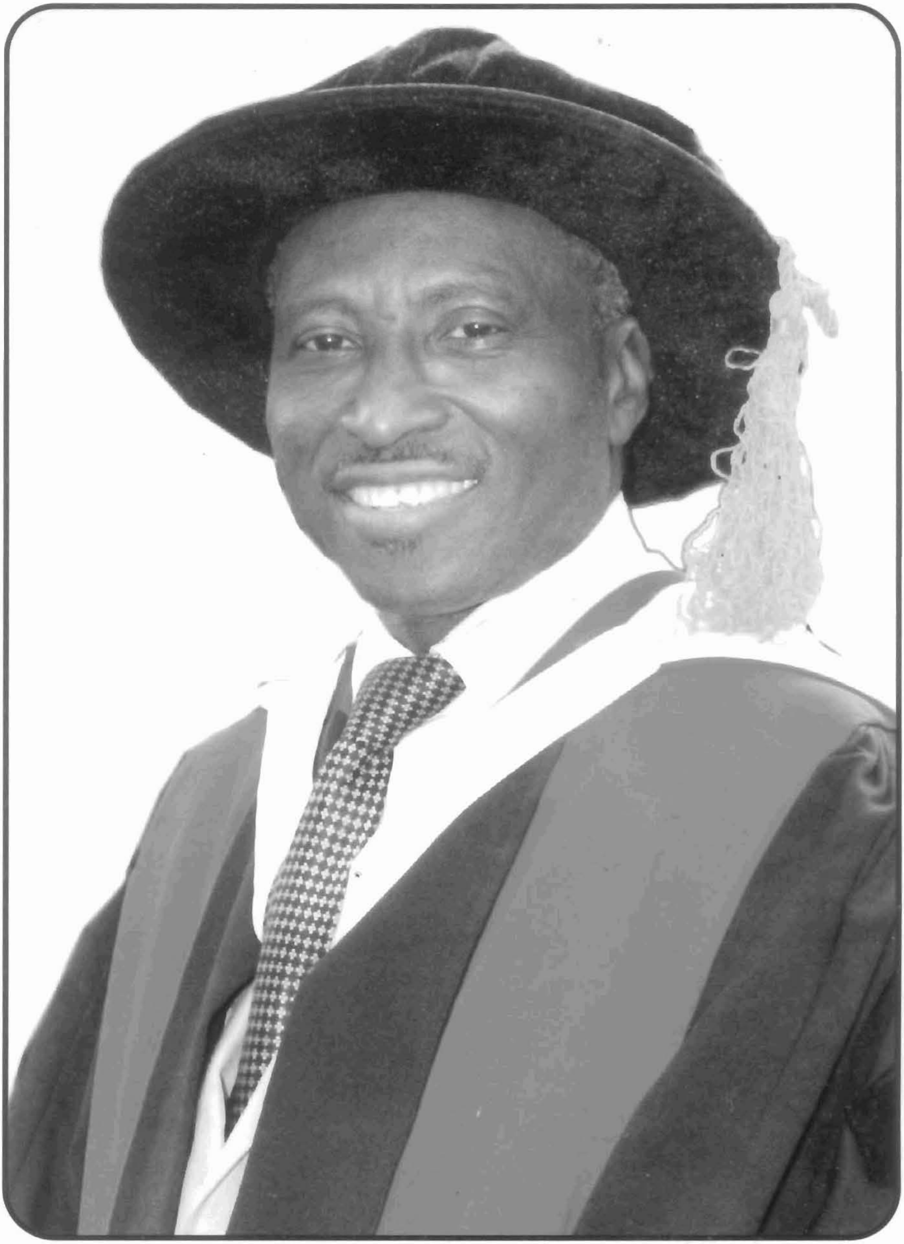
INAUGURAL LECTURE SERIES 315

AGRICULTURAL TECHNOLOGY ADOPTION: PANACEA FOR SUSTAINABLE FARMING SYSTEMS

By

SIMEON ADEBAYO BAMIRE
Professor of Agricultural Resource Economics

OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, NIGERIA.



SIMEON ADEBAYO BAMIRE

Professor of Agricultural Resource Economics

B.Agric. (Hons), M.Phil., Ph.D. (Agricultural Economics), OAU Ile-Ife

AGRICULTURAL TECHNOLOGY ADOPTION: PANACEA FOR SUSTAINABLE FARMING SYSTEMS

An Inaugural Lecture Delivered at Oduduwa Hall, Obafemi Awolowo University, Ile-Ife, Nigeria On Tuesday 27th March, 2018

By

LIB... ...lowo Un... NIGERI...

SIMEON ADEBAYO BAMIRE
Professor of Agricultural Resource Economics
B.Agric. (Hons), M.Phil., Ph.D. (Agricultural Economics), OAU, Ile-Ife

Inaugural Lecture Series 315

OBAFEMI AWOLOWO UNIVERSITY PRESS, 2018

ISSN 0189-7848

Printed by

Obafemi Awolowo University Press Limited,
Ile-Ife, Nigeria.

INTRODUCTION

Mr. Vice Chancellor Sir, Eminent Council Members, Principal Officers of the University, Distinguished Members of Senate, Staff, Other Members of the University Community, Invited Guests, Friends, Family Members, Great Students of this University, Ladies and Gentlemen.

I give praises, honour and adoration to God Almighty for His grace and love in sparing my life to stand before you today to deliver the 315th Inaugural Lecture of this great citadel of learning, titled "***Agricultural Technology Adoption: Panacea for Sustainable Farming Systems***".

Mr. Vice Chancellor Sir, permit me to give a little background to the choice of this title. As a Lecturer II looking for how best to grow within the University system, and while working on my PhD thesis under the supervision of Prof. Y. L. Fabiyi, I was advised at a Departmental Review Meeting to be *focused* in my research activities and publications. This I took in good faith and then resorted to prayers to God to guide me in locating the *focus* in my career as an academic. Just about a week thereafter, I saw an advert of the International Institute of Tropical Agriculture (IITA) requesting for Research Fellows in the area of Agricultural Economics. I readjusted my thesis title along this advert, sent the proposal to IITA and later got a letter accepting the proposal. The thesis titled: "Factors Influencing the Adoption of Fertilizer Technology in Osun State of Nigeria" was co-supervised by Dr. Victor Manyong of IITA who attached a vehicle, driver and all conveniences to me for the conduct of the research. These gave me the opportunity to get to the nooks and crannies of my study locations and to have one-on-one interaction with all my respondents. The training received at the Department from my teachers as well as the small grant won from the Council for the Development of Social Science Research in Africa (CODESRIA) to attend methodological workshops gave me insight into the area of research methodology. The outcome of all these opportunities was that my Thesis was selected by the National Universities Commission (NUC) as one of the best that won the Nigerian

Universities Postgraduate Theses Award Scheme (NUPTAS) in 2001. The Award was the first in the series of the Award by NUC. Immediately after this award, the then Late Prof. Banwo Olufokunbi changed my appellation to "The Award Winner". I remain grateful to God and appreciate the Department of Agricultural Economics, the University, IITA and CODESRIA for making this possible and for helping to locate my *focus*. This motivated me a great deal to creating more interest in the area of "adoption" – the premise of this inaugural lecture.

Mr. Vice Chancellor Sir, in order to capture the salient elements of this lecture, it is imperative to present a preview of what it entails: In many parts of the developing world, from low potential regions to some of the best irrigated lands, the high demand on resources such as farm land arising from population growth, poverty, increased urban competition, and climate change have reached the point where it will be difficult to obtain needed increases in agricultural production for food security and a sustainable farming system without resolving resource management problems. In other words, the traditional ways of farming has not been able to guarantee food security and this portends a great challenge. To facilitate the attainment of food security, it has become necessary for farmers to be more innovative and accept the use of appropriate agricultural technologies. Nonetheless, a greater number of innovative agricultural technologies have been developed and are still being developed but many farmers in the developing world are slow to adopt these technological innovations. Incidentally, the adoption of improved technologies is believed to be a major factor in the success of the green revolution experienced by Asian countries! This raises questions of tremendous concern: What are these agricultural technologies? What benefits or advantages do they have? What are the factors influencing farmers' decision in adopting these technologies as expected? What are the solutions or remedies to foster a sustainable farming system?

In this lecture, I intend to present my contributions to research in the area of agricultural technology adoption and its effect on sustainable farming systems. This shall be preceded by key definitions of technology adoption terms and sustainable farming systems, followed by the benefits, processes and determinants of agricultural technology adoption. I will then attempt to provide ways of enhancing farmers' adoption of agricultural technologies for a sustainable farming system. In other words, the concern here is not only about adoption of improved agricultural technologies but what this translates into in terms of the appropriate application of the technologies for sustainable farming systems.

Definition of Terms

Technology

Technology, simply defined, is the application of scientific knowledge for a certain end. However, some technologies had existed before the science behind them became known (Field and Solie, 2007). For example, the early man was moving his log with a lever ever before the principles of a lever were established. Acupuncture, which had effectively been used by the Chinese for many centuries was initially branded "witchcraft" because the science behind it was unknown. Today, with scientific explanation based on body pressure points, acupuncture is becoming fashionable worldwide. Technology can also precede the science that explains it as it embodies art and culture as well (Palis, 2006).

According to Karehka (2013), technology is the bedrock of human civilization. It determines how production can be realized and sets limits on the amount and types of wealth (goods and or services) that can be derived from a given amount of resources. Gershon and Umali (1993) define technology as "a factor that changes the production function and is associated with some perceived and or objective uncertainty. The uncertainty diminishes over time through the acquisition of experience and information about the technology, and the production function itself may change as adopters become more efficient in the application of the technology. Most technologies have two components: the hardware, consisting of the tool that embodies the technology as a material or physical object and the software, consisting of the knowledge base for the tool.

The United Nations Conference on Trade and Development (UNCTAD, 2004) report depicted technology as involving not merely the systematic application of scientific or other knowledge to practical tasks, but also the social and economic atmosphere within which such application has to take place. This is because the generation/emergence of a technological innovation is in response to scarcity and economic opportunities. Thus, Hayami and Ruttan (1985) argued that the search for new technological innovations is an economic activity that is significantly affected by economic conditions. For example, labor shortages will induce labor-saving technologies, and food scarcity or increased prices of agricultural commodities will likely lead to the introduction of an improved crop variety. The perceived changes in consumer preferences may also suggest the need for new innovations that modify product quality.

Rogers (2003) in his book, *Diffusion of Innovations* - usually used the word "technology" and "innovation" as synonyms. In this lecture, "a *technology* is a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome", while an innovation, the basic element of technological and institutional change, is defined as an idea, method, practice, custom, device or object that is perceived as new by an individual or other units of adoption. Perception is an activity through which an individual becomes aware of objects around oneself and of events taking place. The technologies, which are practices developed through research are innovations. For instance, environmentally friendly activities, agricultural best management and water conservation practices are all considered innovations. Irrespective of the time period the idea or practice was originally developed, when a person first become aware of it, it is an innovation to that person. Thus, "adoption" refers to the stage in which a technology is selected for use by an individual or an organization, while "Innovation" is used as a new or "innovative" technology being adopted. A third item, "Diffusion", occurs when the technology spreads and is generally used and applied. According to Straub (2017), it is the "newness of the idea in the message content of communication that gives diffusion its special character. The acceptance of the technology within the user environment is referred to as "Integration".

There are different stages involved in the generation of an innovation (Udima, Jincai and Owusu, 2017). First is the discovery stage, which is denoted by the emergence of a concept or results that establish the innovation. Second stage is development, when the discovery moves to the field from the laboratory. On the field, the discovery is scaled up, commercialized, and integrated with other elements of the production process. When patentable innovations are involved, there may be a third stage between the time of discovery and development which involves the registration for a patent. If the innovation is incorporated, once it is developed it has to be produced and, finally, marketed. For such innovations, the marketing stage involves educational enlightenment, demonstration, and sales. It is only after these stages that adoption occur, and it is this that guides the use of the technology or innovation. Adoption and diffusion are the processes governing the use of innovations and there is often a significant interval between the time an innovation is developed and made available in the market, and the time it is widely used.

Adoption

Adoption, originating from the old French word "*adoptare*" meaning to "choose for oneself", has been defined as the act of taking something on as one's own. Though it is more commonly referred to as the legal process of becoming a non-biological parent, it also refers to the act of accepting or embracing ideas, habits, methods or attitudes (Henrich, 2013).

Adoption behavior may be depicted by more than one variable. It may be depicted by a discrete choice, whether or not to use an innovation. For Rogers (2003), adoption is a decision of "full use of an innovation as the best course of action available" and rejection is a decision "not to adopt an innovation". The relative speed with which an innovation is adopted by members of a social system is referred to as the "*rate of adoption*". Measures of adoption may indicate both the timing and extent of new technology use by individuals. It is generally measured as the number of individuals who adopt a new idea in a specified period, such as each year or by a continuous variable that indicates to what extent a divisible innovation is used. So the rate of adoption is a numerical indicator of the steepness of the adoption curve for a technological innovation. For example, one measure of the adoption of a high-yield seed variety by a farmer is a discrete variable denoting if the variety is being used by a farmer at a certain time. Another measure is what percent of the farmer's land is planted with this variety. Studies on adoption behavior emphasize factors that affect *if* and *when* a particular individual will begin the use of a technology or innovation.

The rate of adoption of an innovation could be explained by five perceived attributes: relative advantage, compatibility, complexity, triability, and observability (Rogers, 1983). Other attributes include: (i) the type of innovation-decision, (ii) the nature of communication channels diffusing the innovation at various stages in the innovation-decision process, (iii) the nature of the social system in which the innovation is diffusing, and (iv) the extent of change agents' promotion efforts in diffusing the innovation.

Adoption is also usually considered along with diffusion. Diffusion can be interpreted as aggregate adoption (Rogers, 2003; Henrich, 2013). It is the process in which an innovation is communicated through certain channels over time among the members of a social system. Diffusion studies depict an innovation that penetrates its potential market and as with adoption, there may be several indicators of diffusion of a specific technology. For example, one measure of diffusion may be the percentage of the farming population that adopts new innovations. Another is the land share in total land on which innovations can be utilized. This lecture uses a mix of these definitions.

The S-Shaped Diffusion Curve

The contribution of new technology to economic growth can only be realized when and if the new technology is widely diffused and used. The rate of diffusion of an innovation and the form of its diffusion curve (as shown in Figure 1) are also influenced by the characteristic features of a social system.

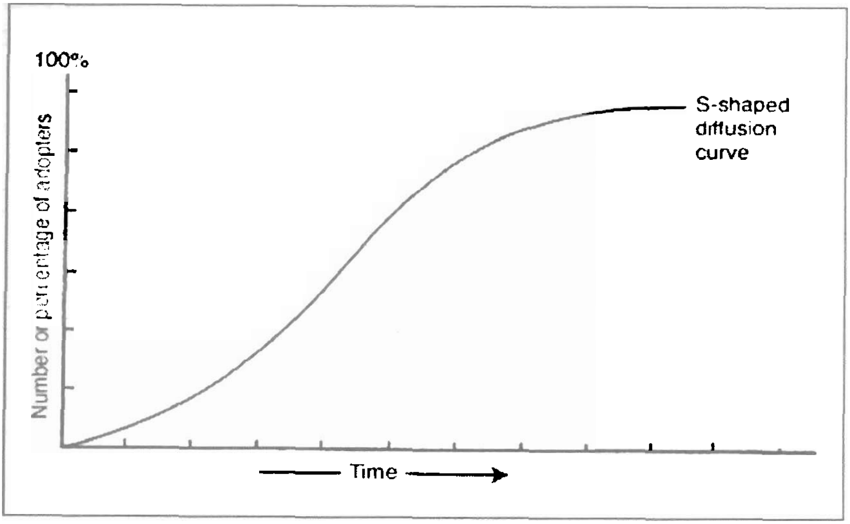


Figure 1: *The S-shaped diffusion curve of an innovation*
Source: Henrich, J. (2013)

In a study on the diffusion of hybrid corn in Iowa, Rogers (1962) compared the diffusion rates of different counties and found that diffusion in most counties was an *S*-shaped function of time. The S-shaped adoption curve applies to virtually all innovations. Figure 1 shows the *S*-shaped diffusion curve which is caused by the fact that the technological innovation has first to come in from outside the social system. This means there is an initial period of introduction of a technology with a relatively low adoption rate but with a high rate of change in adoption as more and more people come in contact with the innovation. A takeoff period then follows when the innovation penetrates the potential market to a large extent within a short period of time. During these two periods, the marginal rate of diffusion actually increases, and the diffusion curve is a convex function of time. A period of saturation follows the take off period when diffusion rates are slow, marginal diffusion declines, and the diffusion reaches a peak. For most innovations, there will also be a period of decline where the innovation is replaced by a new one.

