From Murky to Transparent Agricultural Sector: Mainstreaming e-Agriculture in African Development

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Abstract— **Agriculture remains the mainstay of African economy. However, factors such as the subsistence nature of African agriculture, the dearth of information and corrupt practices in the sector have retarded growth and development. To take agriculture to greater heights for inclusive economic development and social cohesion, adequate and timely information needs to be shared on agricultural inputs distribution (e.g. seeds and fertilizer), research findings on modern farming techniques have to be disseminated in a timely fashion, real-time conversation on climatic change vulnerability and environmental risk has to take place among stakeholders, and the use of online payment systems for agricultural services has to be internalized, among other measures. All these underscore the exigency of mainstreaming technology in this all-important real (social) sector. Leveraging on existing inclusive innovation initiatives such as production of low-cost computers and mobile devices for developing economies by original equipment manufacturers (OEMs), we proposed an n-tier e-Agriculture system. Using Nigeria as case study, Microsoft SharePoint as development platform, and component-based software engineering as development approach,this study designed and implemented an e-Agriculture software application as a viable technology option for galvanizing agriculture in Africa. The researchers gathered requirements, modelled proposed solution, implemented and evaluated the new system. The outcome is a web-based multi-tier system that drives conversations among agriculture stakeholders on an online real-time basis. This proposed dialogue platform will inject transparency into agriculture business, mitigate age-long corrupt practices inherent in distribution of farm inputs, promote inclusive development and scale up the overall contribution of agriculture to national gross domestic products (GDPs) of African countries.**

Index Terms— **African Development, Agricultural inputs, Component-based software engineering, e-Agriculture, Farmers, Inclusive innovation and development, Information**

II. INTRODUCTION

This study was necessitated by concerns over the dwindling fortune of agriculture in Africa. The sector which is known to provide livelihood for about 70% of Africans is now bedeviled with challenges such as corrupt practices in the distribution of farm inputs, unsustainable nature of subsistence farming, poor information flow among sector stakeholders on developments. Though there are many challenges confronting the agricultural sector, of grave concern is the growing trend of corrupt practices in the sector. This negative trend has prevented farm inputs like fertilizers and improved seeds to get to the target audience who are largely rural farmers. The thinking is that promoting transparency in the sector can help solve the puzzle. In this day and age when technology is permeating virtually every field of human endeavour, this research explores the use of Information and Communication Technology (ICT) for stemming the tide of unwholesome practices in the sector. To address this problem, a technology-based solution for promoting transparency and accountability in the distribution of farm inputs was developed. Provision of information on the distribution of farm inputs apart, the solution will disseminate information on new research findings agricultural techniques to the target audience. The proposed solution called e-Agriculture system was developed using component-based software engineering (CBSE) approach. The researcher considered that an e-Agriculture system that drives conversion between government and citizens on the equitable utilization of state resources through agricultural service offerings will suffice. Though e-Agriculture is a vast field of applying ICTs to virtually all agricultural development initiatives, the scope of discussion in this paper is limited to the design and development of an e-Agriculture system that focuses on participatory social accountability. The proposed system is concerned with providing government and its citizens an electronic platform for online real-time exchange of information on agricultural services in tandem with electoral promises and the social contract. This is against the backdrop that a good chunk of agricultural services in Africa are rendered by government ministries, departments and agencies (MDAs) and studies have shown that some government officials are collaborating with middlemen to deprive farmers and the rural poor of agricultural supplies. Besides improving access to accurate and timely agricultural information, the e-Agriculture system will enhance the confidence of the electorate, particularly

farmers, in the political process. Other benefits include availing the people opportunity to criticize service offerings by government; empowers citizens to make inputs into public policies, programmes and projects; promotes transparency and accountability in governance; guarantees optimal utilization of state resources for socio-economic transformation and in the ultimate analysis guarantees peace, prosperity, social justices and security. According to Paime [1], there is a correlation between security and survival. While survival is an essential condition, security is viewed as safety, confidence, free from danger, fear, doubt, among others. Therefore, security is 'survival-plus' and the word 'plus' could be understood from the standpoint of being able to enjoy some freedom from life-determining threats and some life choices [2] . Therefore, making available social services such as agricultural services in a transparent and accountable manner is a developmental agenda that channels the energies of people into national development.

