determine the number of users of the ICT devices by the year, Y_x from the base year, Y_0.

$$x = Y_x - Y_0 + 1 \qquad (1)$$

The number of ICT devices adopted by the respondents of the two (2) security agencies for each year $n_x$was considered as a sequence of terms (equation 2) following which the cumulative total for each successive year was determined till the present year - 2016 (equation 3). Assuming an ICT device which was used starting from a base year, Y_0 = 2001; it will be discovered that the total number of terms in the sequence of users from 2001 till 2015 is t = 2015-2001+1=15 years.

$$n_x = n_1, n_2, n_3, n_4, \ldots\ldots\ldots, n_{15} \qquad (2)$$

The cumulative total number of ICT devices used by respondents of the 2 locations for each year from the base year till the present year was considered as a series of terms (equation 3). In equation (2), it is observed that each n_x for $1 \leq x \leq 15$ represents the number of users of the IT device for each successive year from 2001 till 2015. Equation (2) was converted to a sequence of the cumulative sum of users for each successive year (equation 3). Thus each S_x $1 \leq x \leq 15$ represents the cumulative total number of users of ICT devices *x* years after the base year of infusion, Y_0 (see equation 4).

$$S_x = n_1, (n_1 + n_2), (n_1 + n_2 + n_3), \ldots\ldots (n_1 + n_2 \ldots\ldots + n_{15}) \qquad (3)$$

$$S_x = S_1, S_2, S_3, S_4, \ldots\ldots\ldots\ldots, S_{15} \qquad (4)$$

where: $S_1 = n_1, S_2 = (n_1 + n_2), \ldots\ldots\ldots, S_{15} = (n_1 + n_2 \ldots\ldots + n_{15})$

Hence, the infusion model is thus a polynomial equation of degree *m* which is the best line fit of the cumulative number of users of each ICT device by year, Y_x - *x* years after the base year, Y_0. Thus, the IT infusion model is a polynomial fit of equation (4) expressed in terms of *x* (the number of years after the base year). Hence, the IT infusion model is expressed as:

$$S(x) = a + bx + cx^2 + \ldots\ldots + dx^n \qquad (5)$$

where a, b, c, d ϵ $\mathbb{R}$

4. RESULTS AND DISCUSSIONS

After distribution of the questionnaires among the security personnel selected from the five (5) agricultural research and academic institutions, 169 responses were received out of the 200 questionnaires distributed. Based on the findings of this study, the ICT tools investigated among the 169 respondents chosen for this study were: smartphones, sms, e-mail, computers, office hardware, wireless media technologies, global position satellites, geographical information systems, radio-frequency identification technology and automated systems. Out of 169 respondents selected for this study; 23 (13.61%) respondents were selected from ASCO, 40 (23.67%) were selected from IART, 22 (13.02%) were selected from MOAK, 24 (14.20%) were selected from UNAB, 36 (21.30%) were selected from UNAB-AAS while 1 (0.59%) was missing in transit during data collection. From the respondents considered for the study, it was discovered that majority responded from IART followed by UNAB-AAS with the least number of respondents selected from MOAK (Table 1).

Table 1: Respondents selected for this study

LOCATIONS	TOTAL	%
ASCO	23	13.61
IART	40	23.67
MOAK	22	13.02
UNAB	24	14.20
UNAB-AAS	36	21.30
Missing	1	0.59
Total	**169**	**100.00**

Following the results of the demographic information of the respondents in order to identify those that make use of these ICT tools within the Nigerian security sector, it was observed that there were more male users (58.6% of respondents) than there were female users (36.1%) of ICT tools working in the Nigerian security agencies selected (Table 2).

The results also showed that users within the age interval of 31-50 years (45.8% for the interval 31-40 and 32.5% for the interval 41-50) are more likely to use ICT tools compared to other security personnel identified (Table 2). The majority of the users of IT tools in the agricultural sector belong to the age group 31 – 50 years with 103 (60.95%) respondents falling into the age group followed by respondents within the age group greater than 50 years (> 50) with 38 (22.49%) respondents while the least number of respondents fall in the age group of less than 20 years (< 20) with 6 (3.55%) respondents (table 3).

Table 2: Sex of respondents selected for this study

Gender	ASCO	IART	MOAK	UNAB	UNAB-AAS	TOTAL	%
Male	11	24	13	37	14	99	58.58
Female	11	14	8	9	19	61	36.09
Missing	1	2	1	2	3	9	5.33
Total	23	40	22	48	36	169	100.00

Table 3: Marital Status of respondents selected for this study

Age-group	ASCO	IART	MOAK	UNAB	UNAB-AAS	TOTAL	%
< 20	1	1	0	1	3	6	3.55
21 – 30	3	6	0	3	5	17	10.06
31 – 40	9	15	7	12	9	52	30.77
41 – 50	8	10	7	15	11	51	30.18
> 50	2	8	7	14	7	38	22.49
Missing	0	0	1	3	1	5	2.96
Total	23	40	22	48	36	169	100

Based on their marital status, the results showed that there were more married users than single users of IT tools within the selected locations; 54 (31.95%) respondents were single with 114 (67.46%) respondents were married with 1 (0.59%) questionnaire missing the value of the marital status (Table 4). Based on the category of job description assigned to each of the respondents in their respective location; 1 (0.59%) respondent was scientific officer from IART, 1 (0.59%) respondent was IT officers from IART, 1 (0.59%) respondent was research scientist from IART, 35 (20.71%) respondents were administrators, 2 (1.18%) respondents were students from IART, 35 (20.71%) respondents were marketers, 53 (31.36%) respondents were farmers, 34 (20.12%) respondents were others (not defined) – with none from IART while 7 (4.14%) respondents were missing (Table 5)

Table 4: Marital Status of respondents selected for this study

Marital Status	ASCO	IART	MOAK	UNAB	UNAB-AAS	TOTAL	%
Single	7	17	5	12	13	54	31.95
Married	15	23	17	36	23	114	67.46
Missing	1	0	0	0	0	1	0.59
Total	23	40	22	48	36	169	100

