THE ROLE OF MATHEMATICAL SCIENCES IN SUSTAINABLE DEVELOPMENT GOALS

BOOK *of* PROCEEDINGS

International Conference on
Contemporary Developments in
Mathematical Sciences
in Honour of
Professor Kayode Rufus Adeboye

Department of Mathematics
Federal University of Technology, Minna

70th Birthday & Retirement from Service

Professor Kayode Rufus Adeboye

B.Sc. (Lagos), M.Phil. (Reading), Ph.D. (Ilorin), FMAN, FNMS, FAC

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PROFESSOR Kayode Rufus Adeboye

B.Sc. (Lagos), M.Phil. (Reading), Ph.D. (Ilorin), FMAN, FNMS, FAC

PROFILE

EARLY LIFE AND EDUCATION

Professor Kayode Rufus Adeboye was born in Egbe-Ekiti on April 12th, 1949 to Chief and Mrs. Daniel O. Adeboye. He attended Ekiti Parapo College, Ido-Ekiti, for his Secondary School Education. For his tertiary education, he attended Oluloyo College of Education, Ibadan, Nigeria from 1964 to 1966. He commenced his undergraduate degree programme in 1968 at the University of Lagos and got Western State University scholarship in 1969. He graduated with a B.Sc. with Honours (Second Class Upper Division) in Mathematics in 1971 and following his brilliant performance in his undergraduate course, he was awarded a University of Lagos Postgraduate Scholarship in 1972 and 1973, AFGRAD Scholarship, USA in 1974, Federal Government Postgraduate Scholarship in 1974 and University of Ife fellowship in 1976 to continue his studies at University of Reading, Reading, England. From 1973 to 1975 he worked as a Tutor at the University of Ife now Obafemi Awolowo University.

Professor Kayode Rufus Adeboye left Nigeria in 1975 at the age of 26 on scholarship to pursue postgraduate studies in Mathematics at the University of Reading, Reading, England. On successfully completing this course in 1978, he returned to Nigeria and continued his academic

work as Assistant Lecturer (1978 - 1980) and Lecturer II (1980 - 1982) at the University of Ife and Research Officer (1982 - 1989) at the National Teacher Institute, Kaduna, Nigeria. He embarked on his PhD degree in Mathematics at the University of Ilorin, Nigeria in 1988 supervised by Prof. M. A. Ibiejugba of blessed memory.

Kayode Rufus Adeboye was awarded the PhD degree in Mathematics by the University of Ilorin in 1991 at the age of 42.

He later joined the service of Federal University of Technology, Minna in 1989 as Senior Lecturer in the Department of Mathematics/Computer Science and rose to the rank of a Professor of Mathematics in 1997. He taught mathematics at the Federal University of Technology, Minna for more than 30 years.

AT THE FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

At the Federal University of Technology, Minna, he has been the thesis advisor for twelve Ph.D. students and the joint thesis advisor of many Ph.D. students with Professor N. I. Akinwande, Prof. Y. M. Aiyesimi, Prof. Y. A. Yahaya, Prof. U. Y. Abubakar and Prof. R. O. Olayiwola. He has supervised the studies of 31 M.Tech. Students, 120 postgraduate diploma students between 1994 and 2010 and more than 250 undergraduate students' projects between 1991 and 2019.

The numerous roles he has had at the Federal University of Technology, Minna include but are not limited to the following: School Time-Table Officer (1992 - 1999); Head of Department (1993 - 1999); Member, University Senate (1992 - 2019); Chairman, Computer Centre Service Board (1997 - 2002); Chairman, School Examination Malpractices Committee (1990 - 1999); Member, University Students' Disciplinary and Examination Malpractices Committee (1990 - 2007); Member, School Research Committee (1993 - 2006); Chairman, University Ceremonies Committee (1993 - 2003); Chairman, University Fees Review Committee (1998 - 2003); Member, Appointments and Promotion Committee (1997 - 2000); Chairman, Students' Crisis Investigation Committee, Federal University of Technology, Minna, Nigeria (2001); Chairman, University Staff School Management Board, Federal University of Technology, Minna, Nigeria (1999 - 2003); Chairman, Millenium Bug Committee, Federal University of Technology, Minna, Nigeria (1998 - 2002);Dean, School of Science and Science Education (1999 - 2003); Member, Committee of Deans (1993 - 2003); and Chairman, Senate Committee on Senate Standing Orders (2008).

ACADEMIC AND PROFESSIONAL QUALIFICATIONS

1. Nigeria Certificate in Education (NCE), Oluloyo College of Education, Ibadan, Nigeria. 1967
2. B.Sc. (Hons) Second Class Upper (Mathematics), University of Lagos, Nigeria. 1971
3. M.Phil. (Numerical Analysis), University of Reading, Reading, England. 1979
4. Ph.D. (Mathematics), University of Ilorin, Ilorin, Nigeria. 1991

UNIVERSITY EDUCATION (WITH DATES)

(a) University of Lagos (1968-1971)
(b) University of Reading, Reading, England (1975-1978)
(c) University of Ilorin (1988-1991)

SCHOLARSHIPS AND FELLOWSHIPS AWARDS

(a) Western State University Scholarship (1969)
(b) University of Lagos Postgraduate Scholarship (1972 and 1973)
(c) AFGRAD Scholarship, USA (1974)
(d) Federal Government Postgraduate Scholarship (1975)
(e) University of Ife Fellowship (1976)