Typically, government ministries, departments and agencies (MDA) as organs that translate policies into services share a lot in common in terms of structure, practices and operations, but still have their peculiarities. This scenario suggests that a reuse-based approach to modelling and developing software that will be relevant to several MDAs would yield considerable benefits. Component-based software engineering (CBSE) is a reuse-based model of developing software where certain recurring requirements are individually abstracted, and implemented or sourced as standalone components; thereafter, the identified components are used to accomplish wide-ranging capabilities across many aspects of a developed system. The goal of CBSE is to engage the integration of loosely coupled components to realize a working system or software products. Usually, the objective is to develop reliable systems and gain some advantage in terms of time and cost of development. The application of CBSE for developing an e-Agriculture system is promising in view of the following reasons [3,4, 5, 6].

- o The complexity of an e-Agriculture software system requires an approach that simplifies the process of development.
- o Using components from tested and trusted vendors promotes trust and confidence of end-users in the solution.
- o The fact that we do not have to build from scratch but reuse existing reliable components implies that software can be built more quickly for any government agency that requests.

This paper reports a study of the use of CBSE in building a solution that took into cognisance the socio-cultural peculiarities of Africa. As a pilot project, the researcher designed and developed an e-Agriculture system for the Nigerian agricultural domain in an effort to curb unwholesome practices in the sector. The study practically investigated the impact of online real-time exchange of information between government and its people on agricultural services rendered and its implication for transparency and accountability in the application of state resources for the greater good of the greatest number of people. It was observed that not many reports on empirical application of e-Agriculture system for socio-economic transformation in Africa have been found in the literature. Hence, as a contribution, this work seeks to enrich the existing body of knowledge in information and communication technologies for development in particular, by reporting on a unique practical experience of applying e-Agriculture in Nigeria. This is particularly significant because scarcely does one come across reports of empirical studies of application of sophisticated e-Agriculture system based on software engineering concepts such as CBSE that emanates from the African region.

The remainder of this paper comprises the following: Section 2 gives the background of study and related work; Section 3 presents the methodology and the selected case study; section 4 focuses on results and discussions; and finally, the paper is concluded in section 5.

III. BACKGROUND AND RELATED WORK

A. Agriculture in Africa

Some experts on African affairs have concluded that the low economic activities majorly engineered by corruption has led to slow pace of socio-economic transformation on the continent. The after effect is social tension that manifests in terrorism, kidnapping, vandalism, child labour, human trafficking, just to mention a few. According to Sandbrook [7] , though Africa has abundant natural resources, it remains the world's poorest and most underdeveloped continent, the result of a variety of causes that may include corrupt governments that have often committed serious human rights violations, failed central planning, high levels of illiteracy, lack of access to foreign capital, and frequent tribal and military conflict (ranging from guerrilla warfare to genocide). The United Nations' Human Development Report in 2003 corroborated this stance as it emphasized that the bottom 25 ranked nations (151st to 175th) were all African. A Harvard University study [8] concluded that Africa could feed itself by transiting from importer to self-sufficiency. The study reiterated that there is need for Africa to focus on agricultural innovation as its new engine for regional trade and prosperity. This author considers that a technology innovation such as e-Agriculture could be the game-changer.

B. Corruption and Poverty Perceptions Indices

Transparency International, the global coalition against corruption, says the Corruption Perceptions Index 2013 serves as a reminder that the abuse of power, secret dealings and bribery continue to ravage societies around the world. The Index scored 177 countries and territories on a scale from 0 (highly corrupt) to 100 (very clean).

Although no country had a perfect score, about two-thirds of countries scored below 50 and African countries are reputed for falling within this bracket. This indicates a serious, worldwide corruption problem. To underscore corruption levels in Sub-Saharan Africa, this study statistically modelled corruption prevalence in select countries as shown in Table 1.

