Diffusion of Scientific Knowledge in Agriculture: The Case for Africa

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ABSTRACT

Diffusion of scientific knowledge in the agriculture sector in Africa, primarily in sub Saharan African (SSA) countries, is dominated by traditional extension service that is slow, linear, hierarchical, and poorly funded. Using exploratory research method, this paper set out to investigate existing knowledge diffusion models and their limitations, available best practices, and the potential to infuse translational research as a way to augment extension service programs in SSA agricultural practices. A closer analysis of the extant literature in the topic gave us a valuable insight in the following areas: (1) public private partnerships, including NGOs, and participation across the entire agricultural value chain is critical to forge a trusted and working knowledge exchange practice between the research and farming communities; (2) researchers and their institutions need to consider the needs and priorities of the farmer, the end user of produced knowledge, first; (3) extension services need to focus more on education, training, and face-to-face individual/group interactions by empowering the extension agent to become an effective knowledge broker; (4) translational research will help bolster the existing knowledge diffusion practice by bridging the knowledge to action/decision gap; (5) the potential for ICT use in disseminating new knowledge and creating knowledge networks exist in SSA. With these valuable insights, we also proposed what we called "Agricultural Knowledge Clearinghouse, AKC" that will work in tandem with the extension service. The significance of the AKC can be seen from the point of view of employing knowledge translation methods to integrate, synthesize, and create ready-to-use knowledge packages such as agricultural practice guidelines.

Conference tags: Innovation, digital libraries and repositories, outreach/engagement

INTRODUCTION

Agriculture is the mainstay of the economies of most African countries. Close to 50% of the World's population live in rural areas and most of them (over 83%) are in one way or another depend on and/or engaged in agriculture (FAO, 2013a). Africa is the continent where the economy's main backbone is agriculture and where the largest percentages of people are poor farmers. About two-thirds of the population in Africa, especially in sub-Saharan Africa, and about 72% of those in East Africa is dependent on agriculture for its livelihoods (Adekunle et al., 2012; FAO, 2012; Webersik & Wilson, 2009). These numbers may not change dramatically in the near future although other sectors of the African economy such as commodities and manufacturing, at least in some countries, have picked up momentum thanks in part to good governance and policies making the continent more attractive to investors, both foreign and domestic. In fact, in 2012, the region with the second fastest-growing economy in the world is Sub-Saharan Africa with agriculture as one of the sectors contributing to the growth (Sayeh, 2013).

Africa, often beset by poverty, malnutrition, and hunger, is also working hard to achieve food security and reduce chronic hunger. However, there are dangers lurking that could impede its growth and deny it to achieve sustainable food security. One of these dangers is climate change which could predictably have adverse effects on agricultural production and, in turn, the economy (Sayeh, 2013). Still, according to the latest edition of the 'State of Food and Agriculture 2013' report (FAO, 2013b), Africa has the world's highest prevalence of malnourished people, at nearly 23% of the population. Agricultural output has not kept up pace in Africa compared to other regions of the world. Major initiatives such as NEPAD's Comprehensive Africa Agriculture Development Program (CAADP), the Forum for Agricultural Research in Africa (FARA), New Alliance for Food Security and Nutrition between G-8 and African countries are all gearing up to lift tens of millions of people out of poverty over the next decade. In this critical social mission, the role of scientific knowledge and innovation capacity cannot be overstated as agriculture is knowledge and resource intensive (Ayele & Wield, 2005).

To mitigate the dangers to economic growth for African countries where agriculture is the main driver of that growth, continued investments in innovations and research by governments and non-governmental organizations as well as immediate translation/diffusion of the innovations, results, and findings of that research to practice is crucial.