AWARDS, HONOURS AND DISTINCTIONS

1. Fellow of Mathematical Association of Nigeria (FMAN), 1999.
2. Fellow of Nigerian Academy of Control (FAC), 2000.

3. Best Practices in University Teaching Project (BESTPUT), Mathematics National University
Commission (NUC), Abuja, Nigeria, 2002.
4. IBC's 21st Century Award for Achievement, International Biographical Centre (IBC), Cambridge, UK, 2002.
5. Outstanding Intellectuals of the 21st Century Award, International Biographical Centre (IBC),
Cambridge, UK, 2002.
6. Who's Who in the 21st Century Order of Excellence, International Biographical Centre (IBC),
Cambridge, UK, 2002.
7. IBC Living Legends Award, International Biographical Centre (IBC), Cambridge, UK, 2003.
8. Contemporary Who's Who Award, American Biographical Institute (ABI), Raleigh, NC, USA,
2003.
9. Man of the Year, American Biographical Institute (ABI), Raleigh, NC, USA, 2003.
10. American Medal of Honour, American Biographical Institute (ABI), Raleigh, NC, USA,
2004.
11. Man of the Year Representing Nigeria, American Biographical Institute (ABI), Raleigh, NC,
USA, 2009.
12. Fellow of Nigerian Mathematical Society (FNMS), 2016.

OTHER ACADEMIC ACTIVITIES AND RESPONSIBILITIES

Professor Kayode Rufus Adeboye was an External Examiner and External Assessor to many Nigeria Universities and Polytechnics. He was also the Chairman and Member, NUC Accreditation Team to many Nigeria Universities. The numerous roles he has had outside the Federal University of Technology, Minna include but are not limited to the following:

(i) Sabbatical leave, Ibrahim Badamasi Babangida University, Lapai, Nigeria (2006 - 2007) and
University of Abuja, Abuja (2014 - 2015).
(ii) Course writer, National Teachers' Institute (NTI), Kaduna, Nigeria (1988 -1994).
(iii) Supervisor, NTI-NCE by DLS, Niger state, (1990-1996).
(iv) Supervisor, University of Ibadan External Degree Programme, Niger State, (1990-997).
(v) External Moderator, Niger State College of Education, Minna, (1990- 1998).
(vi) Chief Examiner, JSS (Mathematics), National Examinations Council (NECO), (1999 - To date)
(vii) Chief Examiner, SSCE (Further Mathematics), National Examinations Council (NECO) (2012- To date).
(viii) Resource Person, Postgraduate Course on Computer Science, National Mathematical Centre (NMC), Abuja, Nigeria (1996).
(ix) Coordinator, National Mathematical Centre (NMC), Abuja Internal Conference on Computational Mathematics (1999).
(x) Resource Person, National Mathematical Centre (NMC), Abuja Research programme in Computational Mathematics (1999).
(xi) Chairman, NUC Minimum Academic Standard Curriculum Development for Basic Sciences and Computer Science (1999).
(xii) Coordinator (Mathematics Group), National Open University of Nigeria (NOUN) Course Development Workshop (2002).

(xiii) Member, NUC Minimum Academic Standard Final Year Syllabus for General Studies (2004).
(xiv) Resource Person, National Mathematical Centre (NMC), Abuja Higher Degree Programme (2004, 2007).
(xv) Editor-in-Chief, National Mathematical Centre (NMC), Abuja Seminar Proceedings (2006).
(xvi) Associate Editor, AMSE Journal, France (2005 – 2008)
(xvii) External Examiner, Master's Degree Programme, National Mathematical Centre (NMC), Abuja (2010 - 2016)
(xviii) Associate Editor, Nigerian Mathematical Society (JNMS) (2013 – To date)
(xix) External Assessor, Professorial Appointment, NDA, Kaduna (2019).
(xx) External Assessor for 2 Professorial Appointments, National Mathematical Centre, Abuja (2019)
(xxi) Dean, Faculty of Applied and Natural Sciences, Ibrahim Badamasi Babangida University, Lapai, Nigeria (2006 - 2007).

MEMBERSHIP OF LEARNED SOCIETIES

(i) Member, Nigerian Mathematical Society (NMS).
(ii) Member, Mathematical Association of Nigeria (MAN).
(iii) Member, Nigerian Computer Society (NCS).
(iv) Member, American Mathematical Society (AMS), USA.
(v) Member, International Association of Survey Statistians (IASS), Geneva, Austria.

BOARD MEMBERSHIP

(i) Member, Board of Directors, Internet Exchange Point of Nigeria (IXPN), (2007 – To date).
(ii) Member, Ministerial Committee on Privatization, Federal Ministry of Solid Minerals, Abuja,
Nigeria, (2004 - 2005).
(iii) Member, Advisory Committee, American Biographical Institute (ABI), NC, USA, (2004).
(iv) Member, University Governing Council, Federal University of Technology, Minna, Nigeria,
(2000 - 2002).
(v) Member, Management Board, National Mathematical Centre (NMC), Abuja, Nigeria, (2000 -
2004).

PUBLICATIONS

Professor Kayode Rufus Adeboye has 2 completed University funded Research projects, Inaugural lecture, 12 Book publications and over 60 Journal publications and these publications are as follows:

Completed University Funded Research Projects:

1. Adeboye, K. R. and Ayeni, R. O. (2000). Hybrid-Collocation-Galerkin Method for Differential Equations with Application to Petroleum Reservoir Mechanics.
2. Adeboye, *K.* R. and Bolarin, O. A., (2009), Application of Numerical Methods to Petroleum Reservoir Mechanics.

