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Agricultural Innovation Characteristics and their Utilization in Uganda: A Case of National Agricultural Research Organization

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Abstract: *The research assessed the utilization of agricultural innovations in Uganda, using a case of the National Agricultural Research Organization, with the following objectives: to establish the factors that influence development of agricultural innovations; to determine the relationship between agricultural innovation characteristics and utilization of innovations at farm level; and to examine the effect of market attributes on utilization of innovations in agriculture. Using a cross sectional survey research design, a survey mainly using structured questionnaires was carried out among the National Agricultural Research Organization (NARO) staff to establish factors that influence development of agricultural innovations. A total of 91 households involved in cassava, maize and rice production were interviewed in Kihiihi Sub-county, one of the sub-counties in Kanungu District where the NARO innovations on cassava, maize and rice have been promoted. The data was collected, coded, cleaned and analysed using SPSS to generate frequency tables and STATA to generate an ordered logistic regression . The respondents agreed that it is important to consider the cost, relevance, and end-user opinion of agricultural innovations as important determinants of developing agricultural innovations. Respondents also agreed that in order to sustain innovations, agricultural research innovators need a clear plan on how innovations should be done. The results also indicated that that there was a positive significant relationship between the attribute/characteristics of the varieties and the extent of utilization of varieties. In addition, regression results indicated that innovation characteristics such as relative advantage, compatibility, triability and, other variables such as gender, age, education had a significant effect ($p<0.05$) on innovation utilization by farming communities. However, complexity had a negative significant effect. The age of respondents had a negative significant effect on the utilization of the innovations, while education had a positive significant effect on utilization of innovation.*

Keywords: Agricultural Innovation; Utilization; National Agricultural Research Organization; Agriculture; Innovation; Characteristics

1.0 Introduction

In agriculture, innovations can be generated through research, and once adopted innovations could be one way to sustain agricultural development in Uganda. The National Agricultural Research Organization (NARO), which is an agency of the Ministry of Agriculture Animal Industry and Fisheries (MAAIF), was established as a body corporate by the National Agricultural Research Act of 2005 with the mandate to coordinate and oversee all aspects of agricultural research in Uganda, hence the subject of this study. In business and economics, innovations have been a catalyst for growth. Entrepreneurs continuously look for better ways to satisfy consumers with improved quality, durability, service and price. Innovations in agriculture date back to the domestication of animals and plants up to the developments and techniques for raising productivity. The green revolution which was a series of research, development, and technology transfer increased agriculture production around the world (Hazell, 2009). During the last 50 years, agricultural development has been shaped by three persistent forces of change: globalization, technology and people. Globalization is the force that is increasingly shifting the focus from domestic to international opportunities, as World markets become more accessible. Improved technologies represent forces that are improving the ability to produce and deliver what consumers want and people are exerting their influence, either directly as consumers, or indirectly as custodians of the environment in which food and fibre products are produced (Keulen, 2007).

In Africa, agricultural research was introduced in the late 19th century and early 20th century with the creation of botanical gardens which were mainly used for screening exotic raw materials to support industries for the colonial powers (FAO, 2002).

After the First World War, colonial powers needed more raw materials and more formalized research structures were created to conduct basic research on commodities. From 1960 to 1970 almost all sub-Saharan African countries gained independence. After independence, the responsibility for agricultural research was transferred to each country. The evolution of the system was formed by political decisions made by the new national governments. According to Beintema and Tizikara (2002), in Uganda after independence in 1962, all the national agricultural research agencies were transferred to the government. The regional research organizations which focused on export commodities such as cotton, tea and coffee remained under the East African Community until its collapse in 1977 when the Ugandan government started focusing her research on export crops.

Due to political uncertainties that constrained agricultural research financing of 1970s and 1980s, the existing research infrastructure was severely damaged. Later, a national taskforce on agricultural research recommended the establishment of a semi-autonomous agricultural research agency with a mandate covering crops, livestock, forestry, and fisheries, leading to the establishment of NARO in 1993 by the National Agricultural Research Statute of 1992. During the period 2001-2005, the National Agricultural Research system underwent a structural reform that resulted in the enactment of the National Agricultural Research Act of 2005 which repealed the NARO statute of 1992. Therefore, the National Agricultural Research Organization (NARO), as an agency of MAAIF, was established as a body corporate by the National Agricultural Research Act of 2005 with the mandate to coordinate and oversee all aspects of agricultural research in Uganda. The overall goal of NARO is to enhance the contribution of agricultural research to agricultural productivity, sustained competitiveness, economic growth, food and nutrition security and poverty eradication. The focus is on the development and dissemination of technologies/agricultural innovations that are client-oriented with high impact for sustainable agricultural development.

Besides NARO being involved in development and dissemination of agricultural innovations, and using all possible pathways to ensure their clients utilize research innovations, there are several theories about innovations, their acceptance and adoption which have an influence on the operations of the organization. Hayami and Ruttan (1985) highlighted the theory of induced innovations which links the emergence of innovations with economic conditions. They argued that the search for new innovations is an economic activity that is significantly affected by economic conditions. New innovations are more likely to emerge in response to scarcity and economic opportunities. Farmers press the public research institutions to develop new technologies and, also, demand that agricultural firms supply modern technical inputs which substitute for the more scarce factors. For example, labour shortages will induce labour-saving technologies. However, Olmstead and Rhode (1993) argue that other factors also such as availability of scientific knowledge, presence of inputs especially from the manufacturing industry, and the interaction between farmers and input producers, among others, affect the emergence of innovations.