The extent to which a farmer adopts a particular innovation could be measured as the ratio of actual adoption and the potentiality of adoption. It is expressed as a percentage:

$$\text{Extent of Adoption} = \frac{\text{Number of Practices Adopted}}{\text{Number of Practices Recommended}} \times 100 \qquad \text{.............. (Equation 1)}$$

The adoption-diffusion theories

There are different theories that relate the process of technology adoption. A directional approach to the process is provided by the "top-down" and "bottom-up" models (Henrich, 2013). The theory that relates to the scale of innovation differentiates between macro- and micro-level theories. Macro-level theories focus on the institution and systemic change initiatives. Here, an innovation typically involves a wide range of technologies and practices. Micro-level theories, on the other hand, focus on the individual adopters and a specific innovation or product rather than on large-scale change. Rogers (1995), identified four other adoption/diffusion theories: Innovative decision process theory, individual innovativeness theory, rate of adoption theory, and perceived attributes theory.

- The innovation decision process theory shows the potential adopters of a technology as they progress over time through five stages in the diffusion process. First, they must learn about the innovation (knowledge); second, they must be persuaded of the value of the innovation (persuasion); they must decide to adopt it (decision); the innovation must then be implemented (implementation); and finally, the decision must be reaffirmed or rejected (confirmation). Hence the focus is on the user or adopter.

- Individual Innovativeness Theory shows that individuals who are risk takers or otherwise innovative will adopt an innovation earlier in the continuum of the adoption/diffusion process.
- The Rate of Adoption Theory shows that diffusion takes place over time with innovations going through a slow, gradual growth period, followed by dramatic and rapid growth, then a gradual stabilization and finally a decline.
- The Perceived Attributes Theory reveals that there are five attributes upon which an innovation is judged: that it can be tried out (trialability), that results can be observed (observability), that it has an advantage over other innovations or the present circumstance (relative advantage), that it is not difficult to learn or use (complexity), and that it fits in or is compatible with the circumstances into which it will be adopted (compatibility).

Agricultural Technology Adoption

Agricultural technology is the product of agricultural research and it is one of the most revolutionary and impactful areas of modern technology, driven by the fundamental need for food and for feeding an ever-growing population. The adoption of agricultural technologies is considered as a major driver of the success of the Green Revolution in Asia (Ravallion and Chen, 2004). At the global level, the adoption of improved agricultural technology is considered critical to the attainment of the Sustainable Development Goals (SDGs) 1 and 2 of no poverty and zero hunger

Neill and Lee (2001) reported that the majority of existing literature on agricultural technology adoption is focused on Green Revolution technologies such as the adoption patterns of high-yield variety (HYV) seeds, fertilizers, herbicides, pesticides, zero tillage, other soil fertility management practices (e.g., animal manure, legume intercrop, crop residue, ridging, mounding, earth bunding, contour ploughing and live fence) and irrigation systems, and these have been associated with higher earnings and lower poverty

(Bamire *et al.*, 2002; Bamire *et al.*, 2014), lower staple food prices (Abdoulaye *et al.*, 2012), improved nutritional status and increased employment opportunities (Manyong *et al.*, 2007).

Sustainable Farming Systems

The work of Boserup (1965) and Binswanger and McIntire (1987) on the evolution of agricultural systems considered the early human group as consisting of a relatively small number of members who roamed large areas of land for living as hunters and gatherers and relied on slash and burn farming systems. An increase in population led to the evolution of agricultural systems. The transition to more intensive farming systems that used crop rotation and fertilization occurred as population density increased even further as the traditional way of farming could not guarantee food security.

The word "sustain," from the Latin *sustinere* (*sus* -, 'from below' and *tenere* -, 'to hold'), to keep in existence or maintain, implies long-term support or permanence. As it pertains to agriculture, 'sustainable' describes farming systems that are capable of maintaining their productivity and usefulness to society indefinitely (Feenstra, 2017). Such systems must be resource-conserving, socially supportive, commercially competitive, and environmentally sound. 'Sustainable agricultural farming system' here means building on current agricultural achievements, and adopting a sophisticated approach that can maintain high yields and farm profits without undermining the resources on which agriculture depends (Bamire, 1995; Bamire, 2008). In other words, 'sustainable agricultural farming system' is a whole-systems approach to food, feed, and other fibre production that balances environmental soundness, social equity, and economic viability among all sectors of the public, including international and intergenerational peoples. Inherent in this definition is the idea that sustainability must be extended not only globally, but indefinitely in time, and to all living organisms including humans. Hence, the goal of sustainable agriculture is to meet society's food and textile needs in the present without compromising the ability of future generations to meet their own needs (Binswanger and McIntire, 1987 and Bamire, 1999). Every person involved in the food system; growers, food processors, distributors, retailers, consumers, and waste managers, can play a role in ensuring a sustainable farming system. Today, the practice of sustainable farming system commonly includes: crop rotations that mitigate weeds, diseases, insect and other pest problems; use of integrated pest management techniques; use of resistant cultivars, timing of planting, increased mechanical/biological weed control; more soil and water conservation practices; strategic use of animal and green manures; and use of natural or synthetic inputs in a way that poses no significant hazard to humans, animals, or the environment.

Measuring and Modeling the Agricultural Technology Adoption Process

Technology adoption is the vehicle that allows most people to participate in a rapidly changing world where technology has become central to lives (Straub, 2017). Improved agricultural technology is, nonetheless, particularly relevant for smallholder farmers who are disadvantaged in many ways, thereby making them a priority for development efforts. These farmers for instance, live and farm in areas where rainfall is low and erratic, and soils tend to be infertile. In addition, infrastructure and institutions such as irrigation, input and product markets, and credit as well as extension services tend to be poorly developed (Bamire, 2002; Muzari *et al.*, 2012). However, agricultural technologies are of little value unless the farmers judge them to be appropriate and subsequently adopt them. An improved technology may increase yields or agricultural output, but that does not necessarily mean that it should be adopted or selected for use by an individual or an organization. For example, some crops may have higher yields, but they also may be more sensitive to drought, thereby requiring large investments in irrigation infrastructure for them to be profitable (Abdoulaye *et al.*, 2012).

The adoption process refers to the individual's decision to or not to adopt a technological innovation. It can be a one-time event or a decision to integrate an innovation into the farmer's life. The general framework for adoption decisions of an improved technology could be based on how farmers make decisions in practice or on how they should make decisions (Bamire *et al.*, 2002). However, one of the concerns of agricultural economics is developing a framework for understanding and modelling the processes and consequences of decision making among farmers (Bamire et al., 2012; Abdoulaye *et al.*, 2017). The framework explains the adoption decisions as a dynamic process, assuming a complex interaction of groups of variables.

As the foundation for capturing the factors that influence the choices an individual makes to adopt a technology, Rogers's theory identified and explained five stages that influence the adoption process. It starts with the assumption that a farmer is aware of the new technology or innovation. Awareness means that a farmer or potential user knows that the innovation exists and that it is potentially of practical relevance to him (Adegbola and Gardebroek, 2007; Abdoulaye *et al.*, 2012). However, as the framework is dynamic, a farmer who is not aware of the innovation may acquire more information and become aware of it. For instance, farmer awareness of land improvement techniques increases the probability that a farmer will adopt innovations that help solve these problems. Stage two is assessment, when an individual gains enough knowledge about the benefits of the technologies. At this period, the expected users evaluate the usefulness and usability of the technology and the ease or difficulty of adopting it. Stage three is when an individual decides to adopt or reject the technology. Stage four is learning, when an individual takes action on the decision to acquire and use the technology or not. If they decide to use the technology, the users need to develop the skills and knowledge required to use the technology effectively. The fifth and final stage is the application or usage of the technology. In this stage, the users show appropriate and effective use of the technology (Rogers, 1995). Individuals who are not ready or who cannot adopt will increasingly limit their ability to participate fully in the financial and convenience benefits associated with the technology. In addition, for some innovations, there may be an additional step, in which farmers may decide to modify the innovation in order to adapt it more closely to their individual conditions (Akinbode and Bamire, 2015).

In trying to measure the process of agricultural technology adoption and diffusion, researchers most commonly use three methods to understand the factors that determine the adoption of technology across space and time: time series, cross-sectional, and panel data analyses. Each approach involves collecting and analyzing different types of data and methods, and explains a different aspect of the adoption process. Researchers use time-series data extensively to explain how the rate of technology adoption varies with time, but time-series data does not address the fundamental reasons for adoption. The former associates farmer characteristics with likelihoods of adoption and the latter links characteristics with the time at which adoption occurs. The shortfalls of these data are the unrealistic assumptions required to make the data applicable, mainly that the characteristics are consistent over time. Panel data brings together cross-sectional and time-series data and can be used to explain both adoption processes and the characteristics associated with adoption. They are however, rarely used because they are difficult to collect and hard to manipulate.

The economic literature on farmers' decisions is based on normative theory and on the assumption that decisions can be modeled only in terms of the individual's maximization of profit (Austin *et al.*, 1998; Willock *et al.*, 1999). Farmers' decisions and behavior are not, however, driven only by the maximization of profit but could be studied from two different approaches: purely economic models based on the expected utility theory and the social-psychology theory. The social-psychology theory scientifically involves the use of psychological constructs such as farmer's thoughts, feelings and behaviors to explain their decision to adopt an improved agricultural technology. The expected utility theory presents a farmer that compares any improved technology with the traditional technology and adopts it if its expected utility (based on the farmer's perceptions of benefits and costs) is greater than that of the traditional technology (Bamire, 1999; Bamire and Manyong, 2003). Although the utility function is unobserved, the relationship between the expected utility for each of the two technologies is hypothesized to be a function of the vector of some observed variables and an error term (Adesina and Zinnah, 1993; Bamire and Manyong, 2003).

Empirical studies have analysed the impact of different variables on each farmer's adoption decision using econometric models such as logit, probit and tobit (Bamire, 1999; Akinbode and Bamire, 2015). In identifying which farmers use improved technologies, each micro-level adoption study provides descriptive data on farmer characteristics and most studies estimate the probabilities of a farmer adopting a technology. These studies focus on a cross-section of the population and compare adopters to non-adopters. The regression results of these are often interpreted as representing the probability that a farmer will adopt the technology, whereas the proper interpretation is the probability that a farmer is using the technology. In other words, current information on the farmer is being used, not information on the farmer at the time of adoption. This interpretation provides opportunities for some information on the characteristics of farmers who were using the technology at the time of the studies. Adoption can also be modeled as a continuous optimization problem in which optimal land shares devoted to new technologies and variable inputs are chosen (Just and Zilberman, 1988; Abdoulaye and Sanders, 2006).

THE BENEFITS OF AGRICULTURAL TECHNOLOGY ADOPTION

The adoption of agricultural technologies benefit farmers in different ways: Adoption of improved agricultural technologies has been associated with: higher earnings and lower poverty; improved nutritional status; lower staple food prices; increased employment opportunities as well as earnings for landless laborers (Abdoulaye *et al.*, 2012; Ogunya, Bamire and Ogunleye, 2017). The success stories of the green revolution experienced by Asian countries already proves the advantages of improved agricultural technology adoption (Ravallion and Chen, 2004; Kasirye, 2010).

By virtue of improved input/output relationships, new technology tends to raise output and reduce average cost of production which in turn results in substantial gains in farm income (Bamire *et al.*, 2012; 2014). Adopters of improved technologies increase their production levels, leading to improved livelihood. Farmers are highly motivated by increased production. The increased productivity of crops usually motivates their decision to adopt a particular technology. Majority of the less developed countries population depend on agricultural production and new technology seems to offer an opportunity to increase production and income substantially (Feder *et al.*, 1985). In fact, as farmers production increases, the greater the likelihood that the new crop will be produced in the subsequent year (Bamire and Tijani, 1998; Bamire *et al.*, 2010).

Farmers consider agricultural technology adoption when the process improves food security. According to the World Food Summit "food security exists when all people at all times have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (WFS,1996). The food security in this context denotes an increase in food consumption and an increase in the availability of food supply in the stores for consumption at any given time. It also indicates the introduction of new crops with improved nutritional quality compared to previous times.

The benefits received from agricultural technologies can be summarized as an increase in food choice for daily consumption and in the quantity of available food throughout the year. Manyong, Bamire and Zuckerman (2003) showed that improved food security translates to mean that farm families who were hitherto unable to eat once a day are now capable of eating twice daily. Those who were not having enough food were able to save some for future crises and those who were not sending kids to school were able to afford to pay for their kids' school expenses and satisfy the basic needs of their families. Some farmers also built new houses and expanded their farm land size.

Also, the socio-economic status of women who use new technologies improved dramatically. Alimi and Bamire (2003) and Roberts *et al.* (2004) itemized the benefits of agricultural technology to include reduced infestation by pests, improved soil fertility, increased crop yields and improved fodder and milk productivity. Studies (Abadi *et al.*, 2005 and Bamire *et al.*, 2010) have also shown that new technologies enhance the efficiency of farm operations by conserving energy and time on these operations. It could also lead to increase in household income. The increase in income is usually calculated by deducting the total sales of individual crops from the total expenses of the crops.

Rate of Adoption of Agricultural Technologies

Over the decades, improved technologies have been developed for different agro-ecological zones to meet the needs at every stage of the production process. The majority of farmers in Africa partially adopted technologies out of a package of technologies. Adoption surveys as well as seed production and sales of improved varieties can be used to estimate technology adoption. For instance, adoption studies conducted on different crops in Kenya in 1998 showed high rates of adoption in the high potential areas, less than 20% adoption in the low potential (coast and dry transitional zones) and about 50% in the mid-altitudes (Wekesa *et al.*, 2003; Ouma *et al.*, 2002).

In a study by Bamire *et al.* (2010) on impact of promoting sustainable agriculture on the adoption of improved crop varieties in Borno State of Nigeria, it was shown that the adoption rate varied by crop and by location. The adoption rates of improved soybean varieties were 45% in the Southern Guinea Savanna, 29% in the Northern Guinea Savanna and 20% in the Sahelian Savanna. Findings from Ogunsumi *et al.* (2010) showed that out of a package comprising nine maize technologies, only improved variety, seed rate/spacing, weed control and fertilizer were adopted. However, 36% adopters of these technologies eventually abandoned the technologies because of inadequate capital and high production cost. The Savings and Fertilizer Initiative in Kenya, which offered farmers subsidized fertilizer at harvest time as opposed to planting time, reported between 11% and 14% increase in fertilizer adoption (Bamire *et al.*, 2002; Wekesa *et al.*, 2003; Duflo *et al.*, 2008). The adoption rate for hybrid maize was 30% among smallholder farmers in the drought-prone central rift valley of Ethiopia (Bedru and Wegary, 2014) and only 3% for all districts in Ghana (Tripp, 2011). The 2012 nationwide study for fertilizer use in Ghana recorded an adoption rate of 47% (Ragasa *et al.*, 2013). Akinola *et al.* (2009, 2010), in the study of Balanced Nutrient Management Systems (BNMS), estimated an adoption rate of 40% for BNMS rotation and 48% for BNMS manure from an integrated soil fertility management technology package among maize farmers in Northern Guinea Savanna of Nigeria.

Different high-yielding maize OPVs and Hybrid of varying maturity have been released in Benin Republic, Ghana, Mali and Nigeria for boosting maize productivity (Abdoualye *et al.*, 2009, 2012). In Ghana, results from a study of 420 maize farmers on three Ghana Grains Development Projects' generated maize technologies showed an adoption rate of 54% for modern varieties, 21% for fertilizer and 53% for the plant configuration recommendations (Etwire *et al.*, 2013). Only 12% of the farmers adopted all three technologies as a package. In the forest zone of Nigeria, male farmers recorded the highest adoption rate for improved crop varieties (59%), fertilizer (23%) and row planting (59%), while female farmers had 39% adoption for the improved varieties, 16% for fertilizer and 38% for plant configuration recommendations. In Benin Republic, Baco *et al.* (2010) estimated 75% adoption for improved maize varieties, with females having the highest adoption rate (60%), while variations were found across agro-ecological zones. In a study of 150 maize farming households categorized into wealth groups in Nigeria, Bamire *et al.* (2010) recorded adoption rates of 58% for modern varieties, 50% for fertilizer, 59% for herbicides, 52% for insecticides and 42% for organic manure. In Ghana, variations exist in the adoption rates for herbicide use; Quinones and Diao (2011) reported 19%, whereas Mensah-Bonsu *et al.* (2011) reported 38%. Estimates for Africa south of the Sahara showed 3% adoption of herbicides among maize smallholders (Overfield *et al.*, 2001), less than 5% in South Africa (Gianessi and Williams, 2011) and 0.1% in Uganda (Magyembe, 1997).

The adoption of zero tillage or no-till and other improved technologies for maize cultivation of slashing, no ploughing, no burning and planting without mulch, promoted by the Ministry of Food and Agriculture in the late 90s was practiced on only 4% of the maize area (Etwire *et al.*, 2010), while Mensah-Bonsu *et al.* (2011) reported 38%. Similarly, 68% of maize area was not ploughed by either tractor or animal traction and 30% was not under slash and-burn. Ragasa *et al.* (2013) also reported that only 3% of maize area was applied with animal manure, 40% was intercropped mainly with cassava, 3% was intercropped with legumes, 16% was ploughed in with crop residue and 11% was planted in mulch. Bamire *et al.* (2012) studied farmers in the savanna zone of Nigeria and recorded adoption rates of 8% for local varieties, 10% for hybrids and 83% for OPVs. The adoption rates estimated for improved maize varieties in Tanzania varied across zones in the country when considered as a percentage of the total: 8% in the central region, 19% in the eastern region, 13% in the Lake region, 19% in the northern region, 7% in the southern region, 24% in the southern highlands and 10% in the western region (Moshi, 1997). Also, based on seed sales, Hassan *et al.* (2001) estimated the total national maize area planted to improved maize varieties (OPVs and Hybrids) in Tanzania at only 4%. In Mozambique, 12% of farmers were adopters of improved maize varieties (Lopes, 2010), while Malawi recorded 55% (Katengeza *et al.*, 2012).