Inaugural Lecture:

K. R. Adeboye (2014). Mathematics, Mathematicians and Numerical Analysis: the Bridge and Bridgehead View of Nigeria with Mathematical Prism.

Book Publications:

1. K. R. Adeboye, (2006). Mathematical Methods for Science and Engineering Students, Moonlight publishers, Abuja, Nigeria.

2. K, R. Adeboye, (2006), ICT Policies Development and Applications in Nigerian Educational System, A chapter in a book written to honour Prof Okebukola, former NUC, Abuja Executive Secretary.

3. Adeboye, K. R., (1990), Nigerian Certificate in Education Course Book on Mathematics, Cycle 2, Module 1, Units 1 - 5 (Chapters on Differential Calculus), vol. 1, Published by National Teachers' Institute, Kaduna.

4. Adeboye, K. R., (1990), Nigerian Certificate in Education Course Book on Mathematics, Cycle 2, Module 5, Units 1 - 5 (Chapters on Numerical Analysis), vol. II, 71 - 95, Published by National Teachers' Institute, Kaduna.

5. Adeboye, K. R., (1991), Nigerian Certificate in Education Course Book on Mathematics, Cycle 3, Module 1, Units 6 - 10 (5 Chapters on Introductory Theory of Numbers and Polynomials), vol. 1, 23 - 53, Published by National Teachers' Institute, Kaduna.

6. Adeboye, K. R., (1992), Nigerian Certificate in Education Course Book on Mathematics, Cycle 3, Module 5, Units 6 - 10 (5 Chapters on Real Analysis), vol. II, Published by National Teachers' Institute, Kaduna.

7. Adeboye, K. R., (1993), Nigerian Certificate in Education Course Book on Mathematics, Cycle 4, Module 1, Units 1 - 3 (3 Chapters on Vector Spaces), vol. 1, 1 - 18, Published by National Teachers' Institute, Kaduna.

8. Adeboye, K. R., (1993), Nigerian Certificate in Education Course Book on Mathematics, Cycle 4, Module 2, Units 1 - 5 (5 Chapters on Linear Algebra), vol. I. 71 - 116, Published by National Teachers" Institute, Kaduna.

9. Adeboye, K. R., (1997), CO-Author, MAN Textbook of Mathematics for Science Students in Nigerian Universities, Cornerstone Publications, Ilorin.

10. Adeboye, K. R., (1998), CO-Author, Question and Answer Scries for SSCE by MAN, Cornerstone Publications, Ilorin 11. Adeboye, K. R., (1999), CO-Author, MAN Question and Answer Series for JAMB candidates, Cornerstone Publications, Ilorin.

12. Adeboye, K. R., (2005), Chairman, Editorial Board, Published Conference Proceedings, National Mathematical Centre, Abuja.

Journal Publications:

1. Adeboye, K.R. and Salisu A. (2017). A Re-definition of the Stability Condition for the Parabolic Scheme. *International Journal of Science and Technology (IJST) Uk Publication,* (Accepted for Publication).
2. Adeboye, K.R. and Salisu A. (2017), An H^2-Galerkin Method for the Solution of Parabolic Boundary Value Problems. *Journal of the Nigerian Association of Mathematical Physics,* Vol.41, Pp 453 - 456.
3. Adeboye, K.R., Abiodun A.P. and Salisu A. (2017) A Nonhydrostatic Atmospheric Model for
Numerical Weather Prediction, Using Minna, Nigeria as aCase Study. *NMC Journal* (Presented for Publication).
4. Etuk, Stella Oluyemi and Adeboye, K.R. (2017), Refinements of the Egyptian Fraction Finite Difference Scheme for First and Second Initial Value Problems. *Journal of Science, Technology and Mathematics Education (JOSTMED).*Vol. II
5. K. A Al-Mustapha and Adeboye, K. R. (2017),Variational-Composite Hybrid Fixed Point Iterative Method for the Solution of three-point Boundary Value Problems of Fourth Order Differential Equations. *Journal of the Nigerian Association of Mathematical Physics,* Vol.39, Pp 111-118.
6. Kilicman, Adeboye, K.R. and Wadai, M. (2016), A Variational Fixed Point Iterative Technique for the Solution of Second Order Differential Equations. Malaysian *Journal of Sciences* Vol.35(1), Pp 29 - 36.
7. Adeboye, K.R. and Salisu A. (2016), Super Convergent H^2-Galerkin Method for the Solution of Parabolic Initial Value Problems. *Journal of the Nigerian Association of Mathematical Physics,* Vol.38, Pp 33 - 40.
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15. Adeboye, K. R., Yahaya, Y. A., & Lanlege, D. I. (2013). Effective way of noise smoothing during image processing using multi-scale proportional integral derivative (PID) filter controller. *International Research Journal oj Science, Engineering & Technology (IRJSET), 2* (2), 17-24.

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England.

CONCLUSION

We'll end this biography quoting from his inaugural lecture about the lack of knowledge of mathematics on the part of students –

Mathematics is needed for the development, maintenance, understanding, quantification and record keeping of our society. Since no society is static and the desire for higher heights in science and technology will continue to increase, the demand on mathematics will ever be on the increase. In view of the universal importance of mathematics to man on earth, it becomes compulsory that those charged with education should find ways of involving more of the younger generation of our days in the study of mathematics. Any nation that cannot get school children involved and be interested in mathematics, will never attain true social, economic, scientific and technological independence. Such a nation will continue to look up to those other nations of the world which through sound mathematics education have become world powers, with sound economic, scientific and technological bases, for her needs, even in matters of political guidance.