Yezersky's (2007) General Theory of Innovation (GTI) recognises that knowledge is essential in innovations because it allows any organization to forecast the system's (products, processes, service, among others) future with great precision. GTI points out that every innovation improves the system. The same theory also proposes that innovations involve cost reduction, quality, reliability, performance and productivity improvement and failure prevention. The GTI points out that innovations aim at identifying a change required for repositioning an organization with the purpose of obtaining competitive advantage. Davis (1989) came up with the technology acceptance model which specifies two major parameters: perceived usefulness which is the potential users' subjective likelihood that the use of a certain system will improve his/her action; and perceived ease of use which is the degree to which the potential user expects the target system to be effortless. The belief of a person towards a system may be influenced by other factors referred to as external variables. Later, Venkatesh and Davis (1996) modified the technology acceptance model and asserted that both perceived usefulness and perceived ease have a direct influence on behaviour intention. This model was further modified and other factors such as job relevance, output quality, result demonstrability, performance expectancy, social influence and facilitating conditions all influence perceived usefulness.Rogers (2003) described the innovation-diffusion theory (the process by which an innovation is communicated through certain channels over time among the members of social system) that involves five stages in the innovation-decision-making process. The first stage, the knowledge stage, occurs when an individual becomes aware of an innovation and begins to gain some information. The persuasion stage occurs when an individual forms an attitude towards the innovation, either favourable or unfavourable. The decision stage occurs when an individual either accepts or rejects the innovation. The implementation stage takes place when an individual puts the innovations to use. It is also important to note that as an innovation diffuses, it may go through re-invention, that is, it may be changed or modified during the course of its adoption and implementation. The final stage, the confirmation stage, occurs when individuals validate their innovation-decision. The innovation-decision process is basically an information-seeking and information-processing activity in which an individual assesses the characteristic of an innovation and decides whether to adopt or utilize the innovation. Rogers (2003) notes five qualities or characteristics of innovations that account for their rate of adoption which include: relative advantage, compatibility, complexity, trialability, and observability. Rogers (2003) also pointed out that communication is essential in utilization of technologies and classified adopters in different categories as early adopters, early majority, late majority and laggards.

The adoption of agricultural innovations increases agricultural productivity which results in socio-economic development (Kariyasa and Dewi, 2013). In agriculture, the most common areas of innovations are new crop varieties, management regimes, soil and soil fertility management, pest management, irrigation and water management (Loeverinsohn et al., 2013). Recently, production of agro-machinery for value addition, post-harvest handling and labour reductions have been some of the additional innovations that improve agriculture productivity.

In Uganda, for the last 10 years, the National Agricultural Research Organisation (NARO), supported by an average annual budget of UGX 103 billion, has conducted research and development initiatives and generated 801 technologies and innovations (NARO, 2018). However, the uptake and utilization of NARO innovations has been low. For example, it was reported that in Uganda, only 10% of households planted improved seed (UBOS, 2011). In fact, it is commonly said that there are a lot of NARO innovations on shelf, implying end-users are not applying the innovations.Although a number of factors that limit the adoption of agricultural innovations have been reported based on research carried out in Uganda, there is inadequate information on how innovation characteristics affect adoption/utilization of innovations. According to Jones (1989) and Rogers (2003) perceptions of innovation characteristics affect their utilization. There is also limited information on how the market forces affect utilization of innovations generated by NARO. Therefore, it s important to carry out an investigation on how the customers' perception of product/innovation and market attributes affect the adoption and utilization of innovations in order to guide agricultural research in Uganda.

Agricultural innovations

Innovations are very important in social and economic development since they enhance production and efficient use of resources. Increasing productivity in agriculture, boosting the income of farmers and reducing poverty are some of the benefits of application of appropriate innovations. Agriculture is the backbone of Uganda's economy employing 73% of the country's labour force and contributing 27% of GDP (Kasirye, 2013). The annual agricultural growth in Uganda has been low at 3% compared to 6% growth target set by the African governments under the Comprehensive Africa Agriculture Development Programme (CAADP). One of the factors that can enhance agricultural growth is the adoption/utilization of agricultural innovations. Despite the existence of agricultural innovations agricultural growth has remained low. It is thus important to understand why the innovations are not utilized. It is also worthy to note that there are unique challenges along the commodity value chains that may limit uptake of the innovations. These include poor infrastructure, weak institutions, coordination failures, weak capital to invest, and unfavourable social and political conditions. Nevertheless, government programmes and policies exist to address the infrastructural and economic challenges. The factors limiting innovation uptake could be in the innovations themselves or the perception of end-users.

Adoption/utilization of agricultural innovations

Adoption is a decision of implementing innovations based on knowledge, persuasion of individuals within a given system (Rogers, 1995). There are stages involved in the adoption of innovations. One of them is the knowledge stage where the individual or household is exposed to the innovation and understands how the innovation works. The second stage involves persuading the individuals to use it because they may not regard it as relevant to their situation. The persuasion may lead to either adoption or rejection of the innovation. The fourth stage is the implementation stage where an individual puts an innovation into use. The final stage is confirmation during which the individual seeks reinforcement for the decision made.There are different theoretical approaches that can explain the development and adoption of agricultural innovation. One of the theories is the economic constraint model. This theory perceives farm households as decision makers whose concern is how much to devote to the cultivation of each crop, whether or not to use purchased inputs, which crops to grow on which fields, among others. Therefore the decision made by the farmer depends on their goals or objectives and the resource constraints of the individual farming household. The economic constraint model makes various assumptions. The model assumes that the household acts as a unified unit of production and consumption that aims to maximize utility subject to its production function, income and total time constraint. Another feature of the model is the use of a single decision maker and the assumption that no conflict exists within the household and that all members have the same utility function so that maximizing the household utility would yield similar results as maximising individual functions. This proposition is based on the assumption that household members will sacrifice their individual preferences for the common good of the household. In return, the altruistic head will make decisions based on what is best for the household as a whole.