Extensive literature exists in the area of diffusion of knowledge and innovation in general, and in agricultural sciences in particular (Rogers, 1995, p.157; Rogers, 2004). At the time of the latest publication, the 5th edition in 2003, of Rogers' influential book '*diffusion of innovations*,' a work that was first published in 1962, there were about 5000 diffusion related publications (Rogers, 2004). One can trace diffusion research in agriculture back to the work of Ryan and Gross (1943) on the diffusion of hybrid seed corn in two Iowa communities. This seminal work

was later followed by Griliches' 1957 highly cited article about hybrid-corn adoption in the U.S. The body of work in this area is largely focused on the investigation of characteristics of innovators, why certain innovations are adopted while certain technologies and ideas fail, the rate and speed of adoption of new ideas, etc. (Wejnert, 2002). According to Rogers (1995, p.5; 2004), a leading authority in diffusion research, diffusion is defined as "the process through which an innovation, defined as an idea perceived as new, is communicated through certain channels over time among the members of a social system. It is a special type of communication, in that the messages are concerned with new ideas. Communication is a process in which participants create and share information with one another in order to reach a mutual understanding."

Given the above definition, it is not difficult to extrapolate the fact that relevant actors such as researchers, extension agents, farmers, traders, policy makers, non-governmental organizations (NGOs), and those in industry and manufacturing have all a stake in agriculture and can be members of the larger 'social system' in agricultural sciences. The second element in the definition concerns the notion of 'communication,' and the idea that "members create and share information with one another in order to reach a mutual understanding," is not always reflective of the situation on the ground when one examines the existing communication channel in the field of agriculture in Africa. The existing communication in agriculture in Africa is hierarchical, slow, unidirectional, and lacks the appropriate resources and infrastructure (Bembridge, 1987; Rural Economy and Land Use [RELU], 2007).

As is the case in most regions and countries the world over, scientific knowledge communication is predominantly through professional conferences and scholarly journal publications. Such channels of scholarly communication are not really designed with the farmer in mind because the audience involved, the language of the research findings, and the format of communication are not compatible to the needs and level of competency of the farmer. This is not to suggest that the results of research findings will not reach the farmer at all. For a long time, driven by the basic-applied research divide, while applied research is meant to address problem-solving issues, basic science/research remained neutral. This was evident from Albert Einstein's appeal in 1931: (cited in World Conference on Science by UNESCO, 2000) "concern for humankind itself and its fate must always form the chief interest of all technical endeavors. . . .Never forget this in the midst of your diagrams and equations."

Still today existing scholarly communication practices largely happen within the circle of researchers and scientists. The research-to-application or knowledge-to-decision pathway tends to be linear in that new findings and ideas flow from the research community to the agricultural community via some intermediary, which are often extension professionals or personnel at government agricultural institutions such as ministries or departments. It is not that the extension service is not working. When implemented properly, studies have shown the positive impact and

role of extension work, including in advanced economies (Davis, 2008; Marsh, Pannell, & Lindner, 2000). The fact remains that in such linear model of knowledge diffusion, the research community largely operates in isolation and is divorced from the needs and priorities of the farming community. At its core, the communication and interaction between agricultural research community – extension services – farmers in African context needs re-conceptualizing to bolster effective diffusion of knowledge and innovation. If any of the research findings are to trickle down to the frontline in the farm field in a timely and usable manner, much work needs to be done to package, repackage, and synthesize the knowledge into context-rich processes, procedures, and guidelines that can be readily used and acted upon.

Although there is non-research knowledge that is often communicated to the farmer, when it comes to scientific knowledge, which is the focus of this paper, it is largely produced by the research community. For generations, through interactions with the natural environment, the farming community in Africa has been using non-research based knowledge. Any knowledge diffusion framework to be introduced or research activity that takes place to improve existing agricultural practices need to start with or factor-in the existing local knowledge base, often referred to as indigenous knowledge. Studies have also shown the significance of embedding indigenous knowledge with scientific knowledge to achieve better results (UNEP, 2011).