Table 5: Job description of the respondents selected for this study

Category	ASCO	IART	MOAK	UNAB	UNAB-AAS	TOTAL	%
Scientific Officer	0	1	0	0	0	1	0.59
IT	0	1	0	0	0	1	0.59
Research Scientist	0	1	0	0	0	1	0.59
Administrator	4	11	4	8	8	35	20.71
Student	0	2	0	0	0	2	1.18
Marketer	8	6	7	6	8	35	20.71
Farmer	7	14	8	18	6	53	31.36
Others	3	2	0	16	13	34	20.12
Missing	1	2	3	0	1	7	4.14
Total	23	40	22	48	36	169	100

Based on the classification of the respondents on their years of experience, it was discovered that 43 (25.44%) respondents have spent less than 5 years (< 5), 61 (36.09%) respondents have spent between 6 – 10 years, 36 (21.30%) respondents have spent between 11 – 20 years, 24 (14.20%) respondents have spent more than 20 years (> 20) while 5 (2.96%) questionnaires were not provided information regarding work experience. Most of the respondents selected have been working for 6 – 10 years followed by those working for less than 5 years while the least selected were those working for 11 – 20 years (Table 6). Based on the use of IT at work, 151 (89.35%) respondents used IT at their place of work – including all at IART, 15 (8.88%) respondents did not use IT at their place of work while 3 (1.78%) questionnaires did not provided information; majority of the respondents (about 90%) use IT at their place of work (Table 7). Based on where respondents use IT during work, 4 (2.37%) respondents used IT on the field – none from IART, 68 (40.24%) respondents used IT at the office, 82 (48.52%) respondents used IT at both office and on the field while 15 (8.88%) questionnaires were not provided information regarding the use of IT at work (Table 8)

Table 6: Years of work experience of respondents selected for the study

Years	ASCO	IART	MOAK	UNAB	UNAB-AAS	TOTAL	%
< 5	8	10	7	10	8	43	25.44
6 – 10	12	17	6	13	13	61	36.09
11 – 20	2	6	2	15	11	36	21.30
> 20	1	5	6	8	4	24	14.20
Missing	0	2	1	2	0	5	2.96
Total	23	40	22	48	36	169	100

Table 7: Use of IT at work by respondents selected for the study

Location	ASCO	IART	MOAK	UNAB	UNAB-AAS	TOTAL	%
Yes	13	38	20	45	35	**151**	**89.35**
No	10	0	2	2	1	**15**	**8.88**
Missing	0	2	0	1	0	**3**	**1.78**
Total	23	40	22	48	36	**169**	**100**

Table 8: Where IT is used at work by respondents selected for the study

Location	ASCO	IART	MOAK	UNAB	UNAB-AAS	TOTAL	%
Field	2	0	0	1	1	**4**	**2.37**
Office	5	21	13	16	13	**68**	**40.24**
Both	9	17	7	27	22	**82**	**48.52**
Missing	7	2	2	4	0	**15**	**8.88**
Total	23	40	22	48	36	**169**	**100**

4.1 Results and discussion of ICT infusion models

Based on the results of this study, it was discovered that the most commonly used ICT tools between the years 1994 till 2016 were: computers (62.7%), smartphones and mobiles (59.2%), SMS (58.6%) and e-mail (58.0%) while the least commonly used ICT tools were: automated systems (15.4%), radio frequency identification – RFID (16.6%) and geographic information systems – GIS (26.6%). The result further showed that the adoption of e-mails in 1995 was influenced by the adoption of computers in 1994. The adoption of wireless technologies in 1998 was also likely responsible for the adoption of SMS and smartphones in 1998 and 1999 respectively (Table 9). The cumulative number of users of each ICT devices from 1994 till 2016 is shown in table 10.

Based on the information displayed in tables 9 and 10, the year of adoption of each identified ICT device used among the respondents selected from the five (5) agricultural research and academic institutes is shown in Table 11. Table 11 gives a description of the base year (the year of adoption or infusion) of each ICT devices used among security agencies in Nigeria alongside the initial number of users. The earliest adopted ICT devices were computers, office hardware, e-mails, SMS and wireless technologies in the years 1994, 1994, 1995, 1998 and 1998 respectively. The results of the study further showed that the ICT devices identified were adopted between the years 1994 and 2016 with six (6) ICT devices adopted before the 21st century – between 1994 and 1999. The graphical distribution of the cumulative number of adopters of ICT devices is shown in Figure 1.

For the purpose of formulating the IT infusion model using the polynomial function $S(x)$ with respect to x which represents the number of years after the base year, Y_0 for each ICT device considered for the study. The Microsoft Excel Data Analysis Toolkit for the estimation of trend lines using polynomial fits from the graphs and charts of the cumulative total number of ICT users was used to formulate the infusion model for each ICT device. Thus, the total number of users of ICT tools can be determined for a given year, Y_x given the number of years x from the year of infusion as determined from equation 1 using equation 5.

Table 9: Distribution of the number of adopters of ICT devices between 1994 till 2016

ICT Tools	ICT DEVICE ADOPTERS PER YEAR																						Sum	%
	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	
Smartphone/Mobile	0	0	0	0	0	4	7	2	3	4	10	8	5	4	2	8	8	4	13	3	6	1	8	**100**	**59.17**
SMS	0	0	0	0	1	4	6	4	5	7	12	6	9	2	5	8	7	8	5	2	4	3	1	**99**	**58.58**
Email	0	1	1	0	0	9	8	3	7	3	5	4	10	3	6	6	7	6	8	5	3	2	1	**98**	**57.99**
Computer	2	3	1	2	3	4	9	6	9	3	4	2	10	3	6	4	9	7	8	6	4	0	1	**106**	**62.72**
Office Hardware	6	2	1	3	1	2	8	3	3	4	5	2	8	2	4	5	8	9	6	4	5	1	1	**93**	**55.03**
Wireless Technologies	0	0	0	0	1	2	2	2	3	1	5	5	9	5	9	3	13	7	10	3	5	2	1	**88**	**52.07**
GPS	0	0	0	0	0	0	0	0	0	0	3	5	2	1	4	5	9	6	10	1	3	4	1	**54**	**31.95**
GIS	0	0	0	0	0	0	0	0	0	0	3	1	2	2	2	4	7	6	7	2	5	3	1	**45**	**26.63**
RFID	0	0	0	0	0	0	0	0	0	0	3	0	5	0	2	1	4	1	4	0	6	1	1	**28**	**16.57**
Automated Systems	0	0	0	0	0	0	0	0	0	2	2	0	4	0	2	1	4	1	3	1	5	0	1	**26**	**15.38**