Determinants of adoption of agricultural innovations

The development of most countries in the World with rural populations has come through agricultural revolutions and industrial revolutions. According to NDPII (2015), agriculture is considered as central for economic growth and poverty reduction and as a source of raw materials for agro-processing in Uganda. One of the strategies to enhance agricultural growth involves strengthening research and building human capacity to enhance technology improvement and adoption.

The Uganda Vision 2040 identified limited application of technology and innovation as one of the challenges to be addressed

to transform agriculture from subsistence to commercial farming. According to Schumpeter (1934) innovations are considered as new products, new methods of production, new sources of supply, the exploration of new markets and new ways of organizing business to remain competitive. There is evidence that for the last 10 years the Uganda government either directly or indirectly has supported agricultural research to generate technologies and innovations that improve productivity and enhance farmer income. However, the uptake and utilization of agricultural research innovations has been low. For example, it was reported that in Uganda, 10% of households planted improved seed (UBOS, 2011). The adoption of innovations in agriculture is influenced by the extent to which the farmer finds new technology complex and difficult to comprehend, the financial cost of technology, farmers' beliefs and opinions towards the innovation, the farmers perception of the relevance of the new innovation, and the farmers attitude towards risk and change (Guerin and Guerin, 1994). In a study by Katungi and Akankwasa (2010) on the adoption of banana technologies in Uganda, it was highlighted that farmers' adoption decisions depend on farm and farmer socio-economic and institutional characteristics, technology characteristics and dissemination approach used. In another study by Jogo et al. (2013) it was reported that labour availability increased the chance of adopting bacterial wilt management practices while, on the other hand, practices which were labour-intensive reduced the probability of adopting the management practices. From the same study, it was also pointed out that farmers who perceived the agricultural innovation to be ineffective were less likely to adopt the innovation. On the other hand farmers endowed with resources are more likely to adopt innovations compared to resource-limited farmers. Kalyebara (1999) reported that high-income farmers are about twice as likely to adopt soil conserving measures than poor farmers.

Effect of innovation characteristics on the utilization of innovations at farm level

It is important to understand how innovation characteristics affect the utilization of innovations in agricultural research systems. Jones (1989) reported that the demand for products or innovations is significantly affected by the perceptions of product attributes. For example the quality of sorghum varieties significantly influenced their adoption in Burkina Faso (Adesina and Baidu-Forson, 1995). Similarly, Rogers (2003) reported that relative advantage (how the innovation is subjectively perceived superior to the previous one), compatibility (how the innovation is perceived consistent with the existing values, past experience and needs of potential adopters), complexity (perceived difficulty to understand and use the innovation), trialability (degree to which an innovation may be experimented with on a limited basis), and observability (how the results of an innovation are visible to others) of innovations account for their rate of adoption. The dimensions of relative advantage include the degree of economic profitability, low initial cost, a decrease discomfort and effort. Joo and Kim (2004), Miller and Meek (2004) and Liao and Lu (2008) studied the relative advantage of Integrated Pest Management (IPM) practices and found that additional IPM practices benefits such as economic profitability, decreasing production cost and effort saving influence farmers' decision to adopt an innovation. For example, Mugisha *et al*. (2004) reported low adoption of rice production technologies in Uganda to have been caused by expensive and tedious practices/innovations.

An innovation can be compatible with social norm, previously introduced ideas and client need for innovation. If an innovation is incompatible with the grower's social values and beliefs, it will not be adopted as rapidly as an innovation that is compatible. For example, a study by Sarel and Marmorstein (2003) showed significantly positive relationship between compatibility and perception for adoption. Hence, if an innovation is compatible with an individual needs, then uncertainty will decrease and the awareness and adoption of the innovation will increase. Thus, compatibility is an important part of innovation. Complexity is the degree to which an innovation is perceived as relatively difficult to understand or use (Rogers, 2003). New ideas that are simpler to understand by members of a social system are adopted more rapidly than innovations that require the adopter to develop new skills and understanding. A low level of complexity lead to higher adoption rate or complexity increases the rate of rejection (Rogers, 2003; Sarel and Marmorstein, 2003).

Trialability, on the other hand, refers to the degree to which an innovation may be experimented on a limited basis (Rogers, 2003). For example, Rogers (2003) argues that latent adopters, who are invited to experiment an innovation for trials, would feel more comfortable to adopt innovations. However, it is positively related to perception of adoption and awareness. Furthermore, according to Kolodinsky *et al*. (2004) sometimes trialability provides farmers the ability to evaluate innovation benefits. Consequently, if farmers are given the opportunity to try the innovation certain fears of the unknown and inability to use can be reduced. Finally, observability is the degree to which innovations are visible to others. The results of some ideas are easily observed and communicated to other, whereas some innovations are difficult to observe or to describe with others. Role modeling is the key motivational factor in the adoption and diffusion of technology (Parisot, 1997). Hence, there is a positive relationship between observability and perception for adoption and awareness. Although the National Agricultural Research Organisation has generated a number of innovations over time, there is lack of information on the how the characteristics of these innovations affect their utilization. Availability of information could guide NARO in developing appropriate innovations that will enhance agricultural productivity once they are adopted.

2.0 Materials and Methods

Research Design

The cross-sectional survey research design was used for the study. This was because this study was based on a sample drawn from a population and this design is normally used for population based studies. The design was preferred because it allows data to be collected from different individuals (respondents) at a single point in time and can handle multiple variables such as agricultural innovation characteristics at data collection. The design is inexpensive and fast to accomplish data collection. Therefore, the researcher found it appropriate to apply this design to collect data on maize, cassava and rice farmers in Kihiihi Sub-county, Kanungu District.