In DR Congo, the adoption rates were 10% for improved maize varieties, 6% for mineral fertilizers and 15% for row planting (Lambrecht *et al.*, 2015). It is important to note that most adoption studies tend to be localized and this affects their quality and representativeness, and does not allow policy makers to get useful information on critical indicators that could be actionable. Therefore, documenting lessons on the conditions leading to the adoption of these technologies in these areas becomes imperative. This will allow the designing and implementation of future programmes that will increase the uptake of improved technologies by many farmers.

Despite research efforts in developing improved technologies and the benefits associated with these technologies, the adoption remains generally low in many parts of Africa. In Uganda for instance, in spite of the resources spent on the public extension system, only 6% of farmers used improved seeds in 2006, whereas 3% used inorganic fertilizers (Uganda Bureau of Statistics, 2010). Even for farmers who initially adopted improved technologies, about 50% abandoned the technology within two years (Akinbode and Bamire, 2015). Consequently, it is important to understand why adoption of agricultural technologies has remained very low in Africa despite the documented benefits of these technologies. In addition, the factors that influence technology adoption do not exist in isolation and the presence of one factor may affect others.

FACTORS DETERMINING AGRICULTURAL TECHNOLOGY ADOPTION

For agricultural technology to lead to sustainable farming systems, there is a need to develop an understanding of why farmers are not adopting agricultural technologies as expected. This is necessary in order to identify those factors that constrain farmers' adoption of agricultural technologies for consideration in the sustainability of farming systems.

Different and diverse factors influence farmers' decisions towards the adoption of improved agricultural technologies (Ajayi and Oloruntoba, 2007; Abdoulaye, Bamire, Akinola, Alene, Menkir and Manyong, 2017) as shown in the framework for technology adoption decisions in Figure 2. Traditionally, economic analysis of technology adoption has sought to explain adoption behavior in relation to personal characteristics and endowments, imperfect information, risk, uncertainty, institutional constraints, input availability, and infrastructure (Feder *et al.*, 1985; Rogers, 2003 and Uaiene, 2009). Other literature has included social networks and learning in the categories of factors determining adoption of technology (Abdoulaye *et al.*, 2017).

Some studies classify these factors into different categories. For example, Akudugu *et al.* (2012) grouped the determinants of agricultural technology adoption into three, namely; economic, social and institutional factors. Foster and Rosenzweig (2010) categorized the drivers of successful agricultural technology adoption in developing countries into two: the availability and affordability of technologies; and farmer expectations that adoption will remain profitable, both of which determine the extent to which farmers are risk averse (Bamire *et al.*, 2010). A number of factors drive the above expectations, ranging from availability and size of land, family labor, prices and profitability of agricultural enterprises, and peer effects. Lavison (2013) broadly categorized the factors that influence adoption of technologies into social, economic and physical categories; McNamara, Wetzstein and Douce (1991) categorized the factors into: farmer characteristics, farm structure, institutional characteristics and managerial structure; Nowak (1987) grouped them into informational, economic and ecological, while Wu and Babcock (1998) classified them under human capital, production, policy and natural resource characteristics. Although there are many categories for grouping determinants of technology adoption, there is no clear distinguishing feature between variables in each category. Categorization is done to suit the technology being investigated, the location, and the researcher's preference, or even to suit client needs (Bonabana-Wabbi, 2002). For instance, the level of education of a farmer has been classified as a human capital by some researchers while others classifies it as a household specific factor.

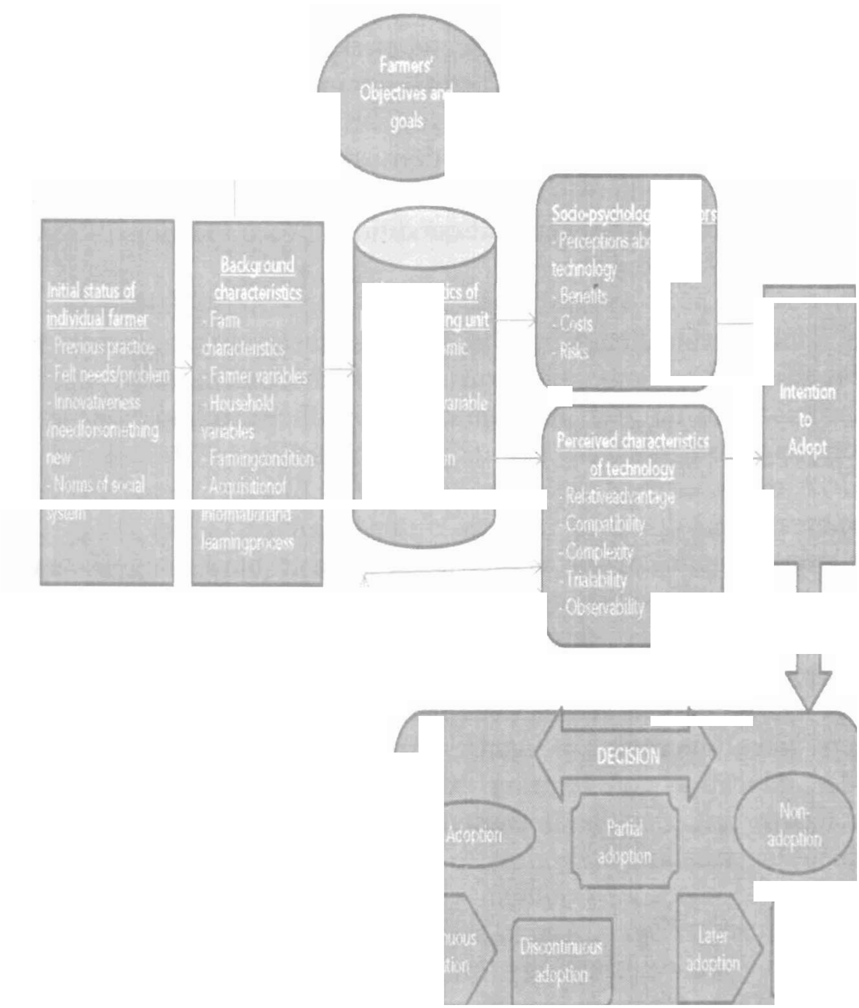


Figure 2: Framework for technology adoption decisions.
Source: Adapted from Joao *et al*. (2015).

In this lecture, the determinants of agricultural technology adoption will be categorized into five: human capital, technological, economic, institutional and environmental factors. The human capital factors include farmers and farm characteristics; technological factors are: perceptions about characteristics of the technology, farmers' objectives and goals at the time of the decision, and perceived costs and risks associated with the technology. The economic factors include: land availability, capital, changing prices, and labor; while institutional factors are: credit, the seed sector, extension delivery system, acquisition of information, research funding, infrastructure and environmental factors relate to weather and soil conditions in the locations where the technology is used.

Mr. Vice Chancellor Sir, the various factors that constrain agricultural technology adoption and which constitute the main determinants of farmers' decisions to adopt these technologies are described as follows:

Human capital

The human capital of the farmer is assumed to have a significant influence on the farmer's decision to adopt new technologies. Most adoption studies have attempted to measure human capital through the farmer's education, age, gender and household size (Bamire *et al.*, 1999; Mignouna *et al.*, 2011; Akinbode and Bamire, 2015). Others have measured it using farmer's age, household size, gender, education and farming experience (Keelan *et al.*, 2014). This lecture presents human capital as comprising farmer and farm characteristics as follows:

Farmer characteristics: Age is assumed to be a determinant of the adoption of new technology but the expected effect of it is unknown. Older farmers are assumed to have gained knowledge and experience over time and are better able to assess the characteristics of new technologies than younger farmers; or it could be that older farmers are more risk averse than younger farmers and have a lesser likelihood of adopting new agricultural technologies (Adesina and Baidu-Forson, 1995). On the contrary, age has been found to have a negative relationship with adoption of technology. This relationship is explained by Adesina and Zinnah (1993) and Bamire (1999) to derive from the fact that as farmers grow older, there is an increase in risk aversion and a decreased interest in long term investments in the farm. On the other hand, younger farmers are typically less risk-averse and are more willing to try new technologies. For instance, Alexander and Van Mellor (2005) found that the adoption of genetically modified maize increased with age for younger farmers as they gain experience and increase their stock of human capital, but declines with age for those farmers closer to retirement.

Household size is simply used as a measure of labor availability. It determines adoption process in that a larger household has the capacity to relax the labor constraints required during the introduction of new technology (Bamire *et al.*, 1999, 2002; Akinbode and Bamire, 2015). Households that use inorganic fertilizers and mulching are more likely to adopt improved maize seeds, while animal manure use and crop rotation are associated with lower adoption of improved seeds. Households with a greater number of relatives are more likely to adopt new technologies since they are able to share risks with relatives (Bamire *et al.*, 2012; Akinbode and Bamire, 2015). However, having larger households connotes increased home consumption and is expected to be inversely related to adoption (Abdoulaye et al., 2017).

The gender variable is associated with embedded norms, behaviors and practices in society that encourage or discourage the adoption of a particular technology by members of the society (Meinzen-Dick *et al.*, 2004). Gender issues in agricultural technology adoption have also been investigated for a long time and most studies have reported mixed evidence regarding the different roles men and women play in technology adoption (Bamire and Deji, 2007). In analyzing the impact of gender on technology adoption, Gaya *et al.* (2016) had found no significant association between gender and the probability to adopt drought tolerant maize varieties in northern Nigeria. They concluded that technology adoption decisions depend primarily on access to resources, rather than on gender. On the other hand, gender may have a significant influence on some technologies. Gender affects technology adoption since the head of the household is the primary decision maker and men have more access to and control over vital production resources than women due to socio-cultural values and norms (Bamire *et al.*, 2002; Mignouna *et al.*, 2011). For instance, a study by Oparinde *et al.* (2014) on cassava varietal adoption found that, gender had a significant and positive influence on the adoption of vitamin A cassava production in Nigeria. The results support that of Lavison (2013) which showed that male farmers were more likely to adopt organic fertilizers than their female counterparts. Evidence from Ghana and Nigeria suggests that gender differences in the adoption of high yielding varieties (HYV) and chemical fertilizers result from differences in access to complementary inputs (Bamire *et al.*, 2016; Ayinde *et al.*, 2013). Clearly, therefore, an understanding of local cultural practices and preferences is important if all farmers are to benefit from the products of agricultural research (Meinzen-Dick *et al.*, 2004). The educational level of a farmer increases their ability to obtain, process and use information that is relevant to the adoption of a technology (Bamire, 1999; Namara *et al.*, 2014).

Farmer's education has been assumed to have a positive influence on farmers' decision to adopt new technologies. The education level of a farmer increases their ability to obtain; process and use information relevant to the adoption of a new technology (Bamire and Abdoulaye, 2013; Abdoulaye *et al.*, 2017). For instance, a study by Bamire *et al.* (2002; 2007) on the adoption of fertilizers found that the level of education had a positive and significant influence on the adoption of technology. This is because higher education influences respondents' attitudes and thoughts making them more open, rational and able to analyze the benefits of a new technology (Bamire *et al.*, 2012). This eases the introduction of innovation which ultimately affects the adoption process (Abdoulaye *et al.*, 2017). Other studies that have reported a positive relationship between education and adoption include:

Bamire (2007) on gender, land tenure arrangements and adoption of new technologies by households in Nigeria and Bamire *et al.* (2012) on soil conservation practices in Nigeria; Goodwin and Schroeder (1994) on forward pricing methods, Huffman and Mercier (1991) and Putler and Zilberman (1988) on adoption of microcomputers in agriculture; Mishra and Park (2005) and Mishra *et al.* (2009) on the use of the internet; Rahm and Huffman (1984) on reduced tillage; Roberts *et al.* (2004) on precision farming; and Traore, *et al.* (1998) on on-farm adoption of conservation tillage. On the other hand, some authors have reported insignificant or negative effects of education on the rate of technology adoption (Abdoulaye *et al.*, 2012; Akinbode and Bamire, 2015; Ogunya, Bamire and Ogunleye, 2017). Studying the effect of education on technology adoption, Gaya et al. (2016) and Mignouna *et al.* (2011) reported a negative influence of formal education on adopting genetically modified crops. The mixed results shown by the above empirical evidence on the influence of education on the adoption of new technology suggests that more studies need to be conducted to come up with a more consistent result.

Farm characteristics: Farm size is an important determinant of technology adoption as it can affect, and in turn be affected by, the other factors affecting adoption. Bamire *et al.* (1999, 2009) showed that large commercial farmers adopted high-yielding crop varieties more rapidly than small farm holders. Many studies have also reported a positive relationship between farm size and the adoption of agricultural technology. Farmers with large farm size are likely to adopt a new technology as they can afford to devote part of their land to try new technology unlike those with less farm size (Bamire *et al.*, 1999; 2012; Abdoulaye *et al.*, 2017). Also, the further away a household is from input and output markets, the smaller the likelihood that they will adopt a new technology (Bamire *et al.*, 2012).

Technological Factors

Farmers' perceptions about technology characteristics: The characteristics of a technology are a precondition for adopting it.

Adesina and Baidu-Forson (1995). Bamire *et al.* (2002, 2010) and Abdoulaye *et al.* (2017) showed that perceptions about the characteristics of technology has a highly significant effect on adoption decisions. They showed that farmers who perceive the technology to be consistent with their needs and compatible with their environment are likely to adopt the technology since they consider it a positive investment.

Also, farmers' perception about the performance of the technologies significantly influence their decision to adopt them. A study by Adesina and Zinnah (1993) showed that farmers' perception of the characteristics of a modern rice variety significantly influenced their decision to adopt it. A similar result was reported by Ogunya, Bamire and Ogunleye (2017) in a study on factors influencing levels and intensity of adoption of new rice for Africa (NERICA) in Ogun State, Nigeria. The study indicated that the perception of farmers towards NERICA facilitated its uptake. It is therefore important that for any new technology to be introduced to farmers, they should be involved in its evaluation to find its suitability to their circumstances (Bamire *et al.*, 2010; Abdoulaye *et al.*, 2012).

Farmers' objectives and goals: An important determinant of sustained adoption is the profitability of agricultural enterprises. Bergevoet *et al.* (2004) found that goals are important determinants of farmers' behavior. Further, Greiner *et al.* (2009), in an exploratory study, hypothesized famers' goals or motivations to be related to the adoption of best management practices. The farmer's objective of maximizing profit affects their decision for improved technology adoption. With small farms, it has been argued that large fixed costs become a constraint to technology adoption (Bamire and Oke, 2003). Economic and other constraints in adopting improved technologies for maize cultivation especially if the technology requires a substantial amount of initial set-up cost are also significant factors (Alimi and Bamire, 2007). Hence, the adoption decisions of farmers can be influenced by the cost and benefit of the technology.

Perceived benefits and costs: A key determinant of the adoption of a new technology is the net gain to the farmer from adoption, inclusive of all costs of using the new technology (Foster and Rosenzweig, 2010). Roberts *et al.* (2004) found that the perceived benefits and costs associated with an improved technology influence its adoption. The benefits included reduced infestation by pests, improved soil fertility, increased maize grain yields, improved fodder and milk productivity. Abadi *et al.* (2005) and Bamire *et al.* (2010) used farmers' perceptions of the riskiness of the innovation as another explanatory variable on the adoption decision, and their findings support that these variables play important roles in adoption, as well as perceived profitability. Lower risk aversion is expected to increase the probability to adopt the technology (Baidu-Forson, 1999).

The cost of adopting agricultural technology has also been found to be a determinant to its adoption. For instance, the elimination of subsidies on prices of seed and fertilizers since the 1990s due to the World Bank-sponsored structural adjustment programs in sub-Saharan Africa has widened this constraint (Muzari *et al.*, 2012). The study conducted by Bamire *et al.* (2002; 2007) on determinants of fertilizer and use of land amendment techniques in Oyo State, Nigeria, reported high cost of labor and other inputs, unavailability of packages requested and untimely delivery as the main constraints to fertilizer adoption. Akinbode and Bamire (2015) when analyzing determinants of adoption of improved maize variety in Nigeria also found high cost and unavailability of seeds as one of the factors responsible for low rate of adoption.

Economic Factors

Mr. Vice Chancellor Sir, for the economic factors, land availability is an important determinant of agricultural technologies.