TABLE 1. CORRUPTION RANKINGS OF SELECT AFRICAN COUNTRIES (SOURCE: TRANSPARENCY INTERNATIONAL)

SN	Country	Year 2013 Score (over 100)	Ranking (out of 177 countries)
1.	Nigeria	25	144
2.	Gambia	28	127
3.	Mali	28	127
4.	Ghana	46	63
5.	Uganda	26	140
6.	Burundi	19	172
7.	Tanzania	33	111
8.	Kenya	27	136

Corruption affects all sectors, agriculture inclusive, and impact negatively on the quality of life and life expectancy. To provide a sense of the impact of corruption on poverty levels in Africa, we relied on scientific evidence from Global Multidimensional Poverty Index. The Global Multidimensional Poverty Index (MPI) Interactive Databank presents data on acute poverty in 108 developing countries around the world. It is a measure of poverty and human development and ranks for multidimensional poverty and destitution. After connecting Table 1 (above) and Table 2 (below), it became apparent that there is a strong link between corruption and poverty in Africa and by extension, insecurity.

TABLE 2. POPULATION IN MULTIDIMENSIONAL POVERTY (SOURCE: OXFORD POVERTY AND HUMAN DEVELOPMENT INITIATIVE (2014) GLOBAL MULTIDIMENSIONAL POVERTY INDEX DATABANK. OPHI, UNIVERSITY OF OXFORD

SN	Country	MPI Poor (%)	Destitute (%)	Population living on less than $1.25 per day (%)
1.	Nigeria	20	30	65
2.	Gambia	58	0	30
3.	Mali	88	0	50
4.	Ghana	17	8	25
5.	Uganda	50	25	30
6.	Burundi	40	40	80
7.	Tanzania	43	22	65
8.	Kenya	45	0	43

The pervasive corruption in Africa is having its toll on the agriculture sector. Notably, farm inputs budgeted for by government get diverted to serve vested interest, deepening poverty and insecurity on the continent. In this light, an e-Agriculture system that holds promise for transparency and accountability should be patronized.

C. ICTs for Development (ICT4D)

Information and communication technologies for development (ICT4D) refers to the use of information and communication technologies (ICTs) in the fields of socioeconomic development, international development and human rights. Tentacles of ICT4D includes e-Agriculture, e-Education, e-Health, among others. The philosophy is that more and better information and communication expedites the development of a society through enhanced provision of social services such as agriculture, education, health, among others. Besides its reliance on technology, ICT4D also requires an understanding of community development, poverty, agriculture, healthcare, and basic education. For the purposes of this work, ICTs comprise electronic technologies for information processing and communication, as well as systems, interventions, and platforms that are built on such technologies. Development includes, but is not restricted to, poverty alleviation, education, agriculture, healthcare, general communication, gender equality, governance, infrastructure, environment and sustainable livelihoods [9].

D. Related Work

Some of the previous efforts that are related to e-Agriculture in African Development in the literature are presented as follows.

Hilbert [10] popularized the ICT4D Cube Framework. The emphasis is that the goal of ICT-for-development (ICT4D) is to make use of transformation by actively using the enabling technology to improve the living conditions of societies and segments of society. He pointed out that in social transformations, the resulting dynamic is an interplay between an enabling technology, normative guiding policies and strategies, and the resulting social transformation. He sees this as a three-dimensional interplay and depicted it as a cube (ICT4D cube framework). In line with the Schumpeterian school of thought, the three factors enabling socio-economic transformations are technology (infrastructure, generic services and capacities/knowledge), social services (agriculture, education, health, business, government) and policies (regulation and incentives). When ICT practices are applied in a regulated and incentivized manner to scale up productivity in the social sectors, we have improved social services variants like e-agriculture, e-government, e-business, e-health and e-education with positive implications for transformation and development. Though the study presented an integrated view of the impact of technology on social services, it did not state how e-Agriculture could be used to tackle corrupt practices and entrench transparency in Africa's agricultural sector for sustained socio-economic development.