Target population

Kihihi Sub-county is one of the sub-counties in Kanungu District where the NARO innovations on cassava, maize and rice have been promoted. Information available from the district profiles indicated that a total of 180 households were involved in the utilization of technologies on cassava, maize and rice in Kihihi Sub-county. On the other hand, according to NARO staff payroll, 25 and 35 staff from Kawanda and Namulonge respectively were directly involved in the generation of innovations.

Sample size determination

The sample size that was used for this study was 125 respondents which was a deviation from the original target of 148 respondents. The original sample size was estimated based on Krejcie and Morgan Table of 1970 (Appendix 1) where it was given that a sample size of 148 was appropriate for a population of 180. The sample size was supposed to consist of 56 NARO staff and 92 households from Kihihi Sub-county, Kanungu District (Table 1). However, the study missed one household from Kanungu when the enumerator accidentally missed to interview the respondent and this error was discovered at data entry and it was difficult to go back to interview the respondent because of resources. However, it is believed that the data that was collected would fully be representative. From NARO there was a relatively big drop from the target of 56 to what was achieved (34). This deviation came as a result of staff being on annual leave, study leave, short-term trainings, field engagements and some resignations.

Sampling techniques and procedures

The study employed purposive, stratified and random sampling techniques. Purposive sampling was used because it helped the researcher to select scientists and technicians who were directly involved in generating innovations within NARO. At the sub-county level, the households were stratified according to the commodities of interest (rice, cassava and maize). Stratifying farmers into different groups helped focus the study because those farmers who had experience in the commodities of interest were interviewed. However, to select the actual households to be interviewed, a list of households in the different categories was generated, given numbers and using random numbers generated by a computer, a sample of the households was selected for the interview.

Data collection methods

The researcher engaged and trained enumerators to collect the data in the field. Although it was costly and time-consuming, training improved the reliability of data. The enumerators were able to make personal observations which were recorded to enrich the investigation.

Data collection instruments

The most commonly used data collection tools in social research include questionnaires, personal interviews and or focused group discussions. This study employed questionnaires and interviews as primary data collection methods as well as documentary reviews to collect secondary data. Two questionnaires were designed; one for NARO staff and the other for the households using NARO innovations. The questionnaires consisted of mainly closed questions using a 5-point scale, ranging from 1-strongly disagree to 6-strongly agree for the innovations. For utilization, 1 represented very low and 5 represented very high utilization.

Quality control

The researcher ensured the validity of the questionnaire after consulting technical people especially the supervisors and other qualified people in the field of innovations. The questionnaire was pre-tested on a sample of 20 farmers in Kihihi Sub-county where the study was to be conducted. The validity of the

data was tested using Pearson product moment correlation using SPSS. Based on the significant value (2-tailed) of 0.0001 which was less than 0.05, it was concluded that the instrument was valid and the data collection proceeded as planned.

Data analysis and management

Data analysis was done after collecting the raw data from the field, editing and checking for accuracy of information, consistency and uniformity. The collected data was analysed both qualitatively and quantitatively. Descriptive statistics such as tables showing frequencies and percentages were generated and presented using SPSS statistical package.

Ethical considerations

The main ethical considerations were voluntary participation, ensuring confidentiality and privacy of respondents. The protection of rights and integrity of participants was observed as their names were not recorded on any questionnaire. The researcher introduced herself to the head of the institute, explained the purpose of the investigation and sought authorization to conduct interviews with staff. Due to the nature of the agricultural innovations the researcher respected intellectual property and will never disclose it to any third party at any time even beyond this investigation. For the farming community, the respondents were accessed by going through the district and administrative structures of the local councils in the area. The respondents were given the confidence that the information provided was confidential and would be used only for research purposes.

3.0 Results and Discussion of the findings

3.1 Results

Relationship between innovation characteristics and their utilization

The frequency of observations based on innovation characteristics per commodity were computed and presented. A chi-square at a probability level of 5% was used to test the relationships between commodities and innovation utilization as per farmers' responses. Frequencies of different parameters that defined the innovation and market attributes were computed and presented. Regression analysis was also used to estimate the relationship between innovation attributes and their level of utilization.

Effect of innovation and market attributes on utilization of innovations in Agriculture

The utilization attribute was considered as the response/ dependent variable and the predictor variables included gender, age, commodity, education, market attributes, relative advantage, compatibility, trialability (degree of experimentation), complexity and quality. In order to carry out an ordered logistic regression of innovation and market attributes on utilization of innovations in agriculture, the model was first tested on how well it fitted with the explanatory variables compared to an empty model. The effects were tested at a 5% probability level.

Factors influencing development of innovations in agricultural research

Table 4.1. Percentage respondents involved in generating innovations on maize, cassava, rice and agricultural machinery

	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
Generation of new crop varieties	44	44			12
Developing new products	47	41	3	9	
Developing new protocols	23	68	3	6	
Improving existing technologies	30	64	6		
Designing new processes	20	62	18		

In the National Agricultural Research Organisation (NARO) agricultural innovations were considered as generation of new crop varieties, developing of new products that have commercial value, developing new protocols, improving existing technologies/innovations and designing new processes. Table 4.1 shows percentage of respondents involved in generation of agricultural innovations. Forty-seven per cent and 44% of respondents strongly agreed that they were involved in developing new products and generating new crop varieties respectively. Similarly 68%, 64% and 62% of the respondents agreed that they are involved in developing new protocols, improving existing technologies and developing new processes respectively. Only a small percentage of 12% strongly disagreed to be involved in generation of crop varieties and
18% of the respondents were not sure that they were involved in designing new processes (Table4.1).