Table 10: Distribution of cummulative total number of adopters of ICT devices between 1994 till 2016

ICT Tools	ICT DEVICE ADOPTERS PER YEAR																						Sum	%
	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	
Smartphone/Mobile	0	0	0	0	0	4	11	13	16	20	30	38	43	47	49	57	65	69	82	85	91	92	100	**100**	**59.17**
SMS	0	0	0	0	1	5	11	15	20	27	39	45	54	56	61	69	76	84	89	91	95	98	99	**99**	**58.58**
Email	0	1	2	2	2	11	19	22	29	32	37	41	51	54	60	66	78	79	87	92	95	97	98	**98**	**57.99**
Computer	2	5	6	8	11	15	24	30	39	42	46	48	58	61	67	71	80	87	95	101	105	105	106	**106**	**62.72**
Office Hardware	6	8	9	12	18	15	23	26	29	33	38	40	48	50	54	59	67	76	82	86	91	92	93	**93**	**55.03**
Wireless Technologies	0	0	0	0	1	3	5	7	10	11	16	21	30	35	44	47	60	67	77	80	85	87	88	**88**	**52.07**
GPS	0	0	0	0	0	0	0	0	0	0	3	8	10	11	15	20	29	35	45	46	49	53	54	**54**	**31.95**
GIS	0	0	0	0	0	0	0	0	0	0	3	4	6	8	10	14	21	27	34	36	41	44	45	**45**	**26.63**
RFID	0	0	0	0	0	0	0	0	0	0	3	3	8	8	10	11	15	16	20	20	26	27	28	**28**	**16.57**
Automated Systems	0	0	0	0	0	0	0	0	0	2	4	4	8	8	10	11	15	16	19	20	25	25	26	**26**	**15.38**

Table 11: Year of infusion (base year, y_0) for each ICT tools used among Nigerian agricultural research and academics institutions

ICT Device	Year of Infusion	Initial Users	Present Users	Percentage number of users (%)
Smartphone/Mobile	1999	4	100	59.17
SMS	1998	1	99	58.58
Email	1995	1	98	57.99
Computer	1994	2	106	62.72
Office Hardware	1994	6	93	55.03
Wireless Technologies	1998	1	88	52.07
GPS	2004	3	54	31.95
GIS	2004	3	45	26.63
RFID	2004	3	28	16.57
Automated Systems	2003	2	26	15.38

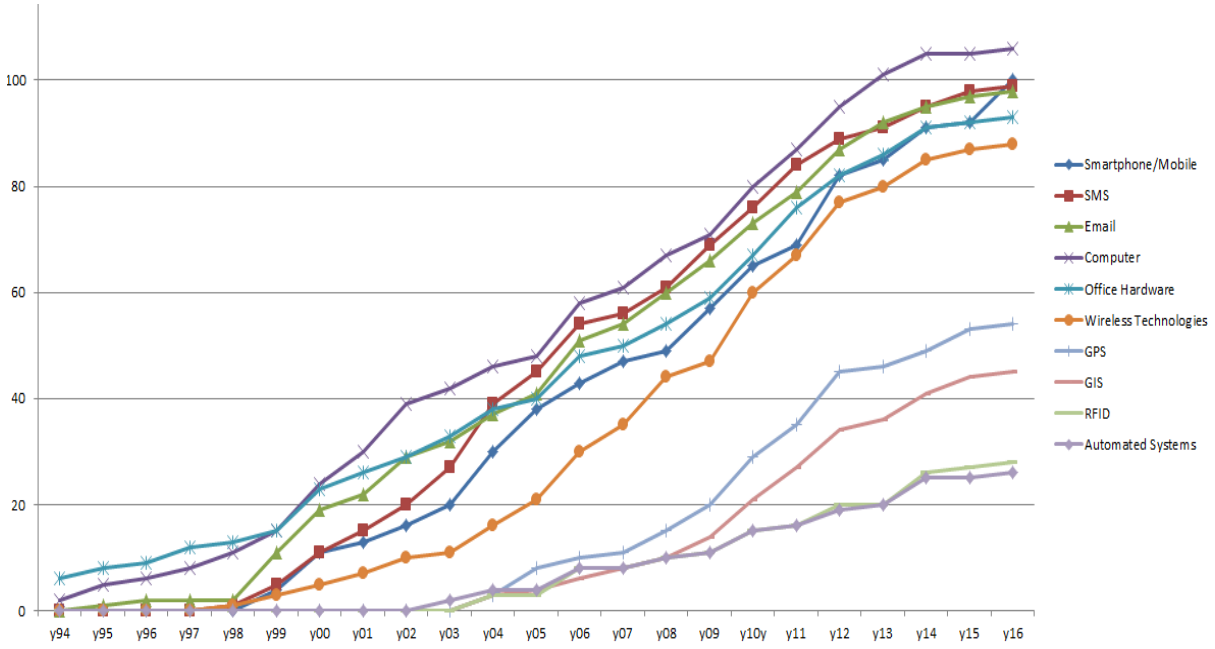

Figure 1: Graphical plot of the cumulative total user of ICT tools between 1994 till 2016

4.2 Infusion model for the use of smartphones and mobile phones

Following the results of cumulative sum of the number of users of smartphones and mobile phone users among agricultural academic and research institutes in Nigeria, it was observed that the year of infusion was 1999 with 4 initial users. Using equation 1, the number of years from 1999 till 2016 is 18 years which corresponds to the 18 points of the cumulative frequency distribution curve shown in figure 2. In figure 2, the base year, Y_0 is point $x=1$ which corresponds to 4 on the y-axis while each consecutive year, Y_x on the x-axis corresponds to the total number of users of smartphones and mobile phones x years after the base year (year of infusion). Using the auto-generated polynomial that forms the best fit (black line) for the use of smartphones and mobile phones from the cumulative distribution in table 11, the results showed that the infusion model for the use of smartphones and mobile phones can be represented using a polynomial of degree $m=2$ as shown in equation 6 which had a coefficient of determination, $R^2 = 0.9934$.