Narsalay et al., [11] beamed their searchlight on the Esoko project in Ghana. The study emphasized that the project is a successful ICT4D initiative which uses mobile phones to give farmers and their businesses the opportunity to share and receive information quickly, affordably and efficiently. Though the researchers pointed out that Esoko features a hosted application that is maintained and organized by the team, they failed to mention if the application injected transparency into the

agricultural sector, the chief motivation for this work. The study equally stopped short of mentioning the software engineering approach used.

Okojie [12] and Natsa [13] reported that the Nigeria's Electronic – wallet (e – wallet) agriculture strategy continues to transform not just the Agricultural sector. In a move to stem corruption in the seeds and fertilizer distribution chains in Nigeria, the Federal Government approved electronic wallets system to help farmers purchase fertilizers and seeds directly from agro-allied shops across the country. The authors stressed that Nigeria was the first country in Africa to develop the electronic wallet system for reaching farmers with subsidized farm inputs on mobile phones. Apart from the fact that the policy has put an end to corruption in fertilizer procurement, the impact is reaching well beyond Nigeria. Several African countries, India, Brazil and China have expressed interest in adopting the electronic wallet system in their own countries. Hence, Nigeria, which used to be paraded as having one of the most corrupt fertilizer sector systems, is today exporting transparency through with the aid of ICTs. As commendable as the findings of these researchers are, there was no mention of the software engineering approach used in developing the e-wallet system.

African Economic Research Consortium [14] (2014) carried out a study tagged *Information, Communication Technology (ICT) and Economic Development in Africa*. The objective of this study was to investigate the status and challenges of ICTs and ICT policy and their impact on economic development in Africa. The study built on the existing knowledge on the nature and extent of access to ICTs in Africa and proceeded to explore the impact of ICT on selected aspects of economic development with a view to drawing policy implications. The thrust of the project was on analyzing the impact of ICTs on economic development. Policy options to enhance the development of ICT and its impact on economic development were explored. However, the study did not address how ICT could be used to curb unwholesome practices in Africa's agricultural sector.

Okewu [15] studied the use of ICTs in enhancing the livelihood of the vulnerable groups (such as rural farmers, the poor, unemployed and women) in Nigeria through social security schemes. He observed that sharp practices in the delivery of social benefits to the less privileged could be nipped in the bud by incorporating biometric systems into social safety net programs. The study went a step further to provide a blueprint for the design and development of the biometric system. Inspite of the transparency consciousness of the study, it was confined to social security services alone. In addition, he did not specify the software engineering approach to be used.

In summary, we observed from the literature that none of the previous studies had focused on the implementation of an e-Agriculture system in an African context using CBSE approach with a view to injecting transparency into the agricultural sector. This is the main motivation for this work.

We therefore commissioned a study that fulfilled this criterion. Whereas the underlying logic is to ensure transparency and accountability in the distribution of agricultural inputs, the strategy is an e-Agriculture system. It provides online real-time information on agricultural services and was developed using component-based software engineering (CBSE) approach.

III. METHODOLOGY - E-AGRICULTURE SYSTEM

The choice of Nigeria as a case study was informed by the fact that it is the largest economy in Africa and accounts for about 25% of Africa's population besides being the most populous black country in the world. We considered that an e-Agriculture system that provides a dialogue framework for government and its people to negotiate how state resources are put into use in offering agricultural services will not only entrench transparency and accountability in the polity, but guarantee socio-economic transformation that mitigates/eliminates corruption, poverty and insecurity. With sense of modesty, the author posits that agricultural trends in Nigeria are, to a reasonable extent, quiet representative of trends on the continent.

Generally, the Nigerian farmers are still trying to come to terms with the role corruption is playing in thwarting public resources from making available to them farm inputs in a timely and sufficient fashion. A transparent approach using the e-Agriculture software application will guarantee unfettered information exchange between government MDAs and farmers on agricultural offerings. Both government and citizens can make proposals on agricultural policies, programmes and projects and communicate same online real-time and get feedback in the same fashion. Consequently, this study was motivated to design and develop an n-tier web-based e-Agriculture system using CBSE approach to guarantee sustainability, scalability and adaptability of the solution in other African countries.