Table 4.2 Factors considered by respondents generating agricultural innovations in

National Agricultural Research Organisation (N=34)

	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
Difficulty in understanding innovation	15	27	30	25	3
Cost of innovation	21	47	24	6	2
End-user belief/opinion of innovation	21	41	29	9	
Relevance of the innovation	41	15	32	9	3
End-user attitude towards risk and change	9	45	40	3	3

On the factors considered by respondents to generate innovations within NARO, there were mixed responses. The results presented in Table 4.2 indicate that 39% of the respondents were not sure that the end-users of the innovation would consider difficulty in understanding the innovation as a factor that would influence the innovation utilization, although a small proportion of 27% of the respondents agreed that this was an important factor to consider when generating innovations. On the factor of cost of the innovation, 27% and 47% of the respondents strongly agreed and agreed respectively that this was an important factor to be considered when generating innovations. On the other hand, 21%, 41% and 29% of the respondents strongly agreed, agreed and were not sure respectively that the belief of the end-user would affect the utilization of innovation. Forty-one per cent of the respondents strongly agreed that the relevance of the agricultural innovation would affect its utilization, although 32% of the respondents were not sure that the relevance of the innovation would affect its utilization. Another important factor that was considered was end-user attitude towards risk and change, with 45% of the respondents agreeing that this was an important factor while 40% of the respondents were not sure that the end-user attitude towards risk and change would affect utilization of innovation.

Table 4. 3 Sustainability of innovations in agricultural research in Uganda (N=34)

	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
A clear plan on how innovations should be done	14	74	12		
Sharing information with colleagues on regular basis	23	68	9		
Bureaucracy is involved in clearing innovations	18	41	29	9	3
Existence of incentives for generating innovations	12	21	35	26	6
A reward system for teams that generate innovations	6	12	56	26	
Tolerance to a certain degree of failure in generating innovations		41	44	15	
Abandoning projects and processes that no longer make a contribution	12	29	44	15	
There is consideration to cost during the process of generating innovations	35	59	6		

For sustainability of agricultural innovations, there were a number of factors to be considered. In agricultural research in Uganda, the results of respondents from NARO are presented in Table

4.3. According to the results, 74% of the respondents agreed that the organization had a clear plan on how agricultural innovations should be generated. Similarly, 68% of respondents agreed and 23% of respondents strongly agreed that colleagues involved in generating innovations shared information regularly. However, among the respondents 41% agreed and 18% strongly agreed that bureaucracy was involved in clearing innovations within the organization. It is important to note what respondents perceive about incentives and a reward system within the organization concerning generating innovations. Thirty-five per cent were not sure and 26% disagreed that incentives existed within the organization for generating innovations. Similarly, 56% and 26% of respondents were not sure and disagreed that the organization had a reward system for teams that generated innovations. However, there was strong agreement that considering costs of generating an innovation was important. For example, results from Table 4.3 indicate that 59% of the respondents agreed that considering cost was important while 35% of respondents strongly agreed with cost considerations in sustaining agricultural innovations.

Table 4.4 Innovations recommended by agricultural research

1. Agronomy: Timely planting, proper spacing, weed management, fertilizer application

2. New crop variety: Variety descriptors, different uses of the variety, yield advantages

3. Disease and pest management: information on resistance to pests and diseases provided, spraying regimes, other disease and pest management practices
4. Value addition: Different products that can be made from the variety

5. Seed system: Importance of using clean seed, seed storage and handling

6: Appropriate machinery to handle different practices

Agricultural research innovators (respondents) were requested to list the recommended packages of innovations under the commodity of interest. Table 4.4 shows the recommendations (packages) from agricultural research in the areas of agronomy, new crop varieties, disease and pest management, value addition, seed systems, and appropriate machinery, among others.

Relationship of innovation characteristics on the utilization of innovations at farm level

Table 4.5. Agricultural innovations used by farmers on different commodities in Kihiihi Sub-county, Kanungu District (N=91)

	Agricultural innovations				
Commodity	New variety	Weed management	Spacing	Mechanisation	Fertilisers
Cassava (30)	56	21	9	35	
Maize (31)	48	7	4	31	39
Rice (30)	54	16	2	31	

At farm level, a profile of agricultural innovations used by farmers was recorded and results are shown in Table 4.5. On cassava, 56% of the respondents were using new crop varieties, 21% were using proper weed management practices; and 35% were using agriculture machinery especially during land opening before planting. On maize, 48% of the farmers were using new varieties, 31% using machinery in land opening and shelling of maize; and 39% were using agricultural inputs such as fertilisers. On rice, 54% of the farmers were using new varieties, 16% of the farmers were using herbicides in weed management, and 31% of the respondents were using machinery to open up land for planting. It should be noted that the machinery used was in most cases hired as farmers did not personally own the different categories of machinery. Hiring was also not consistent every season.

Table 4.6. Frequency of innovation characteristics reported in different commodities in Kihihi Sub-county, Kanungu District

Commodity	Frequency of observations based on innovation attributes					
	Relative Advantage	Compatibility	Trialability	Complexity	Quality	**Total**
Cassava	165	275	55	110	55	**660**
Maize	180	299	61	120	60	**720**
Rice	172	283	57	114	57	**683**
Total	**517**	**857**	**173**	**344**	**172**	**2063**

Generally, of the 2063 observations made as shown in Table 4.6, 517 were on relative advantage, 857 on compatibility, 173 on trialability, 344 on complexity and 172 on quality of the innovation. The trend was consistent among the different commodities.