$$S(x) = 0.0582x^3 - 4.6363x \quad (6)$$

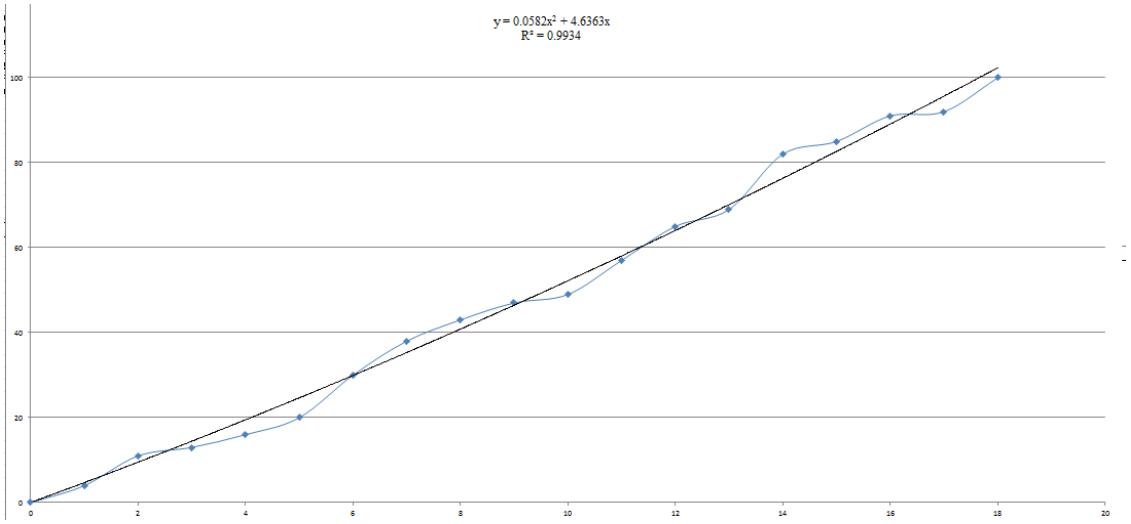

Figure 2: Polynomial fit of the infusion model for smartphones users

4.3 Infusion model for the use of SMS services

Following the results of cumulative sum of the number of users of SMS users among agricultural academic and research institutes in Nigeria, it was observed that the year of infusion was 1998 with 1 initial user. Using equation 1, the number of years from 1998 till 2016 is 19 years which corresponds to the 19 points of the cumulative frequency distribution curve shown in figure 3. In figure 3, the base year, Y_0 is point x=1 which corresponds to 1 on the y-axis while each consecutive year, Y_x on the x-axis corresponds to the total number of users of SMS x years after the base year (year of infusion). Using the auto-generated polynomial that forms the best fit (black line) for the use of SMS from the cumulative distribution in table 11, the results showed that the infusion model for the use of SMS can be represented using a polynomial of degree $m=3$ as shown in equation 7 which had a coefficient of determination, $R^2 = 0.9971$.

$$S(x) = -0.0222x^3 + 0.5872x^2 - 2.0429x \quad (7)$$

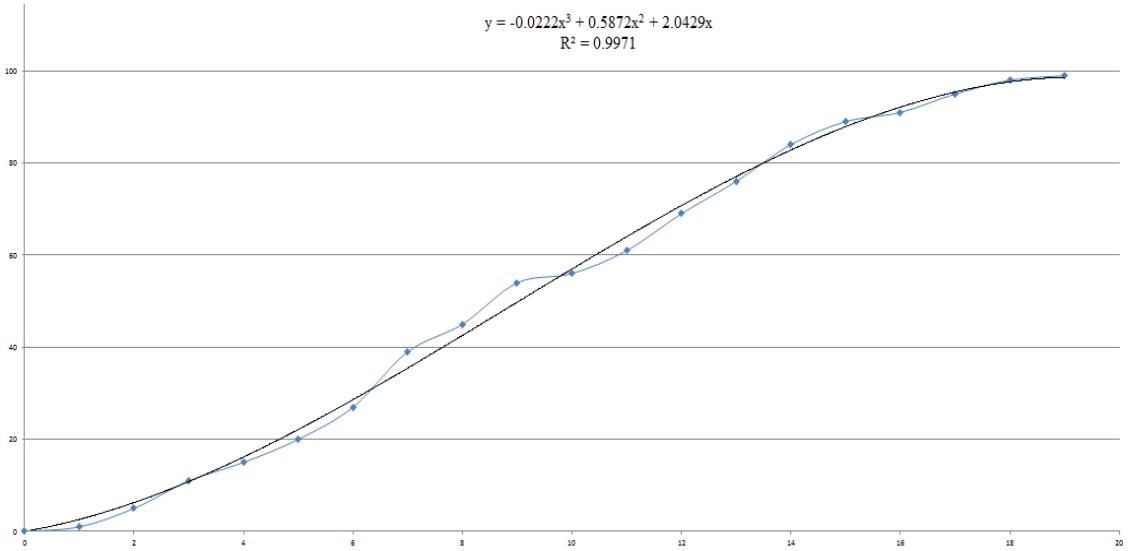

Figure 3: Polynomial fit of the infusion model for sms users

4.4 Infusion model for the use of e-mail services

Following the results of cumulative sum of the number of users of e-mail users among agricultural academic and research institutes in Nigeria, it was observed that the year of infusion was 1995 with 4 initial users. Using equation 1, the number of years from 1995 till 2016 is 22 years which corresponds to the 22 points of the cumulative frequency distribution curve shown in figure 4. In figure 4, the base year, Y_0 is point x=1 which corresponds to 1 on the y-axis while each consecutive year, Y_x on the x-axis corresponds to the total number of users of e-mail x years after the base year (year of infusion). Using the auto-generated polynomial that forms the best fit (black line) for the use of e-mail from the cumulative distribution in table 11, the results showed that the infusion model for the use of e-mail can be represented using a polynomial of degree $m=4$ as shown in equation 8 which had a coefficient of determination, $R^2 = 0.9963$.