Land availability: It is the availability of cultivable land (de Janvry *et al.*, 2011; Carletto *et al.*, 2007; Pingali *et al.*, 2001). Farm size plays a critical role in the adoption process of a new technology. Many authors have analyzed farm size as one of the important determinants of technology adoption. It is argued that the availability of cultivable land helps reduce the liquidity constraints faced by households and also reduces risk aversion. Also, land availability through ownership of large plots of land can facilitate experimentation with improved technologies and also determine the pace of adoption as large landowners are more likely to be the early adopters (de Janvry *et al.*, 2011). On the other hand, the limited availability of land may lead to the use of organic fertilizers in a poor resource setting (Bamire, 1995, 1999; Bamire *et al.*, 2007; Akinola, 2009). Furthermore, the quality of land available may be a major factor in deciding the use of key inputs such as chemical fertilizers or adopting improved crop varieties for higher returns (Bamire *et al.*, 2012). Even in countries with secure property rights but poorly developed financial markets, land availability may not reduce the credit constraint.

Farm size can affect and in turn be affected by the other factors influencing adoption (Bamire *et al.*, 2010). Some technologies are termed as scale-dependent because of the great importance of farm size in their adoption (Bamire, 1999; Bamire *et al.*, 2012). Many studies have reported a positive relation between farm size and adoption of agricultural technology (Mignouna *et al.*, 2011; Abdoulaye *et al.*, 2012; Akinbode and Bamire, 2015). Farmers with large farm size are likely to adopt a new technology as they can afford to devote part of their land to try new technology unlike those with less farm size (Bamire *et al.*, 2010). Consistent with this fact, Abdoulaye *et al.* (2010) found significant negative effect of farm size on the adoption of improved maize varieties in the Guinea Savannas of Nigeria while it was positive and significant in the study of adoption of downy mildew resistant maize by small-scale farmers in Kwara State of Nigeria (Ayinde *et al.*, 2010). Some studies have shown a negative influence of farm size on the adoption of new agricultural technology. Small farm size may provide an incentive to adopt a technology especially in the case of an input-intensive innovation such as a labor-intensive or land-saving technology. Farmers with small land may adopt land-saving technologies such as green-house technology and zero grazing, among others as an alternative to increased agricultural production (Akinbode and Bamire, 2015; Abdoulaye *et al.*, 2017).

Other studies have reported an insignificant or neutral relationship between farm size and adoption. For instance a study by Samiee *et al.* (2009) and Bamire *et al.* (2012) concluded that size of farm did not affect Integrated Pest Management (IPM) adoption, implying that IPM dissemination may take place regardless of farmers' scale of operation. These studies consider total farm size and not crop acreage on which the new technology is practiced. Since total farm size has an effect on overall adoption, considering the crop acreage with the new technology may be a superior measure to predict the rate and extent of adoption of the technology (Lowenberg-DeBoer, 2000; Ogunya *et al.*, 2017). Therefore, technology adoption may best be explained by measuring the proportion of the total land area suitable to the new technology (Bamire *et al.*, 2010, 2012).

Capital: Cost also determines the adoption of an improved technology. Some authors argue that it is not the lack of liquidity per se but the timing of its requirement that constitutes a problem. Farmers often need cash to purchase fertilizers and seeds when rains start. However, they would have sold most of their production since harvest time due to pressing needs (Abdoulaye and Sanders, 2006; Akinbode and Bamire, 2015) leaving them without cash at planting time. In the absence of financing options, they are unable to raise the cash needed to purchase agricultural inputs. Also, the elimination of subsidies on seed and fertilizers since the 1990s due to the World Bank-sponsored structural adjustment programmes in most African countries has widened this constraint (Bamire *et al.*, 2012; Muzari *et al.*, 2012). In order to address the liquidity and supply constraints faced by resource-poor farmers related to technology adoption, a number of African countries, including Malawi, have implemented various forms of 'smart subsidies', an innovative delivery system that targets specific farmers to reduce common problems facing subsidy programmes (Minde *et al.*, 2008). Also, 14 million farmers across Nigeria have received subsidized seeds and fertilizers through the e-wallet system (NATSA, 2014). The farmers have also redeemed 1.37 million MT of fertilizer worth ₦151 billion ($915 million) and 67 991 MT of improved maize seeds, worth ₦43 billion ($260 million). The fertilizer subsidy programme in Ghana encouraged more farmers to use fertilizer in their maize plots, based on the increased adoption rate from 21% (Morris *et al.*, 1999), 25% based on the Ghana Living Standards Survey 5 conducted in 2005 – 6 (Quinones and Diao, 2011) and 47% in a most recent nationwide study (Ragasa *et al.*, 2013).

Based on extensive studies in Ethiopia, it has been shown that younger and much older household heads are risk averse and are less likely to adopt improved technologies. On the other hand, the availability of adult family members within households may facilitate the process of improved technology adoption, because most farming households cannot easily acquire hired labor due to liquidity constraints and other constraints in adopting improved technologies for maize cultivation (Carletto *et al.*, 2007). Furthermore, the continued availability of adult household members is an important determinant of whether households continue with the technology after adoption.

Off-farm income has, however, been shown to have a positive impact on technology adoption. This is because off-farm income acts as an important strategy for overcoming credit constraints faced by the rural households in many developing countries (Bamire *et al.*, 1999; 2012). Off-farm income has been shown to act as a substitute for borrowed capital in rural economies where credit markets are either missing or dysfunctional (Bamire *et al.*, 2012; Diiro, 2013). According to these studies, off-farm income is expected to provide farmers with liquid capital for purchasing productivity enhancing inputs such as improved seeds and fertilizers. For instance, when analyzing the impact of off-farm earnings on the intensity of adoption of improved maize varieties and the productivity of maize farming in Nigeria, Akinbode and Bamire (2017) reported a significantly higher adoption intensity and expenditure on purchased inputs among households with off-farm income compared to their counterparts without off-farm income. A similar result was obtained by Ogunya *et al.* (2017) and Abdoulaye *et al.* (2017). However, not all technologies have shown a positive relationship between off-farm income and their adoption. Some studies on technologies that are labor intensive have shown negative relationship between off-farm income and adoption. This is because the pursuit of off-farm income by farmers may undermine their adoption of modern technology by reducing the amount of household labor allocated to farming enterprises. According to Diiro (2013), off-farm income is expected to provide farmers with liquid capital for purchasing productivity-enhancing inputs such as improved seeds and fertilizers. However, not all technologies have shown positive relationship between off-farm income and their adoption (Akinbode and Bamire, 2017). Thus, off-farm income has an indeterminate effect on adoption decisions.

Changing prices: The relative price of agricultural output to inputs, for example, fertilizer, has been declining in most countries and does not constitute an incentive to invest in input purchase (Abdoulaye and Sanders, 2005). Most farmers that cultivate cereals have to sell more and more grain to be able to afford a kilogram of inorganic fertilizer. The changing prices of agricultural products also constrain improved maize technology adoption (Kijima *et al.*, 2011). With an initial attraction by high product prices, farmers can abandon the improved technologies if the expected benefits from its adoption are lower than the prevailing costs. There are a number of ways through which profitability of products may be lowered. For crops like maize, changes in the international trade regime may negatively affect world prices and consequently reduce local prices. Most seed production systems are seasonal in nature, and this affects the annual cash flow pattern of the seed producers. For commercial seed companies, the costs of carrying large stocks for several months at high interest rates can be devastating. These problems are made worse by the need to dispose of some seed stocks such as grain due to deterioration in store and/or excess production arising from poor demand estimates. The seasonality of agricultural enterprises and the changing profitability introduces a time dimension such that households may be able to adopt improved technologies for only some periods but not for all periods. It is important to note that when a new technology is capable of increasing the yield of a particular crop variety, and also perceived to have higher risk, price-support programmes and policies could increase its relative profitability. This increases both the extent and intensity of adoption.

Labor: In a study conducted in West Africa (Niger), which evaluated the adoption of cereal technologies under weather/rainfall uncertainty, it was found that family labor was used to adopt labor-intensive technologies (Adesina and Sanders, 1991). This is due to rural – urban migration by both young and adult individuals within the farming community in search of better living; while most youths now engage in fast income-generating business activities through the use of motor cycles popularly tagged 'Okada' in carrying passengers from one location to another. This has led to labor scarcity and consequent high cost of hired labor where available (Bamire *et al.*, 2010). The study by Makokha *et al.* (2001) on determinants of fertilizer and manure use in maize production in Kiambu County, Kenya, reported the high cost of labor and other inputs, unavailability of demanded packages and untimely delivery as the main constraints to fertilizer adoption. Cost of hired labor was also reported by Ouma *et al.* (2002) as one among other factors constraining the adoption of fertilizer and hybrid seed in Embu County, Kenya.

Institutional Factors

Mr. Vice Chancellor Sir, the institutional factors considered in this lecture deal with the extent or degree to which institutions impact on technology adoption by smallholders (Bamire *et al.*, 1999; Meinzen-Dick *et al.*, 2004). The institutions include all the services to agricultural development, such as the seed sector, extension service delivery, research funding, acquisition of information, and infrastructure, as well as mechanisms that enhance farmers' access to productive inputs and product markets. The institutions also include the embedded norms, behaviors and practices in society (Bamire, 2016).

Access to credit: Access to credit has been reported to stimulate technology adoption (Bamire and Oguntade, 1994). It is believed that access to credit promotes the adoption of risky technologies through relaxation of the liquidity constraint as well as through the boosting of the household's risk bearing ability (Bamire and Oludimu, 1997). This is because with an option of borrowing, a household can do away with risk reducing but inefficient income diversification strategies and concentrate on more risky but efficient investments (Bamire *et al.*, 2009). However, access to credit has been found to be gender biased in some countries where female-headed households are discriminated against by credit institutions, and as such they are unable to finance yield-raising technologies, leading to low adoption rates (Bamire *et al.*, 2016, 2007, 2010; Muzari *et al.*, 2012). There is therefore the need for policy makers to improve current smallholder credit systems to ensure that a wider spectrum of smallholders are able to have access to credit, more especially female-headed households (Gaya *et al.*, 2016). This may, in certain cases, necessitate designing credit packages that are tailored to meet the needs of specific gender groups (Bamire and Tijani, 1998; Bamire *et al.*, 2012; Gaya *et al.*, 2016). This will help empower women and enable them to adopt agricultural technologies hence enhancing economic growth.

Functional seed sector: The farmers' systems of seed supply and crop development are the most important sources of seed in most farming systems of the world and in Africa. Despite the efforts of large seed programmes to replace the farmers' seed systems for a system in which farmers use seed as an external input, the major part of agricultural land in Africa is still sown with seed that is informally produced by farmers (Kormawa *et al.*, 2000). Studies from the late 1990s and early 2000s suggest that the formal seed industry in Africa provided less than 10% of the seeds needed by the farmers (Kormawa *et al.*, 2000; Abdoulaye *et al.* 2012). The maize seed industry in eastern and southern Africa, for example, has witnessed a proliferation of private seed companies following the liberalization and restructuring of the seed sector. However, despite the increased number of registered maize seed companies in major maize-producing countries between 1997 and 2007, the quantity of seed marketed barely doubled (Langyintuo *et al.*, 2010; Abdoulaye *et al.*, 2012). This suggests that the seed production and deployment environment is less than perfect. This is associated with the non-functional seed production and delivery systems in different countries. For example, the national seed system (NSS) in Nigeria plays a pivotal role in the development of the nation's seed industry, including the production of foundation seeds, supervision, monitoring and quality control. However, an inadequate and delayed funding has made the performance of these functions ineffective.

The NSS has representations at both state and regional levels. Its operations in quality control and seed certification have been drastically reduced due to an inadequate number of trained staff and financial constraints (Badu-Apraku *et al.*, 2014). These have led to low output, which makes it impossible to supply good quality-certified seeds to the farmers. Rather, it has encouraged the sale of adulterated and unlabeled seeds in the market. For example, only 18% of maize area was planted with modern varieties and certified seed in Ghana (IFPRI, 2011). The use of the Growth Enhancement Scheme (GES) programme for reaching millions of farmers with seeds through their telephones or e-wallet system and input subsidies has, however, helped improve the seed delivery system in Nigeria and Malawi (NATSA, 2014). Targeting a formal seed sector that supplies 100% of the seed for planting will only be realistic by linking formal (private and public) and farmers' seed systems as an effective strategy for improving national and local seed.

Extension delivery system: The extension services in most African countries that are entrusted with the training of manpower to handle the technical aspects of the seed industry are either constrained by inadequate finance, equipment and logistics or have collapsed. Staff do not have training opportunities and therefore lack the knowledge and skill required to assist in seed testing, quality control and in providing technical assistance to contract growers. The inadequacy of extension officers makes it impossible to disseminate information on the seed industry, especially about the availability of improved seed varieties to the farmers.

Access to extension services has been found to be a key aspect in technology adoption. Farmers are usually informed about the existence as well as the effective use and benefit of new technology through extension agents. Extension agents act as a link between the innovators (Researchers) of the technology and users of that technology. Extension agents usually target specific farmers who are recognized as peers (farmers with whom a particular farmer interacts) exerting a direct or indirect influence on the whole population of farmers in their respective areas (Bamire and Deji, 2007). Many authors have reported a positive relationship between extension services and technology adoption. A set of good examples include: Bamire *et al.* (2002) on adoption patterns of fertilizer among small scale farmers in Southwest Nigeria; Akinbode and Bamire (2015) on determinants of adoption of improved maize varieties and Ogunya *et al.* (2017) on factors influencing levels and intensity of adoption of NERICA. This is because exposing farmers to information based upon innovation-diffusion theory is expected to stimulate adoption (Bamire *et al.*, 2010). In fact, the influence of extension agents can counter balance the negative effect of lack of years of formal education in the overall decision to adopt some technologies (Bonabana-Wabbi 2002; Bamire *et al.*, 2015).

Acquisition of information: Access to information about a new technology is another factor that determines adoption of technology. It enables farmers to learn about the existence as well as the effective use of technology and this facilitates its adoption. Farmers will only adopt the technology they are aware of or have heard about. As farmers acquire more information about a new technology by adopting it or partially adopting (trial) or using other sources (workshops, social network, etc.), their perceptions and beliefs are expected to change. Based on the innovation-diffusion literature, Adesina and Baidu-Forson (1995), and Bamire and Tijani (1998) showed that participation in workshops is positively related to adoption by exposing farmers to new information. Farmers who are in a network of relation(s) with many previous successful adopters have access to a large information network and, therefore, will be more likely to adopt a new technology (Bamire *et al.*, 2012; Abdoulaye *et al.*, 2012). Farmers may acquire information about new technologies from their peers, and therefore, membership in farmers' groups or associations is positively associated with adoption (Kassie *et al.*, 2013). Belonging to a social group enhances social capital allowing trust, idea and information exchange (Bamire, 1999; Mignouna *et al.*, 2011). Farmers within a social group learn from each other the benefits and usage of a new technology. Bamire *et al.*, 2010; 2012) suggest that social network effects are important for individual decisions, and that, in the particular context of agricultural innovations, farmers share information and learn from each other.

Studying the effect of community based organizations in the adoption of maize technology in Nigeria, Akinbode and Bamire (2015) found that farmers who participated more in community-based organizations were likely to engage in social learning about the technology, hence raising their likelihood to adopt the technologies. Although researchers (Bamire *et al.*, 2009; 2012) have reported a positive influence of social group on technology adoption, social groups may also have a negative impact on technology adoption especially where free-riding behavior exists. Participation in on-farm experimental trials is also hypothesized to be positively related to adoption (Adesina and Baidu-Forson, 1995; Etwire *et al.*, 2013). Access to information reduces the uncertainty about a technology's performance, hence may change individual's assessment from purely subjective to objective over time (Bamire *et al.*, 2015; Abdoulaye *et al.*, 2017). However, access to information about a technology does not necessarily mean it will be adopted by all farmers. This simply implies that farmers may perceive the technology and subjectively evaluate it differently than scientists (Bamire *et al.*, 1999; Akinbode and Bamire, 2017). Access to information may also result to dis-adoption of the technology. For instance, where experience within the general population about a specific technology is limited, more information induces negative attitudes towards its adoption, probably because more information exposes an even bigger information vacuum, hence increasing the risk associated with it (Bamire and Oguntade, 1994; Bamire and Oludimu, 1997; Akinbode and Bamire, 2017). It is therefore important to ensure the information is reliable, consistent and accurate. Farmers need to know the existence of technology, its benefits, and its usage for them to adopt it.

The extent to which farmers learn from each other and the influence of social network also play a vital role in accepting and disseminating new agricultural technologies to a large population. The main source of information for farmers is other farmers, because information is easily available and it is not too costly to utilize it (Anderson and Feder, 2004). Participation in on-farm experimental trials is also hypothesized to be positively related to adoption (Adesina and Baidu-Forson, 1995; Etwire *et al.*, 2013).

Research funding: Long-term research, inputs, skill and expertise, materials and equipment are required in developing improved maize technologies. Governments in many African countries directly support scientific and technical research through budget allocations to the ministries, research institutes and other institutions. This is complemented with funding support from CGIAR centres and other donor agencies that are active in the region. For example, the Bill and Melinda Gates Foundation, a founding member of AGRA, invests in basic research in a number of crops, including maize. However, these institutions can only provide about one-tenth of the overall funding required for research in improved technology in Africa that has been stagnating at that low level (Binswanger-Mkhize, 2009).