Guided by the CBSE lifecycle activities, we embarked on the task of actualizing the proposed e-Agriculture system as a corrective measure for entrenching transparency in Africa's agriculture domain.

A. Requirements Analysis and Specification

The functional requirements for the e-Agriculture system were gathered and analyzed as in Table 3.

TABLE 3. FUNCTIONAL REQUIREMENTS

Requirement ID	Requirement	Brief Description
R01	Add agricultural services information	The system shall allow authorized users to add agricultural services information to the database
R02	Access agricultural services information	The system shall allow authorized users to access agricultural services information from the database
R03	Edit agricultural services information	The system shall allow authorized users to edit agricultural services information on the database
R04	Delete agricultural services information	The system shall allow authorized users to delete agricultural services information from the database

B. System and Software Design

The deployment diagram in Fig. 1 shows third party tool, PC, central processor, as key hardware components for implementing the system.
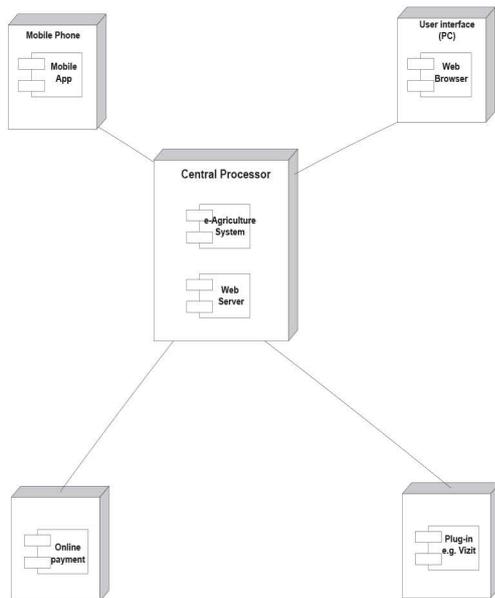

Fig. 4. The e-Agriculture deployment diagram

The e-Agriculture system is visualized as a component with functional points (interface methods) as illustrated in Fig. 2
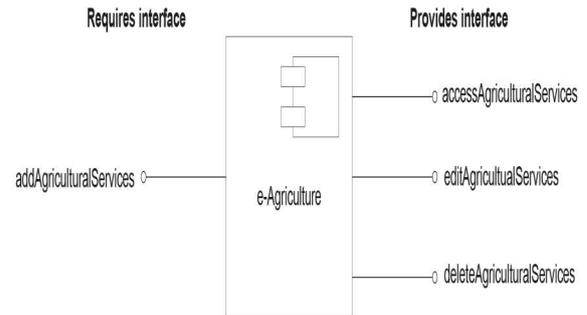

Fig. 5. The e-Agriculture component diagram

In Table 4, a detailed description of the e-Agriculture component is given, showing function points.

TABLE 4. e-AGRICULTURE COMPONENT EXPLAINED

SN	Component	Description	Interface Methods/Parameterized Operations/Function Points
1.	e-Agriculture	Provides information on agricultural services rendered by government ministries, departments and agencies to citizens for background check	addAgriculturalServices accessAgriculturalServices editAgriculturalServices deleteAgriculturalServices

The e-Agriculture algorithm design is as follows:

```
Procedure addAgriculturalServicesInfo()
    agriculturalServicesInfo ← " "
    while (not endOfAgriculturalServicesInfo())
    agriculturalServicesInfo ← addInput()
return(agriculturalServicesInfo)

Procedure accessAgriculturalServicesInfo()
    while (not endOfAgriculturalServicesInfo ())
    getInfo(agriculturalServicesInfo)
return

Procedure editAgriculturalServicesInfo()
    while (not endOfAgriculturalServicesInfo ())
    getInfo(AgriculturalServicesInfo)
    editAgriculturalServicesInfo()
return(AgriculturalServicesInfo)
Procedure deleteAgriculturalServicesInfo()
    while (not endOfAgriculturalServicesInfo())
    getInfo(agriculturalServicesInfo)
    deleteAgriculturalServicesInfo()
return(agriculturalServicesInfo)
```