The agriculture sector and the entire supply chain is a complex system that involves multiple actors such as agricultural science researchers and scientists, technical universities, NGOs, manufacturing and industry, government ministries, traders, extension professionals, and of course farmers. Knowledge diffusion, as opposed to knowledge transfer (which is unidirectional from provider to seeker), is multidirectional and involves the exchange of ideas, best practices, know-how, information and expertise between the range of actors stated (Manning, 2013). In this study we focus on the diffusion of scientific knowledge from the research and scientific community to the farmer as the end-user. Most importantly, we focus on exploring translational research (TR) as a model/strategy to effectively communicate research findings from scientific and research community to the farming community. Recently, translational research has gained wider recognition in medicine and clinical settings as a strategy to benefit patients in clinical settings from the knowledge and findings of basic research in bio-medical sciences (see for example, Brekke, Ell, & Palinkas, 2007; van der Laan & Boenink, 2012; Vignola-Gagne, 2013; Zerhouni, 2003, 2005). We argue that translational research as a new paradigm can be viewed within the framework of the national systems of innovation that is widely recognized in agriculture.

Against this backdrop, we first review existing agricultural extension services that come in different forms and shapes throughout sub Saharan African (SSA) countries (see Davis, 2008 for a complete typology of the extension service in SSA) in order to propose a working knowledge diffusion model that has translational research practice at its core. Given that agriculture is a

complex multi-stakeholder, multi-disciplinary sector and taking into account the limitations in social, technical, and institutional infrastructure in SSA, we aim to propose a framework that overcomes the limitations and augments existing extension services system and proposes a solution that: (1) engages farmers to understand their needs, concerns, and priorities thereby creating the environment for researchers/scientists to work with the farmers instead of for them, (2) in addition to well utilized channels, to include recent advances in social communication tools and mobile technologies; (3) to conceptualize the role of the extension agent as a knowledge broker; and, most importantly (4) to learn from translation research to develop effective knowledge translation programs that bridge the knowledge-to-action gap.

More specifically, as we propose an appropriate model, we aim to find answers to the following three questions:

- What best practices exist to build partnerships between researchers, their institutions, and practice constituencies in the agricultural sector in Africa?
- To what extent can translational research augment existing agricultural knowledge diffusion and extension service in sub Saharan Africa?
- What is the potential of ICT in extension services, learning, and knowledge diffusion efforts in sub Saharan Africa's agricultural practices?

RELATED WORK

Knowledge Diffusion and Innovation Adoption

One will be hard pressed to find a socio-economic activity that, among other things, does not take in knowledge as an input to produce more and better output, including further knowledge production. Agriculture is no exception in this regard. When relevant and useful knowledge is utilized, it has the power to transform agricultural output. The epistemological and philosophical discussion of knowledge aside, knowledge (internal or external) is continuously internalized and externalized through social interactions, shared experiences, and learning. It is in this context that the discussion on knowledge diffusion and innovation adoption comes to the fore. This section reviews the extant literature about the use of agricultural scientific knowledge in Africa, primarily sub Saharan Africa (SSA).

Over the years, different approaches, frameworks, and models were developed to explain and guide activities around knowledge diffusion in agricultural practices. In sub Saharan Africa, a closer analysis of these models reveals that the implementations come down to one of several variations of traditional government led extension service programs (see, for example, Davis, 2008). More recently, under the general umbrella of 'national innovation systems approach,' there is an increasing literature that focuses on a new paradigm based on multi-stakeholder, bidirectional, participatory, and collaborative approaches (Ayele, Duncan, Larbi, & Khanh, 2012; Edquist, 1997; Nelson, 1993). Innovation systems approach is seen as networks of private

and public sector organizations that interact synergistically to create, diffuse, and use knowledge. In addition, we also find related discussions such as scientific and technological capacity building (Ayele & Wield, 2005; Hall, 2005); knowledge networks and social learning (Ingram, 2010); peer-to-peer learning among equals (Topping, 2005), change agent approach (van den Ban & Hawkins, 1996), and learning networks (Riddell, 2001).