Infrastructure: Making technologies profitable requires large investments in irrigation infrastructure, which – in some places – may be very costly. Once the added costs of infrastructure development are factored in, the comparison of costs and benefits for the new crop may not make it worthwhile for either society or for the individual. The individual farmer would benefit more from receiving the money directly since the costs of the technology are greater than the benefits. When calculating whether or not a technology is worthwhile, it is therefore important to take into consideration the labor and capital investments that are necessary to enable adoption of the technology. In the irrigation example, the labor and capital costs of infrastructure development are real costs. In general, if the real costs are less than the total value created by higher adoption rates, then the investment is worthwhile. However, market inefficiencies may add additional "costs" that make the project appear unprofitable. For example, investments with high initial fixed costs, such as irrigation development, may present difficulties for securing a loan if credit markets are weak. The initial investor may not be able to recover these fixed costs from future users if contracting is difficult. Similarly, at the household level, worthwhile investments may be bypassed if market inefficiencies lower the profits that the farmer receives from adoption. In addition to market imperfections, profitability is also affected by factors that range from individual tastes and preferences to macroeconomic policies.

Improved seeds produced by the public sector are often sold to farmers through distribution channels like farmers' supply companies, agro-service centres, ADPs, cooperative societies and so on. The seed distribution system comprises all those activities involved in the flow of information about farmers' seed needs between the farmers themselves and the producing organizations. The seed distribution systems are important in the seed sector as they help in the timely distribution of improved seed to all the locations where they are required by the farmers. However, most rural areas are inaccessible due largely to poor road networks which hinder movement and performance of staff whose activities are required in the rural communities. This makes it difficult for transporters and impossible for farmers in such locations to enjoy the benefits of improved maize technology, and the few agro-dealers who find their way into such rural areas often charge high prices for their stock. The farmers also run the risk of buying fake and adulterated seeds due to poor storage and handling and the unscrupulous behavior of some seed traders (Abdoulaye *et al.*, 2009). This is due to the poor seed policy environment and lack of organized institutions to handle seed distribution among farmers.

Environmental Factors

Depending on the type of technology, agro-climatic conditions like rainfall are expected to influence technology adoption decisions (Ogunfowora, 1993; Akinbode and Bamire, 2015). Abdoulaye *et al.* (2012) hypothesized that favourable rainfall positively impacts on decisions to adopt improved seed types and fertilizer use. Pest and diseases are also expected to influence farmers' decisions and the sign of this variable depends on the type of improved technology (Kassie *et al.*, 2013).

Significant increases in crop production require improved agronomic practices in addition to improved hybrids (Eberhart, 1989). Good soil fertility management, timely date of planting, optimum planting rate, good weed control, good soil and water management, and the rotations of a legume with a cereal, are important factors in increasing yields with no additional cash expenditures (Nguluu *et al.*, 1996). The application of modest amounts of fertilizer is needed for further yield increases which require a cash input.

Also, for the efficient utilization of fertilizers, application rates should be given with consideration to cultural practices and factors such as the inherent fertility of the farm, organic sources of manure, method of application, time of planting, spatial arrangements, crop rotations and cropping sequences (Bamire and Amujoyegbe, 2004). In smallholdings, intercropping offers a diversity of organic sources of manure which may be added to the soil directly as crop residues or in the form of farm yard manure. However, smallholder farmers are not making full use of organic sources of manure and the expensive inorganic fertilizer option in raising agricultural productivity should be combined with cheaper local alternatives (Bamire *et al.*, 2012). In most African smallholder farming systems, organic manure application to crop production systems is constrained by low biomass production, coupled with limited availability of land or small landholding sizes (Alimi and Bamire, 2007; Akinbode and Bamire, 2015). They suggested that this problem can be resolved by incorporating high quality legumes in the nutrient recycling system on the farm. But low rainfall, infertile soils, and intense population pressure on land are likely to limit the effectiveness of the legume option, leading to lower adoption in many smallholder farming areas (Bamire *et al.*, 2010). Although some smallholders in sub-Saharan Africa use inorganic fertilizers, they do not necessarily apply recommended doses (Bamire, 1999, Bamire et al., 2010). The majority of those who apply are doing so at well below the recommended rates, due to the high cost and unavailability of such fertilizers. Researchers and development practitioners should also consider issues that relate to the farmers' exposure to economic, agro-meteorological, biophysical and social shocks in designing technologies for smallholders.

Thus, in general, understanding the role of each of the aforementioned factors that influence farmers' adoption decisions is critical to successful agricultural development and for the sustainability of the farming systems.

MY RESEARCH EFFORTS AND IMPACT

My academic research involvement has provided opportunities for collaborations and networks that had made it possible for me to attract some funds into the University. This has been through personal and joint research proposals that have won grants over the time. These research activities centre on cassava and maize as well as other crops.

Mr. Vice Chancellor Sir, as a Visiting Scientist in IITA in 2004, under Dr. Victor Manyong, I was involved in IFPRI supported research conducted to assess the health and economic burden caused by micronutrient malnutrition, particularly Vitamin A deficiency (VAD), among resource poor rural households in Southwestern Nigeria. VAD causes health problems such as night blindness, measles, corneal ulceration and scars, blindness in children, pregnant and lactating women and premature deaths in children, particularly in the rural communities. The strategies usually used for VAD reduction were through food fortification, pharmaceutical supplementation and dietary education campaign programmes that are expensive, but do not reach poor people, and are not sustainable in the long run. HarvestPlus/IFPRI made efforts to complement these strategies using biofortification – the conventional breeding of staple food crops for enhanced micronutrient content. This requires huge initial investments, hence it became expedient to assess the potential economic and health benefits of the programme. Since biofortified cassava (BC) crops were not yet available for consumption, the study employed an ex-ante approach to evaluate the potential health and economic benefits of increased pro-vitamin A status of cassava roots through biofortification for at risk target groups (comprising children, pregnant and lactating women) in Nigeria. The study targeted cassava, a food security crop and a major staple for more than 60 million Nigerians and for its rich dietary energy, though poor in essential micronutrients such as vitamin A, iron and zinc. Data were analysed using descriptive statistics, the "Disability-Adjusted Life Years" (DALYs) framework - defined as a measure of time lost from premature death and time lived with disability (Equation 1), and ex-ante cost-benefit analysis.

The results from DALYs (based on two scenarios: pessimistic and optimistic) showed that before the introduction of BC, VAD caused an annual loss of about 553,000 years of healthy life in Nigeria, with children aged <5 years accounting for 45% of the total DALYs lost, while pregnant and lactating women accounted for 28% and 27% respectively (Table 1).

The DALYs Framework:

$$DALYs_{lost} = \sum_j T_j M_{ij} \left(\frac{1 - e^{-rL_j}}{r} \right) + \sum_i \sum_j T_j I_{ij} D_{ij} \left(\frac{1 - e^{-rd_{ij}}}{r} \right) \quad \text{Eq.2}$$

$DALYs_{lost}$ is the years of "healthy" life lost
J denotes the target group,
i the disease,
T the size of target group,
M the mortality rate,
L is remaining life expectancy,
r the discount rate,
I the incidence rate,
D the disability weight, and
d the duration of the disease

The biofortification of cassava roots would, however, result in potential annual gains of between 36,668 and 237,929 years of healthy life (Table 2). In economic terms, such a programme would bring gains amounting to between $10 million and $69 million per year. Biofortified cassava would also reduce VAD by between 10.8% and 70.1% and avert between 166 and 1,272 child deaths per year. It was concluded that the health burden by VAD is substantial and children are most affected while the corresponding economic loss is huge. Thus, research and development efforts aimed at the biofortification of cassava roots is a powerful strategy which governments at the national and local levels, and international investors should support to improve the standard of living of the people.

Table 1: DALYs Loss due to Vitamin A deficiency without biofortified cassava products

Loss		Children	Pregnant Women	Lactating Women	Total
Due to Mortality	YLL	94,732	1,306	1,160	97,198
Due to temporal disability	YLD_{Temp}	37,761	27,515	25,116	90,392
Due to permanent disability	YLD_{Perm}	115,381	127,974	122,538	365,893
Total due to Disability	YLD_{total}	153,142	155,489	147,654	456,285
TOTAL	**$DALY_{Lost}$**	**247,874**	**156,795**	**148,814**	**553,483**
% Total		**45%**	**28%**	**27%**	**100%**

Source: Extracts from Manyong *et al.* (2007)

Table 2: Potential annual benefits with biofortified cassava (DALYs Gained)

DALYs Gained	Pessimistic Scenario	Optimistic Scenario
Children	11,128	85,023
Pregnant Women	15,055	89,561
Lactating Women	10,485	63,344
Total	**36,668**	**237,929**
Child Death Averted	**166**	**1,272**

Source: Extracts from Manyong *et al.* (2007)

Mr. Vice Chancellor Sir, as a follow up to that study, I was Principal Investigator for the International Food Policy Research Institute (IFPRI) which funded a study on Consumer Acceptance of Biofortified (yellow) Cassava Varieties in Oyo State, Nigeria. The study was carried out with HarvestPlus/IFPRI Scientists (notably Drs Ekin Birol, Adewale Oparinde and Paul Ilona) and attracted a grant of $24,435 into the University in 2011. The findings showed that some consumers accepted "yellow" cassava varieties only after receiving information on their nutritional benefits while others accepted the varieties even without any information. The yellow colour is due to the higher vitamin A content (Figure 3). This variety of cassava could provide more vitamin A in the diets of over 70 million Nigerians who eat the root crop every day.

Mr. Vice Chacellor, Sir, apart from informing the release in year 2011, of the three first-wave varieties of biofortified vitamin A enriched "yellow" cassava: UMUCASS 38 (TMS 01/1371), UMUCASS 37 (TMS 01/1412) and UMUCASS 36 (TMS 01/1368), this project also led to an intensive Skills Acquisition and Entrepreneurship Development (SAED) training workshop organized by HarvestPlus/IFPRI on the processing of Biofortified Vitamin A Cassava into different products in 2015. Twenty-two people (comprising staff and students of my Faculty - Faculty of Agriculture), were trained on Vitamin A Cassava value addition products such as Combobits and Combostrips (Figure 4). Some of these products (Figure 5) could be found at the Agro-fresh Shop in the Faculty of Agriculture while some of the students trained have found this as an income-generating opportunity, even after their graduation. Mr. Vice Chancellor Sir, this same project led to the donation of 20 units of computer laptops to my Department - The Department of Agricultural Economics.

Figure 3: Vitamin A Enriched Yellow Cassava Roots
Source: HarvestPlus/IFPRI, 2016

Figure 4: Skills Acquisition and Entrepreneurship Development Training Workshop on Vitamin A cassava value addition products Organized by HarvestPlus/IFPRI in 2015

Figure 5: Different Products of Biofortified Vitamin A Cassava
Source: HarvestPlus/IFPRI, 2016

This study also dovetailed into the Baseline Cassava Identification and Varietal Adoption Studies in Oyo, Benue and Akwa-Ibom States. Results showed that the popular cassava varieties in Akwa Ibom were: *Obubut Okpo*, *Afia Okpo* and *Oto Oko Tian* with adoption rates of 13%, 10% and 5% respectively; in Benue state, *Akpu*, *Dan Wari* and *BNARDA* were the popular varieties with adoption rates averaging about 19%, 14% and 8% respectively. In Oyo state, the popular varieties were: *Odongo* with 24% adoption, *Oko-Iyawo* 22% and *Ege dudu* 20% adoption rate. It was concluded that varietal identification of cassava on farmer's field requires a combination of both farmers and experts for proper classification. This should apply to newly introduced vitamin A rich biofortified cassava varieties. Other varieties identified in Oyo include: *Oko-Iyawo Eletun fun fun*, *Molekanga*, *Arubielu*, IITA, Texaco, *Ohori*, and *Ofege/Otegbeye*. In Akwa-Ibom, *Awacha*, *Ekauya* and *Panya* and in Benue *Dongo*, *Oko Iyawo* and *Yanyume wuhe*.

In 2015, a study was also conducted with IFPRI scientists on the profitability of Private Sector Investments in Biofortification using firms in Nigeria as a Case Study. Results showed that Vitamin A cassava has gained a very high level of integration into the cassava businesses, with about 59% of the businesses owned by women investors. Also, in the total volume of cassava traded by all the businesses, vitamin A cassava represented about 53% while white cassava accounted for 47% on the average. The most profitable business types across the states were fufu, high quality cassava flour (HQCF) and *gari* processing with a gross margin of 56%, 55% and 53% respectively, and one of the least profitable was stem/tuber production with a gross margin of 33%. Investing in Vitamin A cassava was found to be profitable but many businesses were not self-sufficient as only 15% sourced their vitamin A cassava needs from personally owned farms. This suggests a significant opportunity to attract more investors into the supply side of the vitamin A cassava market.

In 2016, a post-harvest packaging study was conducted with the German Development Cooperation (GIZ) to reduce storage losses of Cassava derivates in Nigeria. The study investigated the quality of packaging materials used for cassava products in Nigeria. This involved visiting cassava stem/tuber producers, processors and retail shops. The different packaging materials for the products are shown in Figure 6. About 72% of the processors used manual packaging methods, 25% semi-automated (25%) and 3% used full automated methods. The packaging materials used include polythene bags (popularly called "Nylon" bag), polythene-in-bags and propylene bags usually outsourced from another company/organization (service company). Most consumers in urban centres preferred the 150g and 1kg measures for both packaged gari and fufu because they could be consumed by an average household of 3 to 4 persons at once to prevent storage and associated health risks. The adoption of improved packaging technology is expected to add value to the processing operations by reducing stress and increasing production efficiency. It will also reduce attacks by pests and diseases substantially. The results showed that stakeholders in the cassava value chain complained of not getting the right quantity of raw materials for use. The producers are not much informed about the location of processors;

most processors also could not identify producers even when close to them. Processors also found it difficult to locate retail shops and market centres to sell their products. Consequently, these products do not get to the final consumers and the cycle of complaints continued. This study made it possible for many stakeholders in the cassava value chain to start calling themselves on telephone and e-mail exchanges to request for needed raw materials. In other words, developing a data base or information network connecting the different firms across the cassava value chain will facilitate easy access to raw materials for attaining the food security goal for engendering a sustainable farming system.

Figure 6: Packaging materials used for different cassava derivates
Source: Bamire, A. S. (2016)

Mr. Vice Chancellor Sir, I was also involved in adoption and impact studies that were conducted with CIMMYT and IITA. The first was a 5-country study on "Assessment of maize value chain for enhanced investment opportunities and productivity in West and Central Africa" covering Benin Republic, Cameroon, Ghana, Mali and Nigeria and for which I was selected the Principal Investigator. This study was sponsored by CIMMYT, Mexico through IITA and attracted the sum of $100,000 into our University in 2012. The results showed that the future of maize production lies not only on output increase but also on the development of processing industries. The availability of several value added products with assured local markets as well as increasing scale of processing makes the processing business attractive. Apart from this findings, the workshops and seminars conducted on this study brought in scientists from these countries into our University, involved staff and students, and provided a very good platform for networking.

As a follow-up to this, I was appointed the Principal Investigator on a study on Maize Seed delivery Systems in Ghana and Nigeria that attracted a sum of $25,000 into our University in 2014. Results showed that though about 98% of the farmers were aware of the improved maize seed varieties, 68.6% of them used the improved seed varieties (mainly OPVs) on their farms while 31.4% still used the local varieties. An effective extension service delivery system was recommended to enlighten farmers who were using local seed varieties.

In 2016, the continuous collaboration with IITA through the principal scientists in socio-economics (Drs. Victor Manyong and Abdoulaye Tahirou), led to the study on "Nigeria Country Plan Baseline and Varietal Monitoring Survey" tagged NIBAS. This study is on-going, and it is a three-tier Collaboration of OAU-IITA and the Nigerian Institute of Social and Economic Research (NISER), and for which I was appointed the Principal Investigator This attracted the sum of $1,499,998 Million USD into the University from the Bill & Melinda Gates Foundation (BMGF). The study involves obtaining baseline information on six major crops (cassava, maize, cowpea, rice, groundnut and yam) in six States (Benue, Nasarawa, Niger, Kaduna, Kano and Katsina) in Nigeria. Apart from generating data sets that would serve as a basis for productivity measures overtime, it will promote capacity building for the staff and students involved in each of the three institutions through training of trainers in new analytical tools for DNA fingerprinting, Surveybe, Crop cuts and WEAI (a gender analytical tool which has never been used in Nigeria until now). This is with the immense support of Drs. Akinola Adebayo, Ayodeji Ogunleye and Jumoke Adeyeye and members of my Department. It has also provided opportunity to organize workshops and training sessions within and outside OAU that could lead to further networking with other local and international institutions, and further strengthen collaboration of OAU, IITA NISER.

OTHER CONTRIBUTIONS TO RESEARCH AND PRACTICE

Mr. Vice Chancellor, Sir, Ladies and Gentlemen, my contribution is not limited to research alone. I joined the service of this University on 1st December, 1992 as an Assistant Lecturer and was promoted to the rank of Professor in 2008.