Table 4.7. Chi square table showing relationship between commodity and innovation utilization of respondents in Kihihi Sub-county, Kanungu District

	Innovation Utilization					
Commodity	Very low	Low	Moderate	High	Very high	**Total**
Cassava	89	241	196	87	44	**657**
Maize	42	234	273	67	63	**676**
Rice	103	180	165	91	26	**565**
Total	**234**	**655**	**634**	**245**	**133**	**1,899**
Pearson chi^2 (15) = 234.0134	**Pr = 0.000**					

The results from Table 4.7 show the relationship between commodity and innovation utilization of farmer respondents in Kihihi Sub-county, Kanungu District. From the total 1,899 observations made 234,655,630,245,133 utilized innovations at a very low rate, low, moderate, high and very high respectively. Among the 234 who utilized the innovations at a very low stage, 89, 42 and
103 observations were for cassava, maize and rice respectively. Likewise for low utilization, 241, 234 and 180 observations were for cassava, maize and rice respectively. At the moderate level, 196 were for cassava, 273 for maize and 165 for rice. Similarly, at very high level of innovation utilization, 44 were for cassava, 63 for maize and 26 were for rice. It is evident from results that innovations were highly utilized in maize than cassava and rice and the relationship between commodity and utilization of innovation was highly significant (Pearson Chi^2 (15) = 234.0134, Pr = 0.000) (Table 4.7).

Table 4.8. Relationship between innovation characteristics and utilization of new variety for cassava, maize and rice in Kihihi Sub-county Kanungu District

Commodity	Compatibility	Relative advantage	Complexity	Trialability	Quality	**Total**
Cassava	372	132	36	108	NIL	**648**
Maize	348	60	24	144	144	**720**
Rice	372	120	12	120	NIL	**624**
Total	**1,092**	**312**	**72**	**372**	**144**	**1,992**

Pearson chi^2(21) = 2.5e+03 Pr = 0.000

From Table 4.8 the results indicated that all the three commodities cassava, maize, and rice used new variety as one of the major innovations. The results from Table 4.8 show the relationship between innovation characteristic and utilization of new variety for cassava, maize and rice in Kihihi Sub-county Kanungu District. Since p value was less than 0.05, this shows that there was a positive significant relationship between commodity and innovation characteristic. According to observations, compatibility (1092) was the highest attribute followed by trialability (372) and relative advantage 312. It should also be noted that relative advantage, compatibility and complexity had a subset of parameters under them.

Table 4.9. The regression results of innovation utilization with a combination of all study parameters

Source	sum of squares (SS)	degrees of freedom (df)	mean squares (MS)
Model	547.41656	10	54.741656
Residual	2717.13291	2051	1.32478445
Total	3264.54947	2061	1.58396384

Number of obs	=	2062
F (10, 2051)	=	41.32
Prob > F	=	0.0000
R-squared	=	0. 6771
Adj R-squared	=	0.7136
Root MSE	=	1.151

Utilization attribute	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
Gender	.1365483	.0538004	2.54	0.011	.0310393	.2420574
Age	-.03589	.0217804	-1.65	0.100	-.078604	.006824
Education	.0617118	.0257539	2.40	0.017	.0112053	.1122183
Commodity	-.2437981	.032519	-7.50	0.000	-.3075718	-.1800243
market attribute	-.0478834	.0263708	-1.82	0.070	-.0995998	.003833
relative advantage	2.384769	.5804827	4.11	0.000	1.246372	3.523166
Compatibility	1.905091	.5795687	3.29	0.001	.7684867	3.041696
Trialability	1.024452	.5846841	1.75	0.080	-.1221842	2.171089
Complexity	-1.042043	.5813884	1.79	0.073	-.0981298	2.182217
Quality	1.807705	.5847275	3.09	0.002	.6609832	2.954426
_cons	.9673114	.590062	1.64	0.101	-.1898718	2.124495

Table 4.9 shows regression results of innovation utilization with a combination of all study parameters. The R^2 of 0.67 is the proportion of the variation in the response that can be explained by the regressors. The adjusted R^2, determines the extent of the variance of the dependent variable which can be explained by the independent variable. The adjusted R^2 of 0.71 shows that the data in the regression equation was a good fit by predicting 71% of the variation in the response variable. Therefore a

combination of all the regressors explains 71% of variation in the utilization of given innovation. The results show that among other predictor variables, innovation attributes such as relative advantage, compatibility, trialability, complexity and quality had a significant relationship on utilization of a given innovation of a given a commodity.

Table 4. 10. Relationship between different parameters of relative advantage and frequency of utilization of innovations

	Innovation Utilization					
Parameter	Very low	Low	Moderate	High	Very high	Total
Economic profitability	2	3	11	68	80	*166*
Low initial cost	6	67	64	24	4	*165*
Decrease in discomfort	18	64	66	14		*162*
Total	26	134	141	106	84	493

From Table 4.10, economic profitability of the innovation highly (68) and very highly (80) influenced utilization of the innovations. Low initial cost influenced utilization of innovation from low to moderate 64 and 66 observations respectively. The decrease in discomfort had almost a similar trend with low initial cost of the innovation.

Table 4. 11. Relationship between different parameters of compatibility and frequency of utilization of innovations

	Innovation utilization					
Parameter	Very low	Low	Moderate	High	Very high	**Total**
Labour	4	37	94	27	2	**164**
Cropping system	38	31	70	23	2	**164**
Soil type	3	19	130	8	4	**164**
Climate	1	42	101	18	2	**164**
Risk	12	122	25	4	14	**177**
Total	**58**	**251**	**420**	**80**	**24**	**833**

From the results in Table 4.11 compatibility of the innovations with the soil type moderately influenced utilization of innovations with 130 observations, followed by climate with 102 observations. The parameter of risk led to utilization of innovations at a low level with 122 observations.