The educational system in Nigeria as at now is in a state of comma as a result of neglect. The rule then was "acquire now, neglect or even abandon later". The government acquired all the educational institutions from primary to tertiary level in the late 1970's only to neglect or even abandon them in the early 1980's. Some states established universities only to boost their egos. They never considered the cost of running a university before establishing one. They would want to hire lecturers at the rate of two for a kobo! I wish to advise the NUC to add to the conditions to be satisfied before establishing a university that the minimum conditions of service acceptable are those obtainable at the federal universities and this will put paid to the unbridled histrionics often engaged in by the owners.

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K. R. Adeboye (2014). *Mathematics, Mathematicians and Numerical Analysis: the Bridge and Bridgehead View of Nigeria with Mathematical Prism*. 27th Inaugural Lecture series, Federal University of Technology, Minna, Nigeria.

TABLE OF CONTENT

MATHEMATICAL MODELLING

FLUID DYNAMICS

PURE MATHEMATICS

STATISTICS, OPTIMIZATION AND EDUCATION

powers to arrest suspects, detain on process of investigation with necessary assistance/support from Supervisors and the training already got to carry out investigations, prosecution and institutionalization of legal proceedings. Maintenance of religious bodies, trade organizations; checkmating the acts of terrorism social activities, disaster emergency monitoring and management; Rescuing of disaster victims; information and intelligence gathering and management has been well actualized; Rehabilitation of disaster victims; mediate settlement of disputes of members and the public; good knowledge to handle civil matters and cases.

Be that as it may, 60.67% of the personnel are yet to be trained as Armed squad. NSCDC do not have desired facilities for arms training. Regarding grading, Supervisors are always fair and just in assigning jobs and duties to staff as well as appraisal of staff performances for promotions, up grading, re-grading and conversion. Corps report to work timely and stay till the end of the shift or duty. Arrival times, observance of time limits for breaks and launches are also considered. Remuneration is not commensurate with the tasks assigned to them therefore, asking for a better condition of service. Promotions are not very regular, not well effected and most times notional without financial benefits. No good incentives to enhance productivity, allowances are not paid as at when due, hence, poor performance. Lack of motivation results to inefficiency, distrust, hate and poor or no passion for the job and profession. Similarly, the provision of needed equipment like vehicles, arms, good communication gadgets was seen as a problem for efficient operation and performance on the part of the personnel.

10. RECOMMENDATIONS

1. Government of the day in conjunction with the management of NSCDC should improve on the Remuneration of the corps.

2. Provision of good incentives, motivational gifts that all arouse curiosity of exercising duties and enhance productivity.

3. Prompt payment of salaries, allowances and other benefits accruing to the personnel.

4. Regular conduction of recruitment, promotion interviews as well as the implementation of the promotions.

5. Provision of equipment and facilities for effective performance of schedules of duties.

6. Proper communication between personnel and Supervisors as well as the Management of the Corps.

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Green, L. & Kolesar, P. (2004), ''Improving emergency responsiveness with Management Science''. *Management Science, Vol. 50*, 1001-1014.

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E09: A Stochastic Model for Rice Yields Forecast

*[1]Mohammed Yahaya and [2]Lawal Adamu

*[1]*Department of Mathematics, Federal University of Technology Minna*

[2]*Department of Mathematics, Federal University of Technology Minna*

*Email: *[1]yahayamohammed1986@gmail.com and [2]Lawal.adamu@futminna.edu.ng*

Abstract

Rice (Oryza sativa) is one of most consumed food crops in Nigeria and in around the word. Demand for rice has been increasing at fast rate in Nigeria due to population growth and the banning of its importation in to the country has further led to its shortage in supply. This research is poised to provide necessary information to the government to boost rice production in the country. In view of this, a stochastic mathematical model that makes forecast of rice yields with respect to major climatic elements (Rainfall and Temperature) has been developed and implemented in Niger State. The relevant data used in this research were collected from the Niger state Bureau of statistics over a period of 16years (2001-2016). Validity test for the model was conducted which indicates 80% accuracy, this shows that the model is reliable and dependable. Both the validity test and the future forecast of the model showed prevalence of high rice yields, this shows that Niger State is a better place for rice farming. Therefore, results from the study is an important information to Federal Government to boost local rice production in the country.

Keywords: Hidden Markov Model, Stochastic Model, Rice, Niger State, Probability, Baum-Welch Algorithm, yields

INTRODUCTION

The banning of importation of rice into the country coupled with population growth has led to severe shortage in its supply. Hence, this research is aimed at developing a stochastic model for rice yields forecast with a view of providing necessary information to the government to boost local rice production in the country. Rice is the staple food for more than three billion people worldwide. Rice area accounted for approximately 11.5% of the world's arable land area and it provides almost 19% of the global dietary energy in recent times and its annual average consumption per capita is about 65 kg (Ajith *et al.,* 2017). Therefore, rice area mapping and forecasting is vital for food security, where demands often exceed production due to an ever-increasing population. The aim of yield forecasting, is to give a precise, scientifically sound and independent forecasts of crops' yield as early as possible during the crops' growing season by

considering the effect of the weather and climate (Basso, 2013). Timely and accurate estimation of rice areas and forecasting can provide important information for governments, planners, and decision makers in formulating policies with regard to import or export and in the event of shortfall or surplus (Mostafa, 2015).