I have made significant contributions in the area of capacity building and mentoring of students and staff at the Department, Faculty and University levels. I teach both undergraduate and postgraduate students in Agricultural Economics courses.

I have successfully supervised both undergraduate projects and postgraduate theses of students in my Department, Department of Management and Accounting, and co-supervised Masters and PhD students in the African Institute of Social and Policy (AISPI). I have also supervised and still supervise both Masters and PhD students in the African University for Cooperative Development (AUDC) in Cotonou, Benin Republic. In fact, the first PhD candidate in that University was supervised by me and he was specially celebrated.

To the glory of God, I have assisted in assessing colleagues to the rank of Professor or Reader both within and outside Nigeria with subsequent collaboration/ partnership in various other areas. These include colleagues in the Department of Economics, AISPI and Management of Accounting, Federal University of Agriculture, Abeokuta (FUNAAB), University of Ibadan (UI), Ladoke Akintola University, Ogbomosho (LAUTECH), University of Pretoria, South Africa; and Makerere University, Kampala, Uganda.

I have served and still serve as External examiner to several institutions within and outside the University. Specifically, these include: The Department of Agricultural Economics, LAUTECH; Federal University of Technology (FUTA), Ekiti State University (EKSU), Centre for Sustainable Development, Ibadan, Nigeria; AUDC, Department of Agricultural Economics and Management of the University of Swaziland and the Department of Agricultural Economics, Makerere University, Kampala, Uganda. I have also served as member of the Editorial Board for various local, national and international Journal outlets.

I am a member of different national and international professional bodies including: The Nigerian Economic Society, Nigerian Rural Sociological Association, Nigerian Society for Environmental Management, and the Nigerian Association of Agricultural Economists. At the international level, I am a member of the International Society of Roots and Tubers, the Leadership for Environment and Development (LEAD) and now an Associate Senior Evaluation Fellow of the International Centre for Evaluation and Development (ICED), Nairobi, Kenya, and the Nigeria Country Liaison Officer for the Global Property Right Index Development (PRINDEX).

I have participated and presented papers in various conferences, workshops and seminars organized in the field of Agricultural Economics and related fields both in Nigeria and abroad. These include: Research methodology workshops in different countries: AUCD; International Institute of Tropical Agriculture (IITA), International Maize and Wheat Improvement Center (CIMMYT), Forum for Agricultural Research in Africa (FARA), South Africa; Russian Federation CIS; Sao Paulo, Brazil; Ghana;

Ethiopia; South Africa; Lusaka, Zambia; Washington DC, United States, and in Nairobi and Mombasa, Kenya.

I have participated in different research activities that earned me scholarships and grants of IITA and Council for the Development of Social Science Research in Africa (CODESRIA), Dakar, Senegal. I have also received fellowships from the Leadership for Environment and Development (LEAD International), U.K. My joint research efforts with colleagues and scientists in other institutions have won grants like the African Economic Research Consortium (AERC), Nairobi, Kenya; Population research fund grant; International Livestock Research Institute (ILRI) and Directorate for International Development (ILRI/DfID); United Nations University Institute of Natural Resources (UNU-INRA), Accra, Ghana; United Nations University World Institute for Development Economics Research (UNU-WIDER), Helsinki, Finland. I have also been involved in technology on-term evaluation studies with the team in the drought tolerant maize for Africa (DTMA) and now stress tolerant maize for Africa (STMA) programme since inception in 2007 till date, courtesy Dr. Tahirou Abdoulaye and the maize breeders in IITA (Drs. Menkir Abebe and Badu-Apraku), and these have led to different on-farm and off-farm experiences that provide long-term interactions with farm and non-farm households in their communities. These activities have led to more than 70 publications in both local and international outlets and further strengthened collaboration with the various institutions.

Mr. Vice Chancellor Sir, I have served as resource person and consultant in different programmes and fora. I was involved as socio-economist in the audit study of cassava small and medium scale enterprises (SMEs) in Oyo and Ogun States by the Federal Ministry of Agriculture and Rural Development (FMARD) of Nigeria in 2001; I participated, as a resource person, in on-farm training of farmers in three Local Government Areas of Osun State under the UNDP/OSSG/OAU cassava/maize intercrop project in 2006. I served as principal resource person in the household survey of the cowpea industry in Nigeria sponsored by IITA. I was also involved in a study led by Drs. Victor Manyong/ Alene Arega of IITA on developing International Commodity Database for Core Crops of IITA: National Survey of Crop Improvement Programmes in some West African Countries, 2010. This took me to many Research Institutes across countries in West Africa. I served as Resource person for the African Human Development Report on "Food Security for Human Development in Africa in 2011.

I have facilitated the involvement of staff and students of the Department and Faculty in the programme on Integrated Systems for the Humid Tropics in IITA as well as the Forum for Agricultural Research in Africa (FARA) programme.

In the area of administration, I have served in various capacities in different committees in the Department, Faculty and University at large. At the Departmental level, I was Chairman of committees such as Departmental Examination Coordination Committee, Undergraduate committee, Library committee and Postgraduate committee, and eventually became Head of Department. At the Faculty level, I was Vice Dean and Dean of the Faculty which made it possible for me to chairman various committees. As Dean, the collective efforts of Faculty members, Alumni, Friends of the Faculty (Dr. Akin Ogunbiyi, Otunba Emiola Ogunsanya etc.) changed the outlook of the Faculty in different ways.

During my tenure as Dean (1^{st} August, 2013 – 31^{st} July, 2015), I embarked and completed developmental projects in the Faculty through donations from my social capital network and amiable disposition to Faculty staff members, Alumni and friends of the Faculty. These projects include: resuscitating the Faculty water fountain which has now become a centre of attraction for film makers, drama and photography; changing the Faculty Committee Room to wearing a modern outlook; beautifying the Faculty and environment with flower gardens, paint markings of parks and lightings; refurbishing toilets attached to Faculty Committee

Room, Soil and Land Resources Management Department, ground floor and landscaping the frontal part of the Faculty with the inscription of the Faculty name; restructuring of Faculty Agro-fresh Mart; renovating the Faculty Library through the singular efforts of Dr. Akin Ogunbiyi; and many more. Members of my Class in the Faculty of Agriculture) instituted the "Faculty of Agriculture Set 84/85 Alumni Prize: For the best graduating student in the Final B. Agric. Degree Examination during the period.

I have received awards as a result of my service as Dean and in various other settings. These include: Faculty award of excellence for contribution to growth and development of the Faculty of Agriculture as Dean; Nigerian Association of Agricultural Students (NAAS) OAU, Ife - Award of excellence for exemplary leadership and remarkable contributions to the development of the Faculty of Agriculture; Nigerian Association of Agricultural Students (NAAS) OAU, Ife - Award of outstanding achievement for dedication, commitment and progress of the Faculty of Agriculture; Ambassador Award by Great Ife Alumni Association, Home Branch for priceless contributions to the development of educational sector in Nigeria; Distinguished Charlean award for service, dedication and commitment to Alma Mater, St. Charles Grammar School, Osogbo; and Rotary International District 9125 Award of excellence for contribution to research and educational development.

At the University level, my current position as Deputy Vice Chancellor (Academic) of this great institution has given me different opportunities to serve in the University. I will like to appreciate the Vice-Chancellor, Professor Eyitope Ogunbòdede and the Distinguished Members od Senate of this University for the rare opportunity given me to serve.

CONCLUSION

Mr. Vice Chancellor Sir, I have shown in this lecture that agricultural technology is key in any national strategy aimed at increasing agricultural productivity and food security.

I have also shown that the current traditional farming systems cannot guarantee food security in view of the various challenges associated with this system. For example, the farmers live and farm in areas where rainfall is low and erratic, and soils tend to be infertile. In addition, infrastructure and institutions such as irrigation, input and product markets, credit and extension services tend to be poorly developed. Thus, presently, the only approach to addressing these challenges for a sustainable farming system is through farmers' adoption of appropriate agricultural technologies. Research and development efforts have been making provisions for improved agricultural technologies over time for farmers use. These technologies have been developed for practically every stage of the production process, and they include technologies for tilling the soil, planting seeds, organic and inorganic fertilizer application, land irrigation, application of agro-chemicals like herbicides for weeding, protection from pests and weeds, harvesting, and general agronomic practices such as plant spacing.

It has also been shown that despite the benefits associated with these technologies, their rate of adoption by farmers is generally low. Therefore, in understanding the factors influencing farmers' adoption decisions of these agricultural technologies, this lecture grouped the factors into five main categories: human capital, technological, economic, institutional and environmental factors. Farmer and farm characteristics constitute the human capital component; technological factors involve perceptions about characteristics of the technology, farmers' objectives and goals at the time of the decision, and perceived costs and risks associated with the technology; the economic factors include land availability, capital, changing prices, and labor; the institutional factors comprise credit, the seed sector, extension delivery system, acquisition of information, research funding, infrastructure; while environmental factors relate to location of the technology. The role of each factor as they constrain farmers' uptake of agricultural technologies was also highlighted to show that adoption studies are contextual specific (in terms of type of technology and location), as the different factors vary largely even within countries over time.

Mr. Vice Chancellor Sir, these factors constrain and determine to a large extent the rate of uptake and adoption of any improved agricultural technology and therefore should be taken into consideration in any strategy or policy formulation targeted towards farmers for food security and a sustainable farming system.

FOSTERING SUSTAINABLE FARMING SYSTEMS

Mr. Vice Chancellor Sir, in order to address the challenges facing individuals and organizations in the adoption of agricultural technologies, as a result of the various factors highlighted above, the promotion of research activities in the development of agricultural technologies becomes imperative. However, the inadequate funding of the Ministries of Agriculture, research institutes, universities and other scientists makes it difficult for them to engage effectively in research activities. In addition, when funds become available, their late disbursement for technology development and dissemination programmes causes a lot of distortions, with difficulties in acquiring necessary technical materials and equipment. This demoralizes the researchers and scientists with consequent low adoption by users of the technologies. This requires governments political will to increase funding for research in the development of improved agricultural technologies. This could be through policies directed at protecting intellectual property rights regime by granting breeders/developers of the new ideas/technologies strong and long-lasting claims to the economic benefits of their ideas. The patent rights should not, however, prevent further research and the commercialization of the improved technologies.

Improved productivity in the agricultural sector will, among other things, require a concerted effort in providing the farming community with high yielding varieties that are drought and pest resistant. The higher crop yields will reduce costs per unit of output and lead to sustained development of the farming system.

Policy makers and development practitioners should also promote technologies that are simple, available and affordable, as they are likely to have higher adoption rates among resource poor farmers. For example, the introduction of simple technologies that require less labor is likely to fast-track their adoption because the smallholder farming community is beset with chronic shortages of labor during the agricultural season. An understanding of local cultural practices and preferences is also important if smallholder farmers are to benefit from agricultural technologies developed through research.

The promotion of various smallholder income sources such as off-farm employment, remittances, and livestock production, can lead to higher total household income that will finance the purchase of inputs such as fertilizers, seed, and hired labor.

The promotion of greater research-extension linkages will also improve technology adoption. Agricultural training and extension programmes need be intensive enough to promote adoption not only of improved yield-enhancing technologies, such as improved seeds, but also of fertility-restoring and conservation technologies that will help sustain the farming system.

To this end, there is the need for stronger partnership between agricultural researchers and other agents of change, including extension services, local organizations, farmers, community leaders, NGOs, national policy makers, and donors in implementing programs that stimulate and promote farmers' adoption of agricultural technologies that can increase agricultural productivity as well as reduce environmental degradation and the deterioration of soil quality. The technical services of breeders, pathologists, entomologists, agricultural economists and other scientists will thus be made readily available to organizations whenever required.

CLOSING REMARKS

Mr. Vice Chancellor Sir, permit me to quickly appreciate all those, too numerous to mention, who God has positioned to be my Helper in life.

Foremost, I am deeply grateful to God Almighty, The Alpha and The Omega, The Beginning and the End, The Trinity God – God the Father, God the Son and God the Holy Spirit, for His faithfulness, care and immense love to me in my life affairs and in making this day a reality. To Him alone be the Glory.

I want to sincerely appreciate the Vice Chancellor Prof. Eyitope Ogunbodede and his wife, for the confidence reposed in me and for their love and care. I pray that God will give you all that is required to achieve your lined-up vision in taking this University to greater heights. May the good Lord continue to be with you and all yours.

I appreciate the DVC (Administration), Professor Ajila and his wife for their support and encouragement at all times. My great appreciations to all the Distinguished Members of Council, Members of Senate, Principal Officers, Deans, Directors, Head of Departments and Members of the University Community for the atmosphere of friendship provided for me to operate within and outside this University.

I have enjoyed the unalloyed support of members of my Department (Department of Agricultural Economics), the Faculty of Agriculture, Institute of Agricultural Research & Training (IAR&T) and the entire Members of the University Community, who have provided an enabling environment for me to work and learn for the development of my academic career. You are greatly cherished.

I owe a deep gratitude to the families of Pastor S. O. Dunmoye and Mr. M. A. Ogunmodede who, in the pursuit of knowledge, brought me from the North to OAU, Ile-Ife and handed me over to Prof. Y. L. Fabiyi, who eventually became my mentor and Supervisor for the PhD Thesis that won the NUPTAS Award.

The outstanding contributions of my Co-Supervisor, Dr. V. Manyong, to my academic pursuit will always remain indelible in my heart. I do not have the words to express the positive influence you have had on me as a person and my family - your contributions have been highly significant and are greatly appreciated.

I also appreciate my Supervisors at the Undergraduate (Dr. T. O. Williams) and at the Masters level (Prof. O. L. Oludimu) for their contributions in guiding me through my academic career.

The immense contributions of Dr. Tahirou and family can never go unremembered. As a friend and mentor, you have touched my life in more ways than you know over the past years. You have been so wonderful! Thank you very much for always being there for me.
I greatly appreciate all my teachers from Nursery/ Primary, Secondary School and in the University for laying the foundation of knowledge in me to be able to make a day like this. Many thanks for your unquantifiable contributions. I also remain indebted to my students - Postgraduate and Undergraduate for your Love and Support.

I acknowledge the support of the following International Organisations with the various opportunities they provide in supporting my academic career in the area of Agricultural Resource Economics: International Institute of Tropical Agriculture (IITA); Council for the Development of Social Science Research in Africa (CODESRIA), HarvestPlus/ International Food Policy Research Institute (IFPRI), United Nations University World Institute for Development Economics Research (UNU-WIDER), United Nations University Institute of Natural Resources (UNU-INRA), African Economic Research Consortium (AERC), Leadership for Environment and Development (LEAD), and The International Livestock Research Institute & Directorate for International Development (ILRI/DfID), The Royal Tropical Institute (KIT) in The Netherlands and the International Centre for Evaluation and Development (ICED).

To my beloved Parents, both of blessed memory - Late Pa. Timothy Oyekanmi Bamire and Mrs. Dorcas Adepeju Bamire, I thank you for setting my foot right in life and giving me the confidence to pursue my dreams. The memory of their efforts, love, care and kindness remains fresh in my heart. How I wish you were around to witness a day like this, depicting God's grace to you.

To have been able to make this day a reality, requires the support of one's immediate family. I want to specially appreciate my beautiful wife and best friend - Dr. (Mrs.) Felicia Bosede Bamire, for all she has been for me over the years. Your trust and confidence in me as well as your understanding, support and prayers have greatly enriched my being. I am always proud of you. And to the special and wonderful gifts of God to us - Tobiloba, Tolulope, Temitope and Timilehin, thank you for your love, endurance and encouragement.

I appreciate my In-Laws, Brothers and Sisters for their continuous support for me and my family. The support and love of members of St. Charles' Old Boys Association, Ile-Ife branch and other branches is appreciated. Also members of my undergraduate Class - Set 85/86 of the Faculty of Agriculture are greatly acknowledged. I thank Dr. Akin Ogunbiyi for his love and commitment to the progress of this University. Thank you for your contributions.

I thank my Pastors and the members of my church (CAC, Oke-Alafia, Ile-Ife) for their prayers and support at all times. To all my friends who organized this inaugural and reviewed my submissions, I appreciate you greatly. I also thank all my audience from far and near, you are highly appreciated for coming. I say thank you all for your unwavering support.
I thank you all for listening. God bless you.

REFERENCES

Abadi, G.A.K., D.J. Pannell, M.P. Burton (2005). Risk, uncertainty, and learning in adoption of a crop innovation. *Agric. Econ.* 33: 1-9.

Abdoulaye, T. and J.H. Sanders (2006). "New technologies, marketing strategies and public policy for traditional food crops: Millet in Niger" *Agricultural systems*, 90: 272-292.

Abdoulaye, T., **A.S. Bamire**, A.A. Akinola and M. Etwire (2015). Smallholders Perception and Adaptation Strategies to Climate Change in Brong Ahafo and Upper West regions of Ghana. Submitted to CCAFS and IITA, Ibadan, Nigeria.

Abdoulaye, T., **A.S. Bamire**, A.A. Akinola, A. Alene, A. Menkir and V. Manyong (2017). Constraints in Adopting Improved Technologies for Maize Cultivation: The Case of Africa, Chapter 18. In Watson, D. (ed.), Achieving sustainable cultivation of maize volume 1: from improved varieties to local applications, Burleigh Dodds Science Publishing, Cambridge, UK. ISBN: 9784786760081: www.bdspublishing.com.