3.2 Discussion of the Findings

Factors influencing development of innovations in agricultural research

The results on Table 4.1 indicate that all the NARO staff interviewed were involved in generation of agricultural innovations on cassava, maize, rice and agricultural machinery. For example, 68%, 64% and 62% of the respondents agreed that they were involved in developing new protocols, improving existing technologies and developing new processes. The results show that staff activities were aligned with the NARO mission: “To innovate for sustainable agricultural transformation” which focuses on developing and promoting technologies and innovations for agricultural transformation through creating businesses that generate revenue for the organisation" (NARO, 2018).

However, in order for the innovations to be adopted / utilized, they need to address the needs of the end-user. Therefore, one of the areas of concern for this research was whether innovators in agriculture considered the needs of their clients. The researchers were interviewed on factors they would consider before generating innovations in agriculture. The results are presented in Table 4.2. The results indicated that 30% of the respondents were not sure, while 25% disagreed that it was important to consider the difficulty in understanding the innovation by the end-user.

In a study by Abebe et al. (2013), farmers perceived that improved potato varieties were difficult to use because they required

intensive crop management regimes than local varieties and this affected adoption of new potato varieties. It was therefore important that innovation developers understand their clients through participatory rural appraisals, market surveys and baseline studies to understand client needs. Nevertheless, access to wider information helped to broaden farmers' understanding of new technologies (Abebe et al., 2013) although this could increase costs through promotional programmes of innovations. Similarly 40% of the respondents were not sure that it was important to consider end-user attitude towards risk and change. However, according to Guerin and Guerin (1994), end-user attitude towards risk and change would affect adoption of innovations. Therefore, innovation developers should consider taking into consideration the end-user attitude towards a new innovation before investing resources into technology development. Otherwise from Table 4.1 respondents agreed that it was important to consider the cost, relevance, and end-user opinion of innovations as important determinants of developing agricultural innovations. This was in agreement with existing information (Guerin and Guerin,
1994; Katungi and Akankwasa, 2010). In a study on management of bacterial wilt disease on bananas, the end-users perceived effectiveness of the disease management practices significantly affected the adoption of the practices (Jogo et al., 2013).

Another important factor to consider as determinant of developing agricultural innovations concerns sustainability. Table 4.3 shows results on some of the parameters that were considered in order to sustain development of innovations. The respondents (41% agreed and 18% strongly agreed) that there was bureaucracy in clearing innovations in agriculture research; (31% were not sure and 26% disagreed) that incentives existed within the organization; (56% were not sure and 26% disagreed) that there was a reward system for teams that generated innovations within the organization. Bureaucracy can promote or discourage innovation depending on the culture and environment of the organization. Dyer and Dyer (1965) suggested that innovation could occur in the organization if some rigidities in bureaucracy were overcome. The authors suggested that one way of avoiding rigidities was not to suppress information flow. From this research (Table 4.3) there was a perception among respondents that there was free exchange of information among developers of agricultural innovations. Therefore, it could be postulated that in the organization, bureaucracy did not suppress innovation. There were structures within the organization (scientific committees, top management, planning and reviewing committees) which aligned and prioritized resources as research innovations were cleared. In my opinion, this had been effective as shown by the number of high innovations generated by the organization (NARO, 2018). Fontana et al. (2015) reported that incentives could spur innovation among staff. From this study, it was perceived that there were inadequate incentives and rewards to motivate staff carry out innovations. However, there were incentives such as promotions within the organization that were based on staff performance. One of the criteria of promotions was number of innovations generated and published. It was possible that some staff were expecting other incentives and rewards. Recently the organization developed policies (such as the Intellectual Property), among other national policies, that recognize inventors rights and patents under a benefit-sharing arrangement between the individuals involved and the organization. It is very important for the organization at this time to pursue the implementation and access of benefits so that the staffs get motivated to carry out more innovations.
From Table 4.4 it was clear researchers had clear recommendations to improve agriculture productivity. However from the end-users' point of view, farmers were not clear about the recommended packages. The end-users were mainly aware of new varieties. This implies that the end-users did not receive the innovations as a package. This could possibly explain the constant low productivity levels at farm level despite the existence of technological innovations from research institutes to enhance agricultural productivity. There was need to clearly understand the technology pathway from developers to end-users.

Relationship of innovation characteristics and the utilization of innovations at farm level
The results from Table 4.6 indicate that respondents chose innovations based on compatibility (857), relative advantage (517), complexity (344), trialability (173) and quality (172) in that order. This implies that although all the characteristics are important in relation to utilization of innovations, their relative importance differs. Table 4.10 shows that among the relative advantage parameters, economic profitability highly (68 observations) and very highly (80 observations) influenced utilization of innovations. This is in agreement with Mugula and Mishili (2018) who reported that a decision to adopt sustainable agricultural practices was largely influenced by the profit margin between different practices and that a farmer was likely to adopt sustainable agricultural practices after comparing the returns obtained under a number of agriculture practices. Similar results were reported by Liao and Lu (2008) who studied the relative advantage of Integrated Pest Management (IPM) practices and found that additional IPM practice benefits such as economic profitability, decreasing production cost and effort saving influence farmers' decision to adopt an innovation. Therefore it was very important for agricultural researchers involved in generating innovations to consider the economic returns from the innovations.