The nature of interactions and communication channels employed are equally diverse and include mentoring, one-on-one meetings, demonstrations, community radio, farmer field schools, training, and visits (Davis, 2008; Manning, 2013). It has also been found that face-to-face interactions are significant modes of knowledge exchange (RAND Corporation, 2011). In addition, farmer-to-farmer extension work is regarded as beneficial because both parties communicate the same language and the interaction would be relevant and in-context that ensures availability, accountability, and credibility – and once developed offers an element of sustainability as an ongoing model (Scarborough et al., 1997).
Knowledge diffusion in agriculture is not always about the transfer of scientific knowledge from research community to farmers as end users. Over generations, farmers accumulate varied practices and ideas that become part of their indigenous knowledge stock. Indigenous knowledge (IK) is the primary resource and social capital that shapes how local farmers engage with the natural environment and develop problem-solving strategies (Lwoga, Ngulube, & Stilwell, 2011). As important as it is, IK is usually internal, tacit, unsystematic, and derived from local experiences (Lwoga, Ngulube, & Stilwell, 2011). Often contrasted with local knowledge, the definition of IK encompasses all forms of knowledge, including technologies, know-how skills, practices and beliefs that enable the community to achieve stable livelihoods in their environment (Manning, 2013). In view of these, it is apparent to postulate that any knowledge diffusion activity needs to start with the community's knowledge base, assessment of what is and is not working, build on the best practices, and improve on the ones that will not yield desired results (Johnson & Segura-Bonilla, 2001).

The goal of knowledge diffusion is to create a successful environment where end users benefit from the research findings by adopting new ideas and practices in a timely manner. In this regard, learning is an integral part of the end-users embracing innovation and knowledge (Ghadim, Pannell, Burton, 2005). According to Rogers (1995), the rate of adoption, the speed with which new ideas and innovation are embraced by individuals and groups, is hugely predicated by five factors, i.e., (1) relative advantage, (2) compatibility, (3) level of competency, (4) trialability, and (5) observability.

Along with diffusion of research, knowledge transfer, knowledge exchange, and knowledge translation are also closely discussed concepts. The Research Council of UK defines knowledge transfer as "the system and processes by which knowledge, expertise and skilled people transfer between the research environment and its user communities in industry, commerce, public and

service sectors (Rural Economy and Land Use [RELU], 2007). Knowledge transfer is often regarded as one way flow from source to destination without any feedback loop back to the origin. Knowledge exchange, on the other hand, is conceived as a multi-directional flow of information of all kinds that is required as a basis for decision making in the translational research process (RAND Europe, 2011). The following four knowledge transfer/exchange models were adapted from RELU (2007).