Abdoulaye, T., **A.S. Bamire,** A.N. Wiredu, M.N. Baco and M. Fofana (2012). Project community surveys, characterization of maize-producing communities in Benin, Ghana, Mali and Nigeria: West Africa Regional Synthesis Report. Drought Tolerant Maize for Africa (DTMA), 18pp.

Abdoulaye, T., P.S. Amaza, A. Olanrewaju, J. Ellis-Jones (2012). "Promoting the adoption of innovations through participatory approaches: example from northern Nigeria" *Tropicultura,* 30(3): 155-160. ISSN 0771-3312.

Abdoulaye, T., D. Sanogo, A. Langyintuo **A.S. Bamire,** and A. Olanrewaju (2009). Assessment of the bottlenecks affecting the production and deployment of maize seeds in DTMA countries of

West Africa. Submitted to the International Institute of Tropical Agriculture, Nigeria.

Adegbola, P., C. Gardebroek (2007). The effect of information sources on technology adoption and modification decisions. Agri. Econ. 37:55-65.

Adesina, A.A., M.M. Zinnah (1993). Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone. *Agric. Econ.* 9: 297-311.

Adesina, A.A., J. Baidu-Forson (1995). Farmers' perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, W. Africa. *Agric. Econ.*13: 1-9.

Ajayi, M.T. and A. Oloruntoba (2007). Assessment of factors affecting farmers' adoption and utilisation of major agricultural technologies developed by International Institute of Tropical Agriculture (IITA). *Journal of Agriculture, Forestry and the Social Sciences,* 5 (1).

Akinbode, W.O. and **A.S. Bamire** (2015). Determinants of adoption of improved maize varieties in Osun State, Nigeria, *Journal of Agricultural Extension and Rural Development*, 7(3): 65-72.

Akinbode, W.O. and **A.S. Bamire** (2015). Discontinued Use Decision of Improved Maize Varieties in Osun State, Nigeria. *Journal of Development and Agricultural Economics*, 7(3): 85-91.
Akinola, A.A; A.D. Alene; R. Adeyemo; D. Sanogo; A.S. Olanrewaju (2009). "Economic impacts of soil fertility management research in West Africa".*African Journal of Agricultural and Resource Economics*: 3 (2): 159-175.

Akinola, A.A; Alene, A.D; R. Adeyemo; D. Sanogo; A.S. Olanrewaju; C. Nwoke; G. Nziguheba and J. Diels (2010) "Determinants of Adoption and Intensity of use of Balanced in the

Northern Guinea Savanna of Nigeria". *Quarterly Journal of International Agriculture*: 49 (1): 25-45, Berlin.

Akudugu, M., E. Guo, S. Dadzie, (2012) Adoption of Modern Agricultural Production Technologies by Farm Households in Ghana: What Factors Influence their Decisions? *Journal of Biology, Agriculture and Healthcare* 2(3).

Alexander, C., and T. Van Mellor, (2005). Determinants of corn rootworm resistant corn adoption in Indiana. *AgBioForum*, 8(4): 197-204.

Alimi, T. and **A.S. Bamire** (2003). Fodder Innovations in the Agroecological zones of Nigeria (2003), ILRI/DfID, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Anderson, J.R. and G. Feder (2004). Agricultural extension: Good intentions and hard realities, The *World Bank Research Observer* 19 (1): 41-60.

Austin, E., J. Willock, I. Deary, G. Gibson, J. Dent, G. Edwards-Jones, O. Morgan, R. Grieve, and A. Sutherland (1998). Empirical models of farmer behavior using psychological, social and economic variables. Part I: linear modeling. *Agric. Syst.* 58: 203-224.

Ayinde, O.E, M.O. Adewumi, G.B. Olatunji, and O.A. Babalola, (2010). Determinants of Adoption of Downy Mildew Resistant Maize by Small-Scale Farmers in Kwara State, Nigeria. Global Journal of Science Frontier Research, 10pp.

Ayinde, O.E, T. Abduolaye, G. Olaoye, J.A. Akangbe (2013). Gender and Innovation in Agriculture: A Case Study of Farmers' Varietal Preference of Drought Tolerant Maize in Southern Guinea Savannah Region of Nigeria. Albanian, *J. Agric. Sci.* 12(4): 617-625.

Baco, M.N., T. Abdoulaye, D. Sanogo and A. Languitou (2010). Caracterisation des ménages producteurs de mais en zone de savane seche au Benin. Rapport pays – Enquete-menage – Benin. IITA, Ibadan, Nigeria, 38pp.

Badu-Apraku, B., R.A. Asuboah, B. Fakorede and B. Asafo-Adjei (2014). Strategies for Sustainable Maize Seed Production in West and Central Africa. IITA, Nigeria. 140pp.

Baidu-Forson, J. (1999). Factors influencing adoption of land-enhancing technology in the Sahel: lessons from a case study in Niger. *Agric. Econ.* 20: 231-239.

Bamire, A.S. (1999). Factors Influencing the Adoption of Fertilizer Technology in Osun State of Nigeria. A Ph.D. Thesis, Department of Agricultural Economics, Faculty of Agriculture, Obafemi Awolowo University, Ile-Ife, Nigeria.

Bamire, A.S. (2016). Report on the Structure, Conduct and Performance of the Cowpea Industry in Nigeria. Report submitted to the International Institute of Tropical Agriculture, Ibadan, Nigeria.

Bamire, A.S. (2007). Agricultural biomass supply in Southwestern Nigeria. Report submitted to Winrock International Institute for Agricultural Development, USA. January, 2007.

Bamire, A.S. (2007). Contribution of gender, land tenure arrangements and adoption of new technologies to household food insecurity in Nigeria, Report submitted to the United Nations University World Institute for Development Economics Research (UNU-WIDER), Helsinki, Finland.

Bamire, A.S. (2014). Assessing the potential for incorporating cassava peel as a feed input into livestock value chains in West Africa: A Case study of Small Processors in Ajegunle Market in Oyo East LGA in Oyo State, Nigeria. June, 2014.

Bamire, A.S. (2014). Report on Assessment of maize value chain for enhanced investment opportunities and productivity in West and Central Africa. Maize CRP, CIMMYT, July, 2014.

Bamire, A.S. (2016): Packaging Technology to Reduce Storage Losses of Cassava Derivates in Nigeria, Federal Ministry of economic Cooperation and development, Special Initiative ONE WORLD – No Hunger, Green Innovation Centres for the Agriculture and Food Sector – Nigeria, GIZ-AFC PN 14,0967, 1-104.00.

Bamire, A.S. and T. Abdoulaye (2013). A Baseline Cassava Varietal Adoption Study to inform Development, delivery and marketing of Pro vitamin A Cassava in Oyo State, Nigeria. Submitted to HarvestPlus, IFPRI, Washington, DC, USA. January.

Bamire, A.S., A.A. Akinola and R. Kassali (2012). End Line Report on Impact of IAR4D ON Rural Livelihoods in the KKM-PLS Sahel Savannah Agro-ecological Zone, submitted to Institut national De La RechercheAgronomique Du Niger Centre Regional De RechercheAgronomique (CERRA) Maradi, Niger. July, 2012.

Bamire, A.S., R. Abaidoo, N. Jemo, T. Abdoulaye, A.A. Yusuf and C. Nwoke (2012). Profitability Analysis of Commercial Chemical and BiologicalCrop products among Farm Households in Agro-ecological Zones of West Africa, *African Journal of Agricultural Research*, 7(23): 3385-3394.

Bamire, A.S., Abdoulaye, T. and D. Sanogo, (2009). Community assessment report for the drought tolerant maize for Africa (DTMA) project in the dry savanna of Nigeria. Submitted to the International Institute of Tropical Agriculture, Nigeria.

Bamire, A.S., T. Abdoulaye, P. Amaza, A. Tegbaru, A.D. Alene and A.Y. Kamara (2010). Impact of promoting sustainable agriculture in Borno (PROSAB) program on adoption of improved crop varieties in Borno State of Nigeria, *Journal of Food, Agriculture & Environment*, 8:(3&4): 391 - 398.

Bamire, A.S., Adejobi, A.O., Akinola, A.A. and O. Olagbaju (2007). "Socioeconomic factors influencing the choice of soil amendment techniques among maize farmers in Oyo State, Nigeria" Pages 433-441, *in* U. Haruna, S.A. Jubril, Y.P. Mancha and M. Nasiru (eds.). Proceedings of the 9th Annual Conference of the Nigerian Association of Agricultural Economists, on Consolidation of Growth and Development of Agricultural Sector, held in ATBU, Bauchi, Bauchi State, Nigeria. 5th - 8th November, 2007.

Bamire, A.S., O. Oluwasola, and A.T. Adesiyan (2007). "Land use and socio-economic determinants of technical efficiency of rice farms in Osun State, Nigeria". Pages 27-35, *in* U. Haruna, S.A. Jubril, Y.P. Mancha and M. Nasiru (eds.).Proceedings of the 9th Annual Conference of the Nigerian Association of Agricultural Economists, on Consolidation of Growth and Development of Agricultural Sector, held in ATBU, Bauchi, Nigeria. 5th - 8th November, 2007.

Bamire, A.S., T. Abdoulaye, D. Sanogo and A. Langyintuo (2010). Characterization of maize producing households in the Dry Savanna of Nigeria. Country Report – Nigeria, IITA, Ibadan, Nigeria, 46pp.

Bamire, A.S. (1999). "Socio-economic Determinants of Soil Conservation Practices in Nigeria". *Indian Journal of Soil and Water Conservation*,. 27 (3): 246-253.

Bamire, A.S. (2007). Gender, land tenure systems and the adoption of intensification technologies among smallholder maize farmers in the agroecological zones of Nigeria. Report submitted to the United Nations University Institute for Natural Resources in Africa (UNU-INRA), P.M.B., K.I.A., Accra, Ghana.

Bamire, A.S. and A.A. Tijani (1998)."Role of Women in Alleviating Household Poverty Levels in Ilesa Local Government Area of Osun State of Nigeria". In Fabiyi, Y.L. and E.O. Idowu (eds) Poverty

Alleviation and Food Security in Nigeria. *Journal of the Nigerian Association of Agricultural Economists*. 118-121.

Bamire, A.S. and B.J. Amujoyegbe (2004). Economics of poultry manure utilization in land quality improvement among integrated poultry-maize farmers in southwestern Nigeria. *Journal of Sustainable Agric.,* 23 (3): 21-37.

Bamire, A.S. and O.F. Deji (2007). Implications of land tenure and gender differentials on profitability of maize production in Nigeria, *Journal of Agricultural Management and Rural Development,* Nigeria. ISSN 1595-7715, 4: 137-157.

Bamire, A.S. and O.I. Oludimu (1997) "Classifying Smallholder Farmers for Improved Production: A Nigerian Case Study on Farmers' Risk Attitudes". *African Journal of Institutions and Development* (AJID). 3 (1 & 2): 85-92.

Bamire, A.S. and A.E. Oguntade, (1994): Effect of Risk Attitudes on Farm Profitability among Arable Crop Farmers: A Case Study. *The Indian Journal of Economics*, LXXIV, 531-542.

Bamire, A.S. and V.M. Manyong (2003). Profitability of intensification technologies among smallholder maize farmers in the forest-savanna transition zone of Nigeria. *Agriculture, Ecosystems & Environment*, 100: 111-118.

Bamire, A.S. and. J.T.O. Oke (2003) Profitability of vegetable farming under rainy- and dry-season production in Southwestern Nigeria. *Journal of Vegetable Crop Production*, 9(2): 11-18.

Bamire, A.S., T. Abdoulaye, and D. Sanogo (2012). "Determinants of Improved Maize adoption in Nigeria: Are they the same for Poor and Well Endowed Households?" *Ife Journal of Agriculture,* 25: 83-100.

Bamire, A.S., T. Alimi, and A.B. Ayanwale, (2004). Economic efficiency of land improvement techniques among cassava farmers in the wetlands of Nigeria, *Eastern Africa Journal of Rural Development* (EAJRD), 20 (1): 45-56.

Bamire, A.S., Y.L. Fabiyi, (2002). Economic Implications of property rights on smallholder use of fertilizer in southwest Nigeria. *Land Reform, Land Settlement and Cooperatives,* 2001/2. 86-92.

Bamire, A.S., O.O. Olubode and A.A. Akinola (2005). Socioeconomic Analysis of Smallholder Land Management Practices in Rice-based Production Systems in Nigeria, *Eastern Africa Journal of Rural Development*, December: 21(1): 84-95.

Bamire, A.S., T. Abdoulaye, D. Sanogo, and A. Langyintuo (2010). Characterization of maize producing households in the dry savanna of Nigeria. Country Report – Nigeria.: IITA Ibadan, Nigeria. 46pp.

Bamire, A.S., Y.L. Fabiyi and V.M. Manyong (2002) "Adoption Patterns of Fertilizer among Small-Scale Farmers in Two Ecologies of Southwest Nigeria: A Tobit Analysis". *Australian Journal of Agricultural Research.* 53: 901-910.

Bamire, A.S., A.A. Akinola, O.O. Olubode-Awosola, and G. Oyewusi (2008). Economic analysis of crop-livestock production among smallholder farmers in the dry savanna of Nigeria, *Ife Journal of Agriculture*, 23(1): 86-103.

Bamire, A.S. and V.K. Ocran (1995). Traditional seed production, distribution and marketing systems. A paper presented at the Crop Management Research Training (CMRT): Seed Maize Production Techniques, 14–25 August, 1995. Kumasi, Ghana.

Bedru, B. and D. Wegary (2014). Determinants of smallholder farmers' hybrid maize adoption in the drought prone Central Rift

Valley of Ethiopia. *African Journal of Agricultural Research*, 9(17), 1334-1343.

Bergevoet, R.H.M., C.J M. Ondersteijn, H.W. Saatkamp, C.M.J. Van Woerkum, R.B.M. Huirne, (2004). Entrepreneurial behavior of dutch dairy farmers under a milk quota system: goals, objectives and attitudes. *Agric. Syst.* 80: 1-21.

Binswanger, H. P. and J. McIntire (1987). Behavioral and material determinants of production relations in land-abundant tropical agriculture, Economic Development and Cultural Change, 36(1):73-99.

Binswanger-Mkhize, H.P. (2009). Challenges and opportunities for African agriculture and food security: High food prices, climate change, population growth, and HIV and AIDs. Expert Meeting on How to feed the World in 2050, Food and Agriculture Organization of the United Nations Economic and Social Development Department, 24-25 June, 2009.

Bonabana-Wabbi J. (2002). Assessing Factors Affecting Adoption of Agricultural Technologies: The Case of Integrated Pest Management (IPM) in Kumi District, Msc. Thesis Eastern Uganda.

Boserup, E. (1965). The conditions of agricultural growth, The economics of agrarian change under population pressure, Earthscan publications Ltd, London.

Carletto, C., A. Kirk and P. Winters (2007). Non-traditional exports, traditional constraints: The adoption and diffusion of cash crops among smallholders in Guatemala. World Bank Policy Research Working Paper No. 4347.

De Janvry, A., A. Dustan and E. Sadoulet (2011). Recent advances in impact analysis methods for ex-post impact assessments of agricultural technology: Options for the CGIAR. CGIAR Independent Science and Partnership Council.

Diiro, G. (2013). Impact of Off-farm Income on Technology Adoption Intensity and Productivity: Evidence from Rural Maize Farmers in Uganda. International Food Policy Research Institute, Working Paper 11.

Duflo, E., M. Kremer and J. Robinson (2008). "How high are rates of return to fertilizer? Evidence from field experiments in Kenya". *American Economic Review*, 2008, 98(2): 482-488.

Eberhart, S. A. (1989). A comprehensive system of developing improved maize hybrids, Journal of Sustainable Development, 5(8):10 – 38.

Etwire, P.M., I.D.K. Atokple, S.S.J. Buah, A.L. Abdulai, A.S. Karikari, and P. Asungre, (2013). Analysis of the Seed System in Ghana. *International Journal of Advance Agricultural Research.* 1(1): 7-13.

Etwire, M., T. Abdoulaye, K. Obeng-Antwi, A. Bua, R. Kanton, H. Asumadu, M.S. Abdulai, A. Haruna, J. Etwire (2013). "On-farm evaluation of maize varieties in the transitional and savannah zones of Ghana: determinants of farmer preferences". *Journal of Development and Agricultural Economics*, 5(6): 255 - 262, ISSN 2006-9774.

Feder G, R.E. Just, D. Zilberman (1985). Adoption of agricultural innovations in developing countries: A survey. *Econ. Dev. Cultural Change* 33: 255-298.

Feenstra, R.C. (2017). "Restoring the Product Variety and Pro-competitive Gains from Trade with Heterogeneous Firms and Bounded Productivity," *Journal of International Economics.*

Field, H. L. and J. Solie (2007). Introduction to agricultural engineering technology: a problem solving approach. New York, NY: Springer. ISBN 0387369139 (http://www.amazon.com/dp/0387369139? tag=encyclopediap-

Foster, A.D and M.R Rosenzweig, (2010). Micro economics of Technology Adoption. Economic Growth Center Yale University center discussion Paper No. 984.