Rice (Oryza sativa L.) is a primary food for more than three billion people worldwide (Khush, 2005). It is cultivated on about 11.5% of the world's arable land during 2012, however more than 88% production is observed in Asian countries. In the recent decades, two major issues like population growth in particular to the rice consuming countries where ~60% of the world's population lives and climate change put enormous pressure on the rice demand, Intergovernmental Panel on Climate Change (IPCC, 2014). As such, understanding (in other words, forecasting) the amount of rice production prior to the end of growing season is critical in order to ensure food security (Bastiaanssen & Ali, 2003; Nuarsa *et al*., 2012; Huang *et al*., 2013; Son *et al*., 2013). This sort of forecasting may help the governments, planners, and decision makers to formulate appropriate policies to: quantify either how much to import in the event of shortfall or optionally to export in case of surplus (Noureldin *et al.,* 2013). Rice is one of the most important crops in terms of human consumption (as opposed to animal feed) and is produced in 95 countries across the world (Maclean *et al*., 2002). It is the staple food in many countries, accounting for more than 40% of global food production. People in the majority of countries in Asia depend on rice as their main source of nutrition, as well as for income and employment (Maclean *et al*., 2002; Makino, 2011).Rice has been a major contribution to the financial income of many Asian countries as shown in the statistics, 50 % per annum is contributed to countries economy (Fahmi *et al*., 2013). Henceforth, numerous experiments were carried out to create a good quality paddy and to expand its yield due to increase demand in food. Due to consistent climate change some part the

paddy soil are prone to metal contamination (Sow *et al*., 2013).

Reported in (Dahikar *et al*., 2014) is a study of basic requirements for applications of ANNs in yield prediction. Simple network architectures, with one hidden layer and back propagation of errors were tested for different predictors and crops, like cotton, sugarcane, wheat, rice and others. Soil parameters detected to be relevant for crop yield prediction were PH and concentrations of nitrogen, phosphate, potassium, organic carbon, calcium, magnesium, sulphur, manganese, copper and iron. In terms of atmospheric predictors, temperature, rainfall and humidity were the relevant features detected.

Monisha *et al*. (2005) developed a model for corn and soybean yield forecasting with climatic aspect by applying artificial neural network. They have considered the rainfall, Maryland corn and soybean yield data and predict the corn and soybean yield at state, regional and local levels by applying both the artificial neural network technique and the multiple linear regression model. Lastly they compared both the techniques and conclude that the ANN model gives more accurate yield prediction than the multiple linear regressions. Saran *et al*., (2014) proposed a new approach to estimate rice cultivation and harvest dates by using 8-day composite normalized

difference vegetation index (NDVI) derived from Moderate Resolution Imaging Spectroradiometer (MODIS) data. In their work, they divided the rice growth state into 4 states, namely, nothing, growing, mature and harvest state and applied Hidden Markov Model (HMM). Then, they assigned the state to the NDVI time-series data by using the Viterbi algorithm. By using those derived state, they were able to estimate the rice cultivation and harvest dates. The date estimation results were compared with the ground truth data to access the accuracy and they found that the average cultivation dates and harvest dates to have errors of 15.48 days and 6.525 days, respectively. They derived a simple linear regression model for wheat yield estimate and forecast based on NDVI images during the wheat grain filling period. They validated their results against official data and found good correlations between the two.

MATERIAL AND METHOD

Study Area and Data source: The data used in this research work, were collected from the Niger State Bureau of Statistics for the period of 16 years (2001 – 2016). Niger state with a population of 5,556,247 million people (National population commission, 2016) is located in the North central zone along the Middle Belt region of Nigeria. It is classified as one of the largest states in the country, spanning over 86,000 km^2 in land area with 80% of the land mass conducive for agriculture (Tologbonse, 2008).

Hidden Markov Model: A Hidden Markov Model (HMM) is a double stochastic process in which one of the stochastic processes is an underlying Markov chain which is called the hidden part of the model, the other stochastic processes is an observable one. Also a HMM can be considered as a stochastic process whose evolution is governed by an underlying discrete (Markov chain) with a finite number of state which are hidden, i.e. not directly observable (Enza, Daniele, 2007 and Lawal, 2017). Hidden Markov Model is characterized by the following

N= number of state in the model

M= number of distinct observation symbols per state

Q = a state sequence of length T taking values from S,

$$Q = q_1, q_2, q_3, .. q_T \quad (1)$$

O = an observation sequence consisting of T observations.

$$O = o_1, o_2, o_3, .. o_T \quad (2)$$

$A = \{a_{ij}\}$, a transition probability matrix A, where each a_{ij} represents the probability of moving from state s_i to state s_j, with $\sum_{j=1}^{N} a_{ij} = 1$

$B = \{b_j(o_t)\}$, observation probability matrix

Where

$b_j(o_t) = p(o_t \mid q_t = s_j)$ is the probability that the symbol O_t is emitted when the system is in state s_j

If the observation is continuous a probability density function is used as follows:

$$\int_{-\infty}^{+\infty} b_j(x)dx = 1 \qquad (3)$$

$\pi = \{\pi_j\}$

An initial probability distribution, where π_i

Indicates the probability of starting in state s_i.