$$S(x) = -0.00004x^4 - 0.0121x^3 + 0.487x^2 - 0.0825x \quad (8)$$

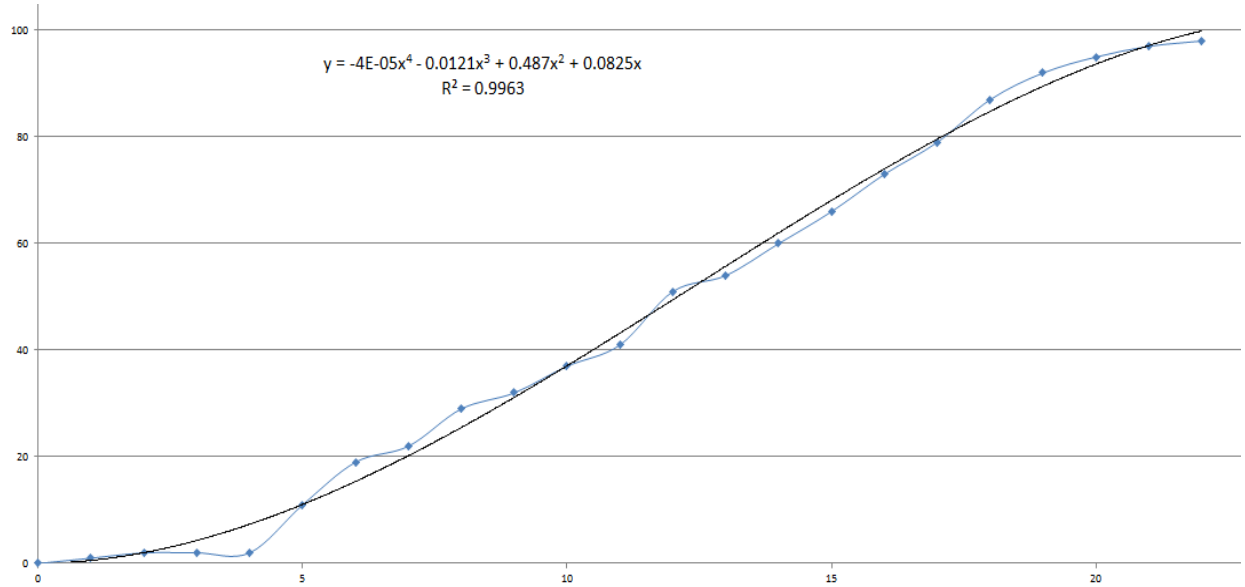

Figure 4: Polynomial fit of the infusion model for e-mail users

4.5 Infusion model for the use of computers

Following the results of cumulative sum of the number of users of computers users among agricultural academic and research institutes in Nigeria, it was observed that the year of infusion was 1994 with 2 initial users. Using equation 1, the number of years from 1994 till 2016 is 23 years which corresponds to the 23 points of the cumulative frequency distribution curve shown in figure 5. In figure 5, the base year, Y_0 is point x=1 which corresponds to 2 on the y-axis while each consecutive year, Y_x on the x-axis corresponds to the total number of users of computers x years after the base year (year of infusion). Using the auto-generated polynomial that forms the best fit (black line) for the use of computers from the cumulative distribution in table 11, the results showed that the infusion model for the use of computers can be represented using a polynomial of degree $m=4$ as shown in equation 9 which had a coefficient of determination, $R^2 = 0.9951$.

$$S(x) = -0.0002x^4 - 0.0029x^3 + 0.2943x^2 + 1.3946x \quad (9)$$

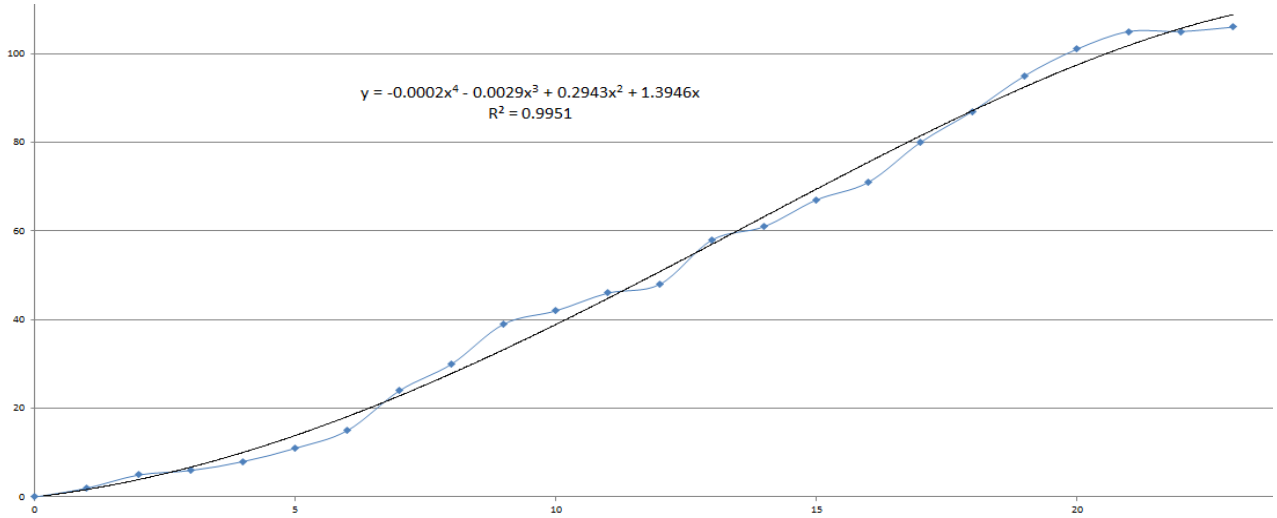

Figure 5: Polynomial fit of the infusion model for computer users

4.6 Infusion model for the use of office hardware

Following the results of cumulative sum of the number of users of office hardware users among agricultural academic and research institutes in Nigeria, it was observed that the year of infusion was 1994 with 6 initial users. Using equation 1, the number of years from 1994 till 2016 is 23 years which corresponds to the 23 points of the cumulative frequency distribution curve shown in figure 6. In figure 6, the base year, Y_0 is point x=1 which corresponds to 6 on the y-axis while each consecutive year, Y_x on the x-axis corresponds to the total number of users of office hardware x years after the base year (year of infusion). Using the auto-generated polynomial that forms the best fit (black line) for the use of office hardware from the cumulative distribution in table 11, the results showed that the infusion model for the use of office hardware can be represented using a polynomial of degree $m=4$ as shown in equation 10 which had a coefficient of determination, $R^2 = 0.9961$.