Foster, Andrew D. and Mark R. Rosenzweig (1996) "Technical Change and Human Capital Returns and Investments: Evidence from the Green Revolution", *American Economic Review* 86(4): 931-953 September.

Gabre-Madhin, Z. and S. Haggblade, (2001). Success in African Agriculture: Results of an Expert Survey. International Food Policy Research Institute. Washington DC. June 2001.

Gaya, H.I., A. Tegbaru, **A.S. Bamire**, T. Abdoulaye and A.D. Kehinde (2016). Gender differentials and adoption of Drought Tolerant Maize Varieties among farmers in Northern Nigeria. *European Journal of Business and Management*, ISSN (Paper) 2222-1905 ISSN (Online) 2222-2839.

Gershon, F. and D.L. Umali (1993). The adoption of agricultural innovations: A review. *Technological Forecasting and Social Change,* 43(3–4): 215-239.

Goodwin, B.K., and T.C. Schroeder (1994). "Human capital, producer education programs, and the adoption of forward pricing methods." *American Journal of Agricultural Economics*, 76, 936947.

Greiner, R., L. Patterson, O. Miller (2009). Motivation, risk perceptions and adoption of conservation practices by farmers, *Agric. Syst.*99: 86-104.

Hassan, R., M. Mekuria and W. Mwangi (2001). Maize Breeding Research in Eastern and Southern Africa: Current Status and Impacts of Past Investments Made by the Public and Private Sectors, 1966-1997., Mexico, D.F.: CIMMYT.

Henrich, J. (2013). Cultural Transmission and the Diffusion of Innovations: Adoption Dynamics Indicate That Biased Cultural Transmission Is the Predominate Force in Behavioral Change. *American Anthropologist*,103(4): 992-1013.

Huffman, E., and S. Mercier, (1991). "Joint Adoption of Microcomputer Technologies: An Analysis of Farmers' Decisions." *The Review of Economics and Statistics* 73(3): 541-546.

Idrisa, Y.L., T. Abdoulaye , S.T. Mohammed and A.A. Ibrahim, 2014. "Analysis of Drought-Tolerant Maize Adoption and its Effect on Food Security among Farmers in the Sudan Savanna of Northeastern Nigeria". *Asian Journal of Agricultural Extension, Economics & Sociology 3(6): 496-504,* 2014; Article no. AJAEES.2014.6.003 SCIENCEDOMAIN international. www.sciencedomain.org

IFPRI (2011). Leveraging agriculture for improving nutrition and health, Highlights from an international conference, International Food Policy Research Institute (IFPRI), Pp.15.

Karehka, R. (2013). What is technology – meaning of technology and its use, Techucation.

Kassie, M., M. Jaleta, B. Shiferaw, F. Mmbando, M. Mekuria (2013). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. Technol. Forecast. *Soc. Change* 80: 525-540.

Katengeza, S.P., J.H. Mangisoni1, T.K. Girma, C. Sutcliffe, A. Langyintuo, R. La Rovere and W. Mwangi (2012). Drivers of improved maize variety adoption in drought prone areas of Malawi, *Journal of Development and Agricultural Economics*, 4(14): 393-403.

Keelan, C., F. Thorne, P. Flanagan, C. Newman, (2014). Predicted Willingness of Irish Farmers to Adopt GM Technology. *The journal of Agrobiotechnology Management and Economics* 12(3).

Kijima, Y., K. Otsuka and D. Sserunkuuma (2011). "An inquiry into constraints on a green revolution in Sub-Saharan Africa: The case of NERICA rice in Uganda". *World Development*, 39, 1: 77-86.

Kingamkono, M. Msabaha, J. Nduguru, B. Lemaga and G. Tusiime (eds). Tropical root and crops: Opportunities for poverty alleviation and sustainable livelihoods in developing countries. Proceedings of thirteenth triennial symposium of International Society for Tropical Root Crops (ISTRC) held at AICC Arusha, Tanzania , 10-14 November 2005.

Kohli, D., and N. Singh, (1997). The green revolution in Punjab, India: The economics of technical change. Technical report, Conference on Agriculture of the Punjab at The Southern Asian Institute, Columbia University.

Koppel, B.M. (Ed), (1994). Induced Innovation Theory and International Agricultural Development: A Reassessment the Johns Hopkins University Press, Baltimore.

Kormawa, P.M., J.N. Chiano, and V.M. Manyong, (2000). Cowpea Demand and Supply Pattern in West Africa: the case of Nigeria. Accessed from: http.//www.iita.org/info/cowpea

Langyintuo, A.S., W. Mwangi, A.O. Diallo, J. MacRobert, J. Dixon, M. Bänziger (2010). Challenges of the maize seed industry in eastern and southern Africa: A compelling case for private–public intervention to promote growth. *Food Policy*, 35, 323–331.

Lavison, R. (2013). Factors Influencing the Adoption of Organic Fertilizers in Vegetable Production in Accra, Msc Thesis, Accra Ghana.

Lopes, H. (2010). Adoption of Improved Maize and Common Bean Varieties in Mozambique an unpublished thesis submitted to Michigan State University, In partial fulfillment of the requirements for the degree of Master of Science, Agricultural, Food, and Resource Economics.

Lowenberg-DeBoer, J. (2000). "Comment on "Site-Specific Crop Management: Adoption Patterns and Incentives." *Review of Agricultural Economics*, 22(1): 245-247.

Magyembe, J.M. (1997). Herbicide Use in Uganda. 16th East African Biennial Weed Science Conference Proceedings. 165-169.

Makokha, S., S. Kimani, W. Mwangi, H. Verkuijl, F. Musembi, (2001). Determinants of Fertilizer and Manure Use for Maize Production in Kiambu District, Kenya. CIMMYT (International Maize and Wheat Improvement Center) Mexico.

Kingamkono, M. Msabaha, J. Nduguru, B. Lemaga and G. Tusiime (eds). Tropical root and crops: Opportunities for poverty alleviation and sustainable livelihoods in developing countries. Proceedings of thirteenth triennial symposium of International Society for Tropical Root Crops (ISTRC) held at AICC Arusha, Tanzania , 10 -14 November 2005.

Manyong, V.M., **A.S. Bamire** and J-P Banea (2006). The Effect Of Micronutrient Malnutrition On National Development In Sub-Sharan Africa: Evidence From Vitamin A Deficiency In West And Central Africa. Communication to National Nutrition Conference on Nutrition in National Development. Dar es Salaam, Tanzania. November 27-30, 2006.

Manyong, V.M., **A.S. Bamire** and P.S. Zuckerman (2003). Resource use, Income and Expenditure Patterns of Smallholders in Akinlalu and Ilero Communities in Southwestern Nigeria, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Manyong, V.M., **A.S. Bamire**, I.O. Sanusi, D.O. Awotide, A.G.O. Dixon, and I.O. Akinyele (2004). Impact and Policy analysis of Biofortified Cassava Based Diets in West and Central Africa. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and HarvsetPlus, IFPRI, Washington, D.C. U.S.A.

Manyong, V.M., **A.S. Bamire,** I.O. Sanusi and D.O. Awotide (2007). "Ex-ante cost-benefit analysis of biofortification of cassava roots in Nigeria". Pages 1-8, *in* N.M. Mahungu and V.M. Manyong (eds.) Proceedings of the Ninth Triennial Symposium jointly organized by the International Society for Tropical Root Crops – Africa Branch (ISTRC-AB) and Kenya Agricultural Research Institute (KARI), held at the Whitesands Hotel, Mombasa, Kenya, 1-5 November, 2004.

McNamara, K.T., M.E. Wetzstein and G.K. Douce (1991). Factors affecting peanut producer adoption of integrated pest management. *Rev. Agric. Econ.* 13: 129-139.

Meinzen-Dick, R., M. Adato, L. Haddad, and P. Hazell (2004). Science and Poverty: An Interdisciplinary Assessment of the Impact of Agricultural Research.

Menkir, A. and M. Ouedraogo (eds.) (2007) Demand-driven technologies for sustainable maize production in West and Central Africa. Proceedings of the Fifth Biennial Regional Maize Workshop, IITA-Cotonou, Benin, 3–6 May 2005.

Mensah-Bonsu A, DB Sarpong, R. Al-Hassan, S. Asuming-Brempong, I.Egyir, J.Kuwornu, Y. Osei-Asare (2011). Technology Adoption and Land and Water Management Practices among Maize Farmers in Ghana. Available online at http://addis2011.ifpri.info/files/2011/10/Paper_2A_Akawasi-MensahBonsu.pdf

Mignouna, B., M. Manyong, J. Rusike, S. Mutabazi, and M. Senkondo (2011). Determinants of Adopting Imazapyr-Resistant

Maize Technology and its Impact on Household Income in Western Kenya: *AgBioforum*, 14(3): 158-163. Hall, B. and B. Khan, (2002) Adoption of new technology. New Economy Handbook.

Minde, I., T.S. Jayne, E.W. Craawford, J. Ariga and J. Govereh (2008). Promoting fertilizer use in Africa: Current issues and empirical evidence from Malawi, Zambia and Kenya. ReSAKSS Working Paper 20. Pretoria: Regional Strategic Agricultural Knowledge Support System for Southern Africa.

Morris, M.L., R. Tripp, and A.A. Dankyi (1999). Adoption and impacts of improved maize production technology: A case study of the Ghana Grains Development Project, Economics Program Paper 99-01. Mexico, D.F.: CIMMYT.

Moshi, A. (1997). Economic impact of maize research in Tanzania. Southern African Center for Cooperation in Agricultural and Natural Resources Research & Training, Gaborone, Botswana.

Muzari, W., W. Gatsi, and S. Muvhunzi, (2012). The Impacts of Technology Adoption on Smallholder Agricultural Productivity in Sub-Saharan Africa: A Review, *Journal of Sustainable Development*; 5 (8).

Namara, R.E., L. Hope, S.E. Owusu, C. De Fraiture, and D. Owusu (2014). 'Adoption Patterns and Constraints Pertaining to Small-Scale Water Lifting Technologies in Ghana', *Agricultural Water Management*, 131: 194- 203.

Natsa, R.T. (2014). Counting Gains of Agricultural Transformation Agenda. Leadership. http://leadership.ng/reporter/ruth-tene-natsa/ Accessed: 25th February, 2016.

Neill, S.P. and D.R. Lee (2001). Explaining the Adoption and Disadoption of Sustainable Agriculture: The Case of Cover Crops in Northern Honduras, *Economic Development and Cultural Change,* 49(4): 793-820.

Nguluu, S.N., J.K. Ransom, C.C.K. Ariithi, and L. Muhammad, (1996). Adoption of Improved Maize Technology in Eastern Kenya Following a Community Based Farmer Training Project.

Nowak, P.J. (1987). The adoption of conservation technologies: economic and diffusion explanations. *Rural Sociology* 42: 208-220.

Ogunfowora, B. (1993). "Analysis of fertilizer supply and demand in Nigeria. In Migindadi, Phillip and Jayaraman (eds.). Alternative pricing and distribution systems for fertilizers in Nigeria. FACU Study series No. 93/1, FACU, Ibadan.

Ogunsumi, I.O., A.J. Farinde, and G.E. Ogbosuka (2010). Comparative analysis of extension services of agricultural programme in Edo and Osun states of Nigeria, American *Journal of Social and Management Sciences* 1(2): 186-190.

Oguntade, A.E., A.G. Daramola and **A.S. Bamire** (2001). Diagnostic review of oil Palm Companies in Nigeria (2001). Report submitted to KPMG Consulting, Ilupeju, Lagos.

Ogunya, L.O., **A.S. Bamire**, S.A. Ogunleye (2017). Factors Influencing Levels and Intensity of Adoption of New Rice for Africa (NERICA) among Rice Farmers in Ogun State, Nigeria. *International Journal of Agricultural Economics*, 2(3): 84-89.

Oparinde, A., D. Asare-Marfo, **A.S. Bamire**, P. Ilona, T. Abdoulaye, D. Roy, A. Adepitan and E. Birol (2014). A Baseline Cassava Varietal Adoption Study to inform Development, Delivery and Marketing of Pro-Vitamin A Cassava in Benue State, Nigeria. Submitted to HarvestPlus, IFPRI, Washington, DC, USA. September.

Oparinde, A., D. Asare-Marfo, **A.S. Bamire**, P. Ilona, T. Abdoulaye, D. Roy, A. Adepitan and E. Birol (2014). A Baseline Cassava Varietal Adoption Study to inform Development, Delivery and Marketing of Pro-Vitamin A Cassava in Oyo State, Nigeria. Submitted to HarvestPlus, IFPRI, Washington, DC, USA. June.

Ouma, J., F. Murithi, W. Mwangi, H. Verkuijl, M. Gethi, and H. De Groote, (2002) *Adoption of Maize Seed and Fertilizer Technologies in Embu District, Kenya* . Mexico, DF: CIMMYT (International Maize and Wheat Improvement Center). Chapter 18.indd 27 28-09-2016 19:15:11.

Overfield, D. (2001). Socioeconomic study of the uptake of herbicide technology in maize based cropping systems (R7404, ZA0301). Final technical report, University of Greenwich, Natural Resources Institute, Chatham, 39pp.

Palis, F. G. (2006). The role of culture in farmer learning and technology adoption: A case study of farmer field schools among rice farmers in central Luzon, Philippines, *Agriculture and Human Values*, 23(4):491.

Pingali PL (2001). CIMMYT 1999-2000 World Maize Facts and Trends. Meeting World Maize Needs: Technological Opportunities and Priorities for the Public Sector. CIMMYT, Mexico DF.

Putler, D.S. and D. Zilberman (1988). Computer use in agriculture: Evidence from Tulare county, California, *Journal of Agricultural Economics*, 70(4).

Quinones, E.J. and X. Diao (2011). Assessing crop production and input use patterns in Ghana. What can we learn from the Ghana living standards measurement survey (GLSSS)? IFPRI/Ghana strategy programme working Paper 0024. Washington, DC.

Ragasa, C., G. Berhane, F. Tadesse and A.S. Taffesse (2013). Gender differences in access to extension services and agricultural productivity, *The Journal of Agricultural Education and Extension*, 19(5): 437-468.

Rahm, W.E. and M.R. Huffman (1984). The adoption of reduced tillage: The role of human capital and other variables, *American Journal of Agricultural Economics*, 6(4): 405-413.

Ravallion, M. and S. Chen (2004). China's (uneven) progress against poverty, *Journal of Development Economics*, 82(2007): 1-42.

Roberts, R.K., B.C. English, and J.A. Larson, R.L. Cochran, W.R. Goodman, S.L. Larkin, and J.M. Reeves (2004). Adoption of site-specific information and variable-rate technologies in cotton precision farming, *Journal of Agricultural and Applied Economics*, 36(1): 143-58.

Rogers, E. (1995). Diffusion of innovations; 4th Edition, Free Press, New York.

Rogers, E. (2003). Diffusion of innovations (5th ed.), New York, NY; Free Press.

Samiee, A., A. Rezvanfar, E. Faham (2009). Factors affecting adoption of integrated pest management by wheat growers in Varamin county, Iran: *African Journal of Agricultural Research*, 4(5): 491-497.

Straub, E.T. (2017). Understanding Technology Adoption: Theory and Future Directions for Informal Learning, *Review of Educational Research*, 79(2): 625-649.

Traore, N., R. Landry, and R. Amara (1998). On-farm adoption of conservation practices: the role of farm and farmer characteristics, perception and health hazards, *Land Economics*, 74(1): 114-127.

Tripp, R. (2011). The performance of low external input technology in agricultural development: A summary of three case studies, *International Journal of Agricultural Sustainability*, 3(3): 143-153.

Uaiene, R., C. Arndt, W. Masters, (2009) Determinants of Agricultural Technology Adoption in Mozambique. Discussion Paper No. 67E.

Udima, T.B., Z. Jincai, S.M. Owusu and A.E. Caesar (2017). Factors influencing the agricultural technology adoption: The case of improved rice varieties (NERICA) in the northern region, Ghana, *Journal of Economics and Sustainable Development*, 8(8). ISSN 2222-1700.

Uganda Bureau of Statistics (2010). Uganda National Household Survey 2009/10: Socio-Economic Module Abridged Report, Kampala: Uganda Bureau of Statistics.

UNCTAD (2004). The shift towards services, United Nations Conference on trade and development, World Investment report, United Nations, New York and Geneva.

Wekesa, E., W. Mwangi, H. Verkuijl, K. Danda, and H. De Groote, (2003). Adoption of Maize Technologies in the Coastal Lowlands of Kenya . Mexico, DF: CIMMYT.

Willock, J., I.J. Deary, G. Edwards Jones, G.J. Gibson, M.J. McGregor, A. Sutherland, J.B. Dent, N.A. Wiredu, K.O. Gyasi, T.

Wu, J.J., and B.A. Babcock (1998). "The Choice of Tillage, Rotation, and Soil Testing Practices: Economic and Environmental Implications." *Amer. J. Agric. Econ.* 80(1998): 494-511.