Table 4.11 shows that soil type and climate led to moderate level of utilization of agricultural innovations. Innovation end-users were interested in having innovations that were compatible with their farming systems. For example, the farmers expected to have new varieties that were adapted to marginal soils, and drought among other harsh environmental conditions. Similarly, as risky innovations such as those that were susceptible to pests and diseases were associated with low utilization of innovations. In case an agricultural innovation was incompatible with the grower's farming system, it would not be adopted as rapidly as

an innovation that was compatible. For example, a study by Sarel and Marmorstein (2003) showed significantly positive relationship between compatibility and perception for adoption. Thus, compatibility was an important part of innovation. The difficulty to understand an innovation can cause low levels of utilization of an innovation as shown in Table 4.12. The results agree with similar works by (Rogers, 2003; Sarel and Marmorstein, 2003) who reported that a low level of complexity led to higher adoption rate and complexity increased the rate of rejection. Overall, Tables 4.9 and Table 4.13 summarise the relationships between innovation and market attributes on the utilization of innovations on cassava, maize and rice in Kihihi Sub-county, Kanungu District. The adjusted R2, of 0.71 shows that among other predictor variables, innovation attributes such as Relative advantage, Compatibility, Trialability, Complexity and Quality had a significant relationship on utilization of a given commodity innovation. The results from the mixed effects model (Table 4.13) all predictor variables had a significant (p=0.000) relationship with the innovation utilization except market attributes.

Effect of innovation characteristics and market attributes on utilization of innovations in Agriculture

All innovation attributes had a positive significant effect on utilization of innovations, implying that improvement in a given innovation attributed increases the log odds of innovation utilization by the given coefficient value from very low to very high. On the other hand, complexity had a negative significant effect (Table 4.14). These results agree with what has been reported about innovation characteristics (Kolodinsky et al., 2004; Sarel and Marmorstein, 2003; Rogers, 2003). This implies that to enhance adoption/utilization of innovations the developers/generators should take into consideration the innovation characteristics. Innovators should try to ensure that their products are easily adaptable to the life styles of their clients. Although market attributes did not significantly have an effect of utilization of innovations according to the ordered logistic regression model, results in Table 4.15 show that profitability and market share influenced more of the utilization of innovations on rice than on maize and cassava. This could be due to the fact that rice is more of a commercial crop than maize and cassava. Besides, there is a lot of price fluctuation in maize prices than for rice. Other significant effects include gender, age and education level. The effect of gender is ascribed to the fact that female involvement in intervention has proven success due to maximum human resource participation and utility. For age, it could be attributed to the fact that aging may result in losing interest to utilization of innovations, while education could be associated with the fact that increase in education increases the chances of technical know-how of utilizing emerging innovations.

4.0 Conclusions and Recommendations

The study was initiated to assess agricultural innovation characteristics and their utilization in agricultural research in Uganda using a case of the National Agricultural Research Organisation with the three main objectives: i. To establish the factors that influence development of agricultural innovations; ii. To determine the relationship between agricultural innovation characteristics and utilization of innovations at farm level; iii. To examine the effect of market attributes on utilization of innovations in agriculture.

In order to establish factors that influence the development of agricultural innovations, several approaches were used. In one of the approaches, the respondents that were involved in agricultural research were given a chance to validate the agricultural innovations that they were involved in. These were generation of new crop varieties, development of protocols, improving existing technologies, and designing new process. There was an agreement (strong and very strong) that the respondents were involved in these activities. On the factors to be considered by respondents before embarking on generating innovations, cost of innovation, end-user belief/opinion, relevance of the innovation came out strongly from the respondents. However, there were mixed feelings among respondents on other factors such as the difficulty in understanding the innovation and end-user attitude towards risk and change. Finally, respondents were given an opportunity to give their opinions on how the organization sustains the momentum of innovations. It came out clearly that there was a clear plan on how innovations should be done; there was sharing information with colleagues on regular basis; bureaucracy/structures were involved in clearing innovations; there was tolerance to a certain degree of failure; and projects that no longer made a contribution could easily be abandoned. However, it was pointed out that the organization did not have enough incentives and a clear reward system to motivate the staff that were involved in generating agricultural innovations.

The study also set put to establish the relationship between innovation characteristics and the utilization of innovations. The results from this investigation indicate that respondents chose innovations based on compatibility, relative advantage, complexity, trialability and quality in that order. The results also indicated that the respondents utilized innovations at different rates ranging from very low to very high and the differences were highly significant. The results indicated that there was a significant relationship between innovation characteristics and utilization of innovations by the farming community in Kihiihi Sub-county, Kanungu District. Finally, it was also interesting to note that innovations were highly utilized in maize than cassava and rice. The final objective was to determine the effect of innovation and demand (market) attribute on the utilization of innovations. The results indicated that all innovation characteristics except complexity had a positive significant effect on utilization of innovations. One of the attributes, complexity, had a negative significant effect. Although market attributes did not significantly have an effect of utilization of innovations according to the ordered logistic regression model, profitability and market share influenced more of the utilization of innovations on rice than on maize and cassava.

4.2 Recommendations

Based on the study findings, the researcher makes the following recommendations:

1. Before initiating any programme on generation of agricultural innovations, agricultural researchers should carry out a needs assessment through participatory rural appraisals, market surveys and baseline studies to understand client needs. The identified needs should guide the generation of innovations.
2. There is need to motivate staff and teams involved in the generation of agricultural innovations. From this study it was perceived that there were inadequate incentives and rewards to motivate staff to carry out innovations. It is necessary for the organization to address the issue of benefits so that the staff can get motivated to carry out more innovations.
3. The disparity between what is recommended by agricultural researchers and what the end- users apply indicates a need for further studies to identify the gaps and understand the challenges within the innovation pathway from research to end-users.
4. In order to enhance adoption/utilization of innovations, the developers/generators should take into consideration the innovation characteristics. Innovators should ensure that their products are easily adaptable to the life styles of their clients.

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