$$S(x) = -0.001x^4 + 0.0395x^3 + 0.4042x^2 + 4.2235x \quad (10)$$

4.8 Infusion model for the use of wireless technologies

Following the results of cumulative sum of the number of users of office hardware users among agricultural academic and research institutes in Nigeria, it was observed that the year of infusion was 1998 with 1 initial user. Using equation 1, the number of years from 1998 till 2016 is 19 years which corresponds to the 19 points of the cumulative frequency distribution curve shown in figure 7. In figure 7, the base year, Y_0 is point x=1 which corresponds to 1 on the y-axis while each consecutive year, Y_x on the x-axis corresponds to the total number of users of office hardware x years after the base year (year of infusion). Using the auto-generated polynomial that forms the best fit (black line) for the use of office hardware from the cumulative distribution in table 11, the results showed that the infusion model for the use of office hardware can be represented using a polynomial of degree $m=4$ as shown in equation 11 which had a coefficient of determination, $R^2 = 0.9983$.

$$S(x) = -0.0028x^4 + 0.0784x^3 - 0.355x^2 + 1.967x \qquad (11)$$

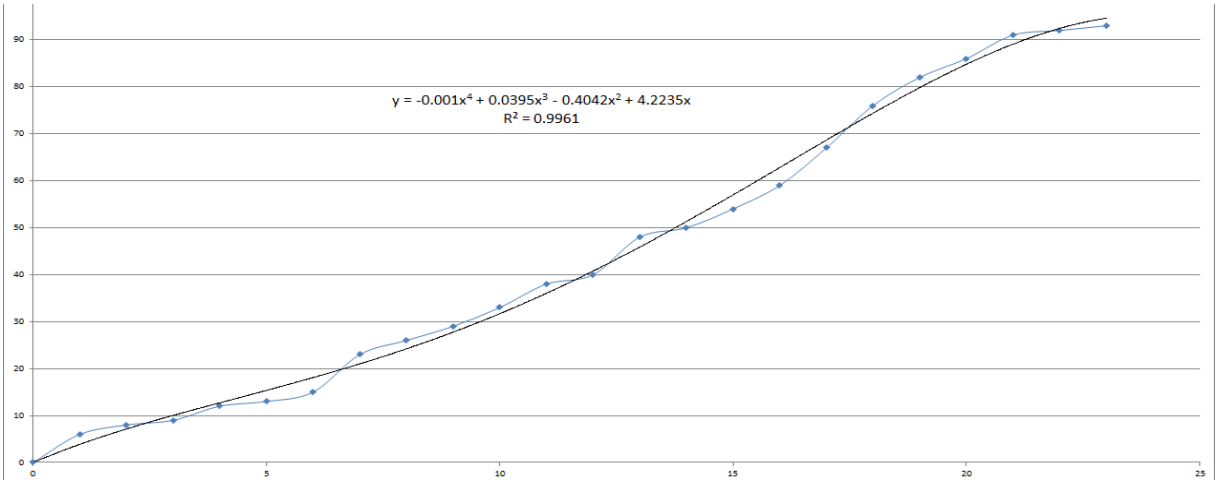

Figure 6: Polynomial fit of the infusion model for office hardware users

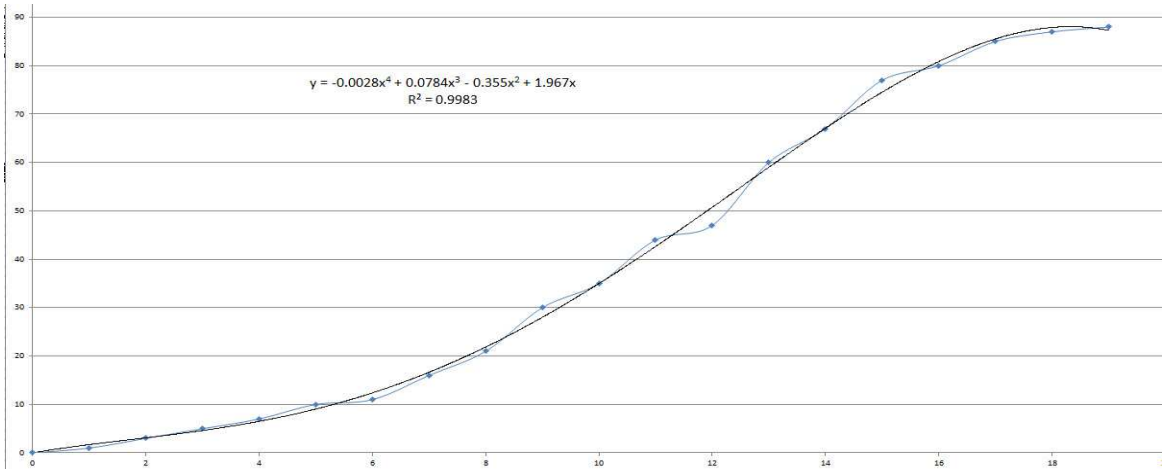

Figure 7: Polynomial fit of the infusion model for wireless technologies users

4.9 Infusion model for the use of GPS

Following the results of cumulative sum of the number of users of GPS users among agricultural academic and research institutes in Nigeria, it was observed that the year of infusion was 2004 with 3 initial users. Using equation 1, the number of years from 2004 till 2016 is 13 years which corresponds to the 13 points of the cumulative frequency distribution curve shown in figure 8. In figure 8, the base year, Y_0 is point x=1 which corresponds to 3 on the y-axis while each consecutive year, Y_x on the x-axis corresponds to the total number of users of GPS x years after the base year (year of infusion). Using the auto-generated polynomial that forms the best fit (black line) for the use of GPS from the cumulative distribution in table 11, the results showed that the infusion model for the use of GPS can be represented using a polynomial of degree $m=6$ as shown in equation 12 which had a coefficient of determination, $R^2 = 0.9962$.

$$S(n) = 0.0003x^6 - 0.0089x^5 + 0.087x^4 - 0.1999x^3 - 0.634x^2 + 5.0517x \quad (12)$$