Also,

$\sum_{i=1}^{N} \pi_i = 1.$

The parameters of hidden of Markov model (HMM) denoted by

$$\lambda = (A, B, \pi) \qquad (4)$$

Model Formulation: Hidden Markov Model is used to examine the impact of rainfall and temperature in forecasting rice yield**.** The quantity of rice yield to a great extent relies upon these climatic components they contribute colossally to rice yield in a growing years. But we can't ordinarily quantify how every one of them contribute to the general yield (the quantity of rice yield). The quantity of rice yield relies upon them and their measure are not static or deterministic but they vary randomly from year to year, which makes the measure of rice yield in each growing year to change.

This circumstance follows a doubly stochastic process, with the measure of rice yield per hectare as the observation of the HMM depending on the state (measure of rainfall and temperature). In perspective on this, we have taken the measure of rice yield per hectare within a growing year as an emission of the HMM while the measure of rainfall and temperature within a similar period is taken as state of our model. We make the following assumptions.

1. The transition between the states is governed by first order Markov reliance as represented by equation (5)

$$P\{X_{n-1}=J|X_o=i_o,..X_{n-2}=i_{n-2},X_{n-1},=i_{n-1},X_n=i\}=P_{ij} \quad (5)$$

2. The probability of conveyance of generating current observation symbol depends on current state, as represented by equation (6)

$$P(O \mid Q,\lambda) = \prod_{t=1}^{T} P(o_t \mid q_t,\lambda) \quad (6)$$

3. Quantity of rainfall is viewed as low in the event that it is underneath 193.65mm
4. Quantity of rainfall is viewed as high in the event that it is above 194.65mm
5. Measure of temperature is viewed as low in the event that it is underneath 27.95^0c
6. Measure of temperature is viewed as high in the event that it is above 28.95^0c
7. Quantity of rice yield is viewed as low on the off chance that it is underneath 2.986 metric tons
8. Quantity of rice yield is viewed as high in the event that it is above 3.992 metric tons
9. Quantity of rice yield is viewed as moderate in the event that it is in the range of (2.986-3.992) metric tons

Following (Lawal, 2017), we have the following states and observations for our model

State 1: low rainfall and low temperature

State 2: low rainfall and high temperature

State 3: high rainfall and low temperature

State 4: high rainfall and high temperature

Observations.

L = O_1 = low yield

M = O_2 = moderate yield

H = O_3 = high yield

The classification of states and the observations, and the assumption made in this work are based on the study area and the data obtained