C. Implementation and Unit Testing

We used Microsoft SharePoint as the development platform for the tailor-made e-Agriculture system. SharePoint is a web-based enterprise development tool that makes services (components) available for reuse. It is a component platform with Microsoft COM+ as the component model. It provides an integrated development environment (IDE). As observed by Okewu and Daramola [16], its core components are Document Library, Custom List and Tasks, which are not only independent but are distributed.

D. System Integration

With *addAgriculturalServices* as minimal e-Agriculture system, regression test was conducted as more function points were added. This was to ascertain that there were no interface errors. In situations where errors existed, debugging took place before adding another function point. In the final analysis, *addAgriculturalServices* will be the most tested sub-component in e-Agriculture systems.

Test cases were developed and used to test the various function points prior to integrating them. Then we used system test cases at the point of integration for regression tests.

E. System Verification and Validation

We verified and validated the process-correctness and requirements-compliance of the e-Agriculture architecture by examining the various software representations - requirements documents, design documents and program code. Our concern was to ascertain that user requirements had been well catered for in each software representation in the build-up process as well as ensured that the software product met both operational needs of users and emergent properties.

F. Operation Support and Maintenance

A number of technical staff and end-users have been trained to put the application into effective and efficient use. While the end-users operate the software, the technical staff will provide ongoing support for end-users.

IV. RESULTS AND DISCUSSION

In a bid to extract information and measure outcomes of this study objectively, we used software experiment. We also evaluated possible threats to our results.

A. Results of Software Experiment

With the development server located in Lagos (University of Lagos), we tested for both remote and local access. Though accessing the e-Agriculture development server from remote locations cost more response time than local access, the basic user operational needs of adding, accessing, editing and deleting agricultural services were successful. To enable the cardinal objective of an interactive interface between government MDAs and citizens, the proposed e-Agriculture system was built as a community site. For this experiment, some users posed as government while others were citizens and the platform enabled both to make postings on agricultural services offered.

We accessed the system from three locations - Lagos, Abuja (the Federal Capital Territory) and Lafia in Nassarawa State. While access in Lagos was within and outside the University of Lagos network, access from Abuja and Lafia were thousands of kilometers away from Lagos where the development environment is. Though access from Lafia was difficult, the same could not be said of Abuja. The difficulty of accessing from Lafia is a subject for further investigation.

Outcomes of the test-run as graphically demonstrated in Figs. 3-5 below clearly indicate that both government and the citizenry could deliberate on services rendered with the ultimate goal of ensuring that state resources are judiciously utilized for overall socio-economic development. This way, transparency is guaranteed and the agricultural sector is better repositioned to serve the economy as the mainstay.
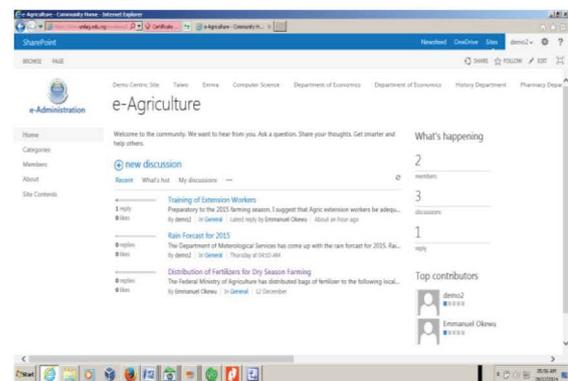

Fig. 6. The e-Agriculture sub-site showing simulated dialogue between government and citizens on services rendered in the agricultural sector