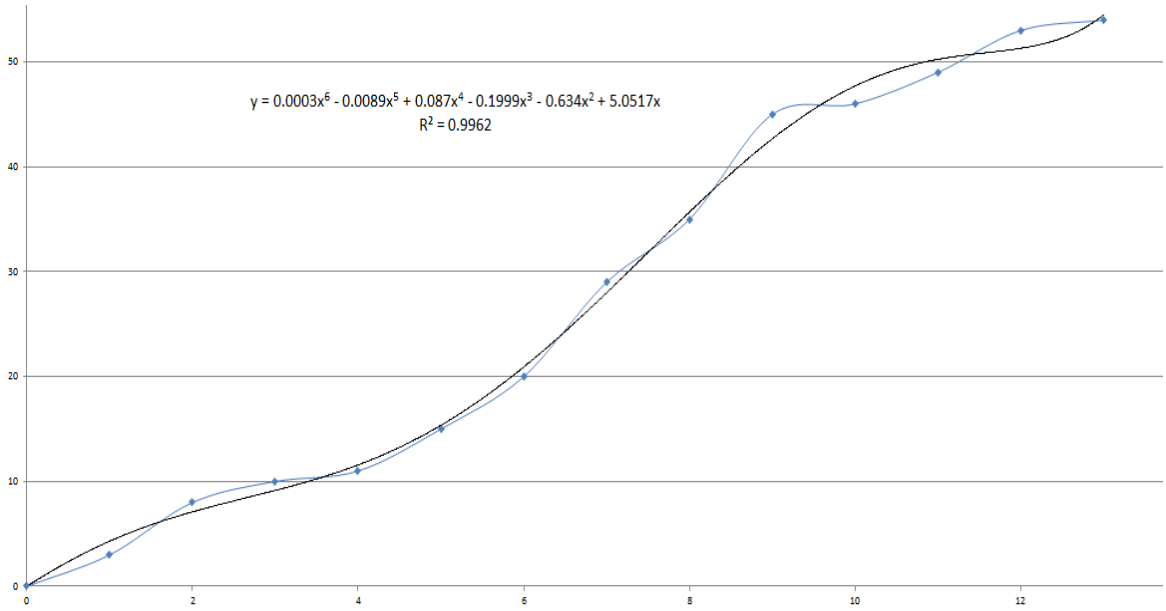

Figure 8: Polynomial fit of the infusion model for users of GPS users

4.10 Infusion model for the use of GIS

Following the results of cumulative sum of the number of users of GIS users among agricultural academic and research institutes in Nigeria, it was observed that the year of infusion was 2004 with 3 initial users. Using equation 1, the number of years from 2004 till 2016 is 13 years which corresponds to the 13 points of the cumulative frequency distribution curve shown in figure 9. In figure 9, the base year, Y_0 is point x=1 which corresponds to 3 on the y-axis while each consecutive year, Y_x on the x-axis corresponds to the total number of users of GIS x years after the base year (year of infusion). Using the auto-generated polynomial that forms the best fit (black line) for the use of GIS from the cumulative distribution in table 11, the results showed that the infusion model for the use of GIS can be represented using a polynomial of degree $m=4$ as shown in equation 13 which had a coefficient of determination, $R^2 = 0.9960$.

$$S(x) = -0.0065x^4 + 0.1323x^3 - 0.5473x^2 + 2.4974x \quad (13)$$

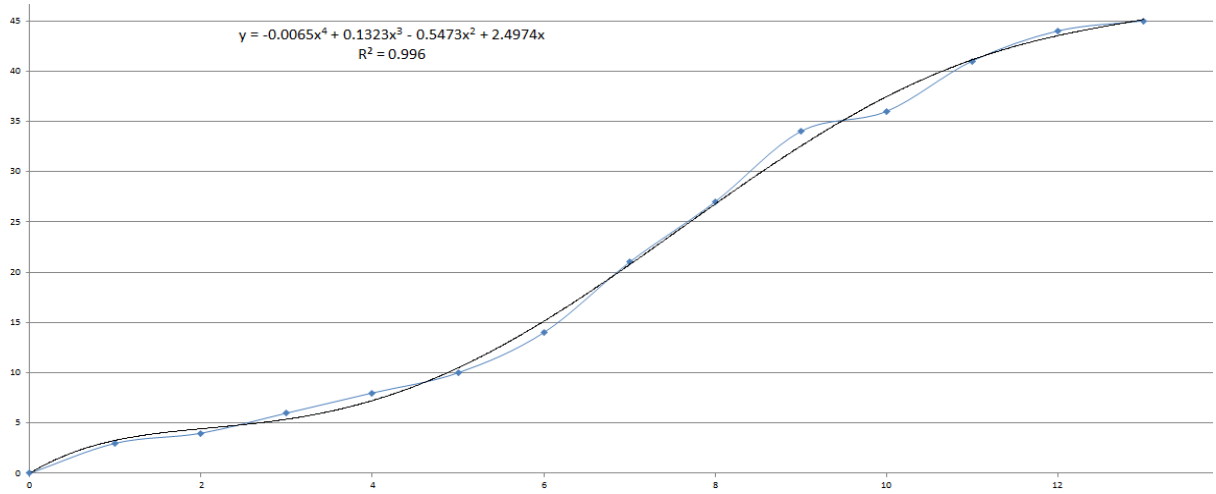

Figure 9: Polynomial fit of the infusion model for GIS users

4.11 Infusion model for the use of RFID technologies

Following the results of cumulative sum of the number of users of RFID technologies users among agricultural academic and research institutes in Nigeria, it was observed that the year of infusion was 2004 with 3 initial users. Using equation 1, the number of years from 2004 till 2016 is 13 years which corresponds to the 13 points of the cumulative frequency distribution curve shown in figure 10. In figure 10, the base year, Y_0 is point x=1 which corresponds to 3 on the y-axis while each consecutive year, Y_x on the x-axis corresponds to the total number of users of RFID technologies x years after the base year (year of infusion). Using the auto-generated polynomial that forms the best fit (black line) for the use of RFID technologies from the cumulative distribution in table 11, the results showed that the infusion model for the use of RFID technologies can be represented using a polynomial of degree $m=4$ as shown in equation 14 which had a coefficient of determination, $R^2 = 0.9846$.