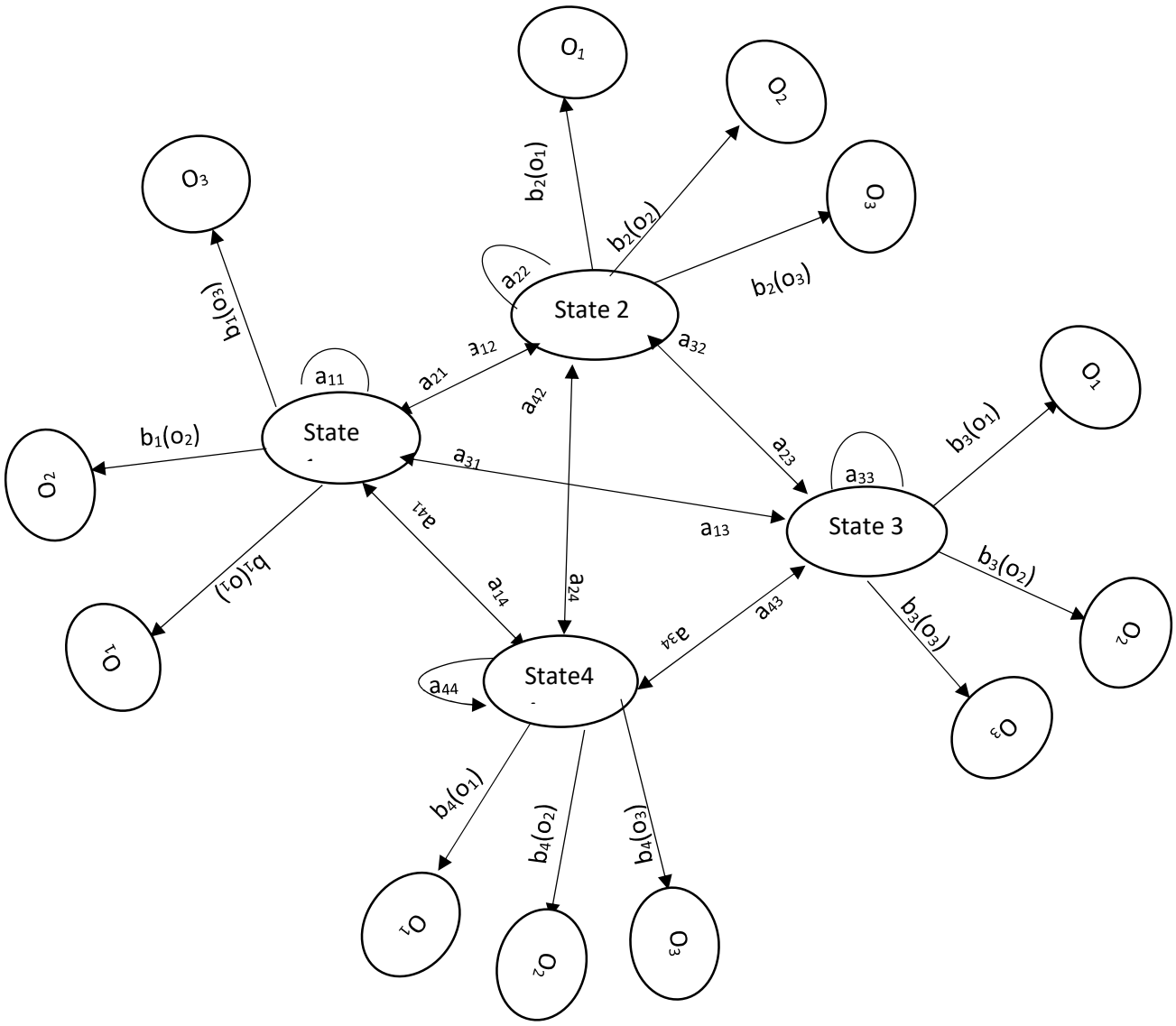

Figure 1: Transition Diagram of the Rice Yield Model

Making Prediction with the Model: Making prediction with the model is done along with the training of parameters of the model. The parameters of the model are initialized then trained using Baum-Welch algorithm to attend maximum likelihood. The forward probability of the training observation sequence is determined from time t=1 to time T using Forward Algorithm (Rabiner, 1989 and Lawal, 2017). To predict the next state at time T+1 and its observation given the present state at time T, we calculate forward probability for every conceivable observation of the states, at that point, the sequence with most elevated value of the forward probability at time T+1 is taken as predicted state and its observation. The prediction is made for the following three years (year 2 at time T+2, year 3 at time T+3 and year 4 at time T+4).

RESULTS AND DISCUSSION

Application of the Hidden Markov Model for Rice Yields Forecast. The data used in this illustration was collected from the archive of Niger State Bureau of Statistics for the period of 16 years (2001-2016).The summary of the data is presented in Table 1

Table 1: The States and Observations of the Hidden Markov Model for Period of sixteen years

Years	States	Observations
2001	1	L
2002	1	M
2003	2	M
2004	2	M
2005	2	M
2006	4	M
2007	3	H
2008	3	H
2009	1	H
2010	4	H
2011	2	H
2012	2	M
2013	2	H
2014	4	H
2015	3	H
2016	4	H

Validity Test for the Model*:* To test for the validity of the model, we divide the data set into two sets, one of the sets was used to build the test model (HMM1) and the other set was used to test for the reliability of the model. We estimate the parameters of HMM1 utilizing Rainfall, Temperature and Rice yield data from 2001 to 2012, then test for the reliability of the model using data set for the following years 2013, 2014, 2015 and 2016.

The Transition Count Matrix, Pseudo Count Transition Matrix and Transition Probability Matrix are given in Equations (7), (8) and (9) respectively.

$$C = \begin{bmatrix} 1 & 1 & 0 & 1 \\ 0 & 3 & 0 & 1 \\ 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 0 \end{bmatrix} \tag{7}$$

$$S = \begin{bmatrix} 2 & 2 & 1 & 2 \\ 1 & 4 & 1 & 2 \\ 2 & 1 & 2 & 1 \\ 1 & 2 & 2 & 1 \end{bmatrix} \tag{8}$$

$$A = \begin{bmatrix} 0.2857 & 0.2857 & 0.1428 & 0.2857 \\ 0.1250 & 0.5000 & 0.1250 & 0.2500 \\ 0.3333 & 0.1666 & 0.3333 & 0.1666 \\ 0.1666 & 0.3333 & 0.3333 & 0.1666 \end{bmatrix} \tag{9}$$

While Observation count matrix, Pseudo count Observation matrix and Observation probability matrix are given in equations (10), (11) and (12), respectively.

$$E = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 4 & 1 \\ 0 & 0 & 2 \\ 0 & 1 & 1 \end{bmatrix} \tag{10}$$

$$D = \begin{bmatrix} 2 & 2 & 2 \\ 1 & 5 & 2 \\ 1 & 1 & 3 \\ 1 & 2 & 2 \end{bmatrix} \tag{11}$$

$$B = \begin{bmatrix} 0.4000 & 0.2000 & 0.2222 \\ 0.2000 & 0.5000 & 0.2222 \\ 0.2000 & 0.1000 & 0.3333 \\ 0.2000 & 0.2000 & 0.2222 \end{bmatrix} \tag{12}$$

The initial state probability is given in equation (13)

$$\pi = [0.25, 0.4167, 0.1666, 0.1666] \quad (13)$$

The general HMM1 is represented by equation (14)

$$\lambda_1 = (A, B, \pi) \quad (14)$$

After 1000 iteration of Baum Welch Algorithm, equation (14) settled to (15)

$$\lambda_1^* = (\hat{A}, \hat{B}, \hat{\pi}) \quad (15)$$

Where

$$\hat{A} = \begin{bmatrix} 0.0000 & 1.0000 & 0.0000 & 0.0000 \\ 0.0000 & 0.4283 & 0.0000 & 0.5717 \\ 0.0000 & 0.0000 & 1.0000 & 0.0000 \\ 0.0000 & 0.0000 & 0.5717 & 0.4283 \end{bmatrix} \quad (16)$$

$$\hat{B} = \begin{bmatrix} 1.0000 & 0.0000 & 0.0000 \\ 0.0000 & 1.0000 & 0.0000 \\ 0.0000 & 0.0000 & 1.0000 \\ 0.0000 & 0.2102 & 0.7898 \end{bmatrix} \quad (17)$$