The following snapshots (Fig. 4 and Fig. 5) show simulated postings on agricultural services involving distribution of fertilizers to select local governments for current dry season farming. The simulation shows information exchange between the Federal Ministry of Agriculture and a citizen on the status of farm input (bags of fertilizer) supplied to his local government area.
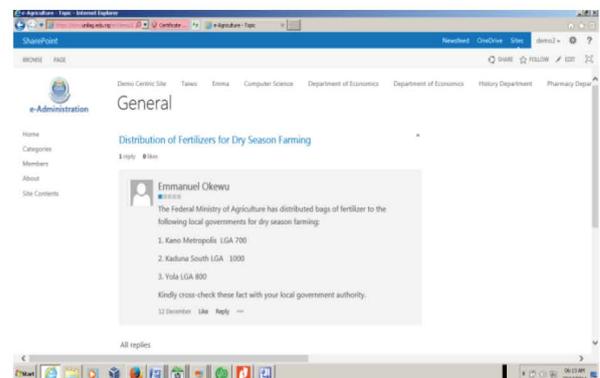

Fig. 7. Simulated information on release of farm input (bags of fertilizer) by Federal Ministry of Agriculture
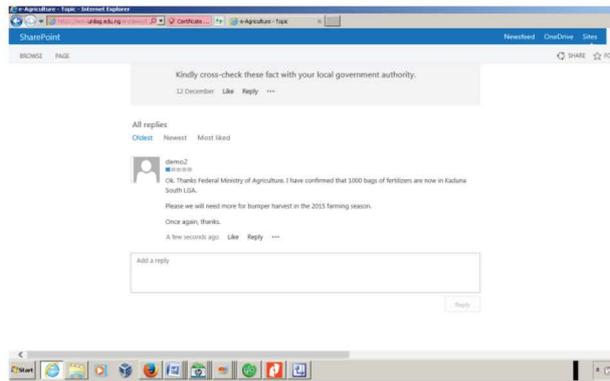
Fig. 5. Simulated response of citizen to information on release of farm input (bags of fertilizer) by Federal Ministry of Agriculture

B. Evaluation Threats

We acknowledge that a more elaborate evaluation of the different modules of the e-Agriculture system could throw up new insights. In any case, the subjects that participated in the survey have the required practical knowledge of Nigeria's agriculture challenges - corruption, dearth of information, and its subsistence nature. They equally had sufficient practical engagements with the e-Agriculture system. This offered them good basis to make objective comparison between the old way of doing things and the e-Agriculture way of stakeholders interactions. Therefore, there is sufficient reason to take their views seriously.

In addition, only 2 classes of people were involved in the evaluation - one representing government while the other represented the farmers, which could in a sense limit the statistical significance of the outcome. However, the result of the experiment clearly indicates that both parties who incidentally are the major stakeholders in the agricultural space were adequately represented and were functional in the exchanges on acceptable agricultural service levels . This is considered to be a good result because at this point in the project, the core objective is to gain a first impression of the transparency and accountability injected into agricultural governance by the e-Agriculture system. Therefore, despite the limitation of using a limited number of evaluators, there is sufficient ground to infer that there is a positive and preferential disposition to the e-Agriculture system as a tool for curbing unwholesome practices through the injection of transparency in agricultural transactions with farmers. We can thus generalize that the CBSE-developed e-Agriculture system is effective for the transition from murky to transparent agricultural sector for the purpose of rapid socio-economic development of Sub-Saharan Africa.

V. CONCLUSION

The bottom-line of this study is that promoting participatory social accountability in governance can engender transparency in all sectors and nip corruption in the bud. In the context of this work which focused on the agriculture sector, we introduced technology to promote transparency in the distribution of agricultural farm inputs and dissemination of research findings on improved farming techniques to farmers. The design and implementation of the proposed e-Agriculture system

demonstrated that technology can drive online real-time conversation between government and its citizens on policies, programmes and projects in the agricultural sector. Hence, public expenses on agricultural services can be monitored to ensure corrupt practices perpetuated by government officials and middlemen in the distribution of farm inputs are curbed. Such technology-induced fiscal discipline promotes inclusive development which in turn impacts positively on national development.

It is therefore safe to say that mainstreaming e-Agriculture in African development will transform the agricultural sector from a murky sector to a transparent sector for the greater good of the greatest number of people.

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