$$S(x) = -0.0028x^4 + 0.0784x^3 - 0.355x^2 + 1.967x \qquad (14)$$

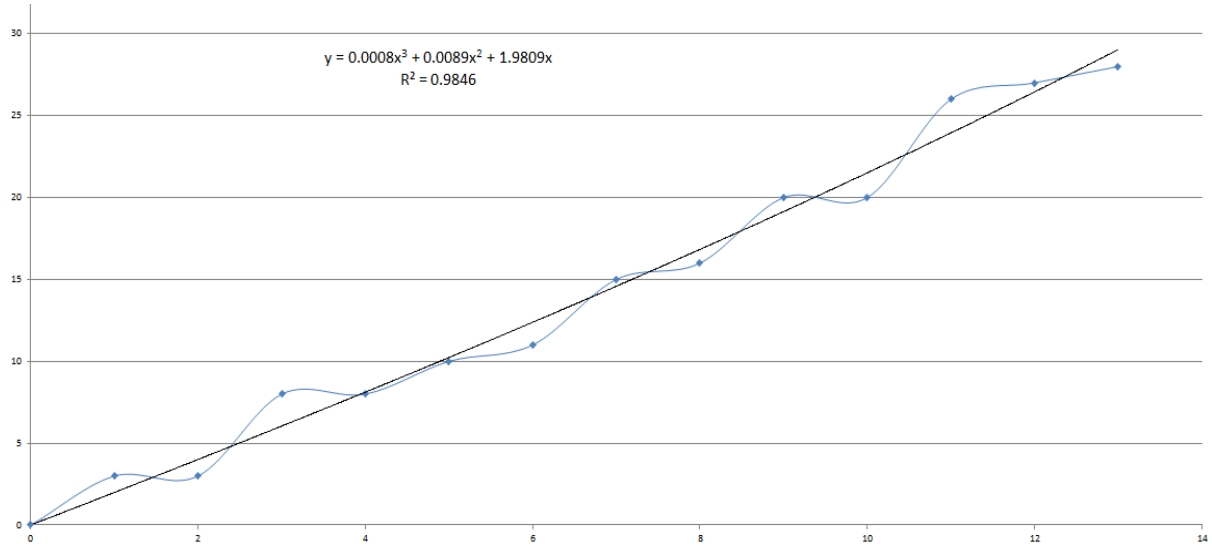

Figure 10: Polynomial fit of the infusion model for RFID technologies users

4.12 Infusion model for the use of automated systems

Following the results of cumulative sum of the number of users of automated systems users among agricultural academic and research institutes in Nigeria, it was observed that the year of infusion was 2004 with 2 initial users. Using equation 1, the number of years from 2003 till 2016 is 14 years which corresponds to the 14 points of the cumulative frequency distribution curve shown in figure 10. In figure 10, the base year, Y_0 is point x=1 which corresponds to 2 on the y-axis while each consecutive year, Y_x on the x-axis corresponds to the total number of users of automated systems years after the base year (year of infusion). Using the auto-generated polynomial that forms the best fit (black line) for the use of automated systems from the cumulative distribution in table 11, the results showed that the infusion model for the use of automated systems can be represented using a polynomial of degree $m=3$ as shown in equation 15 which had a coefficient of determination, $R^2 = 0.9876$.

$$S(x) = -0.0024x^3 + 0.0725x^2 + 1.3829x \qquad (15)$$

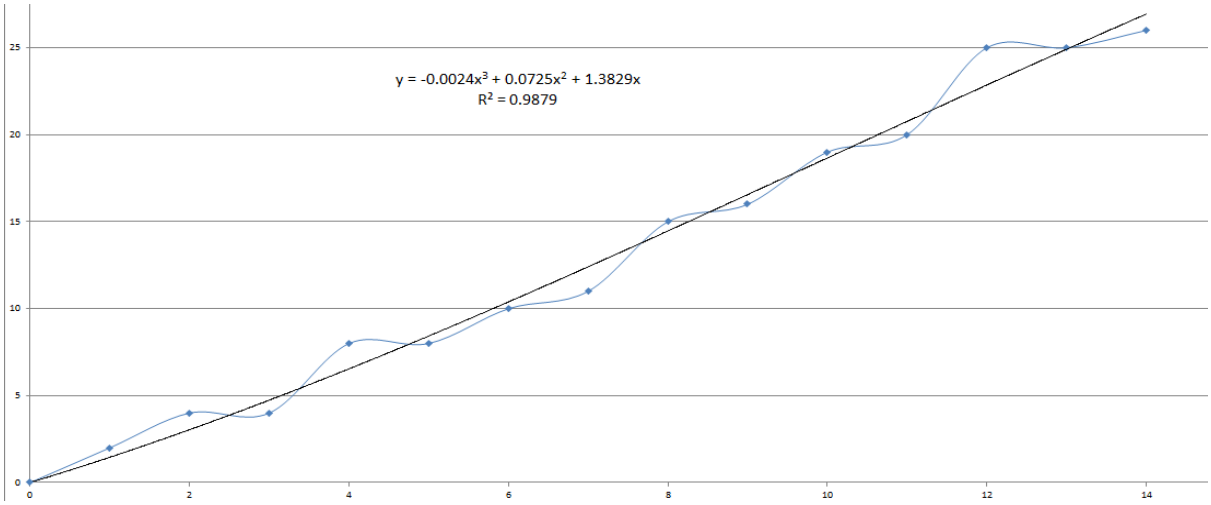

Figure 11: Polynomial fit of the infusion model for users of automated systems

5. CONCLUSIONS

This study revealed the infusion of ICT devices used among respondents selected from five (5) agricultural research and academic institutions in Nigeria. Based on the findings of this study, the ICT devices identified to be used among the 169 respondents chosen for this study were: Smartphones (tablets and/or notebooks + mobile apps), Short Messaging Service (SMS), electronic mail (e-mail), computers (servers, PCs and/or laptops), office hardware (photocopy, scanners, fax and printers), wireless technologies (Bluetooth, Wi-Fi hotspots etc.), global position satellites (GPS), Geographical Information Systems (GIS), Radio-frequency Identification (RFID) technology and automated systems (e.g. factory plant robots).

Following the analysis of the information collected using 200 questionnaires distributed with 169 filled complete information among the respondents of the agricultural institutions selected for this study, a number of observations were made. Majority of respondents who used ICT were married male within the age group of around 31 – 40 years of age with around 6 – 10 years' work experience. It was also observed from the study that majority of the workers used ICT tools at work for the discharge of duties at the office and during field work.

The results of this study also showed that the adoption of computers and smartphones and mobile phones influenced the adoption of SMS, e-mails and wireless technologies in the discharge of their respective duties.

The results of the study also showed that the earliest ICT tools adopted were: computers, office hardware, and e-mail technology in the early 90s and SMS, wireless technologies and smartphones in the late 90s while by the beginning of the 21st century, GPS, GIS RFID and automated systems were adopted for which smartphones and computers had the highest number of users. The results also showed that the infusion model developed using a polynomial expression of a certain degree m in terms of x - the number of years after ICT infusion/adoption could be used to estimate the number of users adopting ICT.

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