Comparison of the Predicted States and Observations, and the Actual States and Observations from the Dataset

Predicted States and Observations:

States: 2(2012)→2(2013)→4(2014)→3(2015)→3(2016)

Observations: M M H H H

Actual States and Observations:

States: 2(2012)→2(2013)→4(2014)→3(2015)→3(2016)

Observations: M H H H H

The parameters of the HMM1 were determined utilizing rainfall, temperature and rice yield data from 2001 to 2012. After 1000 iterations of the Baum Welch Algorithm, λ_1 settled to a new

model, λ_1^*, this new model was used to test for rice yield for 2013, 2014, 2015, and 2016. From the test, the HMM1 was in state 2 at time T (2012) emitting Moderate rice yield, at that point, it then make move to state 2 at time T+1 (2013) emitting a Moderate rice yield, then make move to state 4 at time T+2(2014) emitting a High rice yield, next, it make move to state 3 at time T+3(2015) emitting a High rice yield and move to state 3 at time T+4 (2016) emitting a High rice yield. The transition between the states are governed by the first order Markov dependence as referenced in the past section. The validity test shows 80% precision in the rice forecast when compared with the actual rice yield from the dataset.

Hidden Markov Model (HMM2) for future forecast: HMM2 was developed to forecast rice yield for future years, the parameters of the HMM2 were determined utilizing rainfall, temperature and rice yield data from 2001 to 2016, at the point, we made forecast for 2017, 2018, 2019, and 2020.

Transition Count Matrix

$$C = \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 4 & 0 & 2 \\ 1 & 0 & 1 & 1 \\ 0 & 1 & 2 & 0 \end{bmatrix} \quad (18)$$

Pseudo count Transition Matrix

$$S = \begin{bmatrix} 2 & 2 & 1 & 1 \\ 1 & 5 & 1 & 3 \\ 2 & 1 & 2 & 2 \\ 1 & 2 & 3 & 1 \end{bmatrix}$$

(19)

Transition Probability Matrix

$$A = \begin{bmatrix} 0.2857 & 0.2857 & 0.1428 & 0.2857 \\ 0.1000 & 0.5000 & 0.1000 & 0.3000 \\ 0.2857 & 0.1428 & 0.2857 & 0.2857 \\ 0.1428 & 0.2857 & 0.4285 & 0.1428 \end{bmatrix}$$

(20)

Observation Count Matrix

$$C = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 4 & 2 \\ 0 & 0 & 3 \\ 0 & 1 & 3 \end{bmatrix}$$

(21)

Pseudo count Observation Matrix

$$S = \begin{bmatrix} 2 & 2 & 2 \\ 1 & 5 & 3 \\ 1 & 1 & 4 \\ 1 & 1 & 4 \end{bmatrix}$$

(22)

Observation Probability Matrix

$$\mathrm{B} = \begin{bmatrix} 0.4000 & 0.2222 & 0.1535 \\ 0.2000 & 0.5555 & 0.2307 \\ 0.2000 & 0.1111 & 0.3076 \\ 0.2000 & 0.1111 & 0.3076 \end{bmatrix}$$

(23)

Initial State Probability

$$\pi = \begin{bmatrix} 0.1875 & 0.1875 & 0.250 & 0.375 \end{bmatrix}$$

(24)

$$\lambda_2 = (A, \quad B, \quad \pi)$$

(25)

After 1000 iteration of Baum Welch Algorithm, equation (25) stabilized to (26)

$$\lambda^* = \left(\hat{A}, \quad \hat{B}, \quad \hat{\pi} \right)$$

(26)

Where

$$\hat{A} = \begin{bmatrix} 0.0000 & 1.0000 & 0.0000 & 0.0000 \\ 0.0000 & 0.7500 & 0.0000 & 0.2500 \\ 0.0000 & 0.0000 & 0.8750 & 0.1250 \\ 0.0000 & 0.0000 & 1.0000 & 0.0000 \end{bmatrix}$$

(27)

$$\hat{B} = \begin{bmatrix} 1.0000 & 0.0000 & 0.0000 \\ 0.0000 & 1.0000 & 0.0000 \\ 0.0000 & 0.0000 & 1.0000 \\ 0.0000 & 1.0000 & 0.0000 \end{bmatrix}$$

(28)

Future Forecast States and Observations:

States: 4(2016)►3(2017)►3(2018)►3(2019)►3(2020)

Observations: H H H H H

The parameters of the HMM2 were determined using rainfall, temperature and rice yield data from 2001 to 2016. After 1000 iteration of the Baum Welch algorithm, λ_2, settled to a new model, $\lambda_2^{\bullet}$, this new model was then used to makes a forecast for future years. From the forecast, the HMM2 was in state 4 at time T (2016) emitting High rice yield, at that point, it then make movement to state 3 at time T+1 (2017) emitting High rice yield. Similar interpretation is given to movement to state 3 at time T+2 (2018), move to state 3 at time T+3 (2019), movement to state 3 at time T+4 (2020) all emitting High rice yield.

Conclusion

A hidden Markov Model to forecast Rice yield with respect to major climatic elements (rainfall and temperature) has been developed and implemented in Niger State. The validity test for the model show 80% precision in Rice yield forecast. Both the validity test and the future forecast shows pervasiveness of high Rice yield, this shows that Niger State is a better place for rice farming. The model could likewise be used to forecast Yield of other crops with little or no modification.