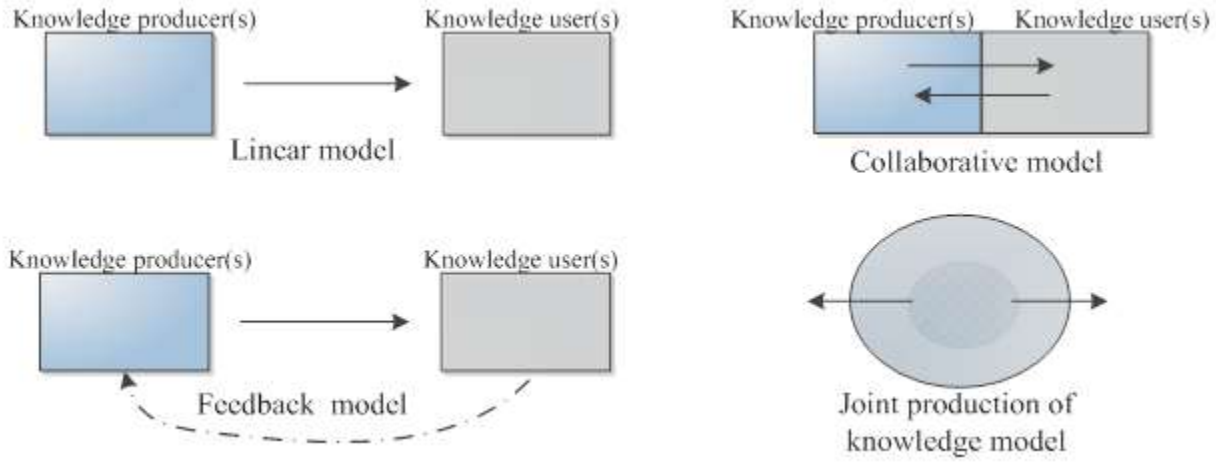

Figure 1. Knowledge transfer/exchange models

The above models conceptualize the direction of the information/knowledge flow at a higher and broader level and do not tell us much about the role of actors involved in agricultural practices. More and more, the integrated agricultural practices and the innovations systems approach are gaining wider attention. In the African context, Forum for Agricultural Research in Africa (FARA) is spearheading integrated agricultural research for development (IAR4D), which uses an innovations systems approach to bring together stakeholders as partners (Adekunle et al., 2012). In order to evaluate the usefulness of multiple stakeholder innovation systems approaches to support IAR4D, FARA investigated 21 case studies from eastern, southern, and western African countries. According to the findings, the successes from the case studies are mixed and dependent on a wide range of facilitating and inhibiting factors, the key elements of which include (Adekunle et al., 2012, p.6-7):

- Building and supporting partnerships
- Strengthening farmer organizations
- Involving the private sector and ensuring use of market driven approaches
- Improving access to information, knowledge, and training
- Scaling up and adding value to country agricultural strategies
- Sustainability

Moreover, diffusion has its own characteristics in that (1) it tends to be adopted over time and it exhibits a wave-like s-shaped pattern, and (2) it has also a spatial dimension in which it tends to concentrate in the geographic region where it started and reaching other areas in outward fashion (Trajtenberg & Yitzhaki; 1989; Wejnert, 2002).

Extension Service and Knowledge Diffusion

The current state of knowledge diffusion in Africa (especially in SSA) is dominated by extension service that is largely coordinated by the ministry of agriculture (and their equivalent institutions) in respective countries. Extension is defined as "the conscious use of communication of information to help people form sound opinions and make good decisions," (van den Ban & Hawkins, 1996). Traditionally, extension was regarded as the delivery of information and technologies to farmers that in turn led to the characterization of agriculture extension as the technology transfer model (Davis, 2008). In agriculture, extension services are key to communicate new knowledge and ideas to farmers. An extension service is often characterized as the conduit between the research community and the farmer (Marsh, Pannell, & Lindner, 2000). Extension service plays a significant role in introducing new ideas and innovations to the farmer during initial stages of adoption (Marsh, Pannell, & Lindner, 2000).

Extension agents often employed personal interactions, field visits, demonstrations, outreach, workshops, etc. as a mechanism to transfer new knowledge and innovation. The structure and execution of an extension service varies from one country to another. In Africa, where the economy is largely centralized, extension agents are from the government, based mainly in agriculture ministries and departments, deployed to execute the plan, to supervise instead of teach, and to enforce the quantitative attainment of goals instead of the qualitative impact (Blanckenburg, 1982). Davis (2008) reviewed extension services throughout SSA countries and offers three general categories, i.e., diffusion or government-driven; participatory or demand-driven; and private or supply driven. The following table summarizes extension models, and numbers of agents (also called agent density) in selected SSA countries (Davis, 2008).

Table 1.
Extension models and agents by country

Country	Current Model(s)
Angola	Rural Development and Extension Programme; FFS
Benin	Participatory management approach; decentralized model; FFS
Burkina Faso	FFS
Cameroon	National Agricultural Extension and Research Program Support

	Project; FFS
Ethiopia (65,000)	Model based on SG-2000 approach: Participatory Demonstration and Training Extension System; FFS
Ghana	Unified Extension System (modified T&V); pluralistic with NGOs and private companies part of the national extension system; decentralized; FFS
Kenya	Pluralistic system including public, private, NGOs; FFS; stakeholder approach (NALEP): sector-wide, focal area, demand-driven, group based approach
Malawi	Pluralistic, demand-driven, decentralized; "one village one product;" FFS
Mali	Modified T&V; both private and parastatal services for cotton; FFS; SG-2000
Mozambique (1,068)	Government-led pluralistic extension; FFS
Nigeria (5,252)	FFS; participatory; SG-2000
Rwanda (500)	Participative, pluralistic, specialized, bottom-up approach; FFS
Senegal	FFS; government-led demand-driven and pluralistic system; FFS
Tanzania (7,000)	FFS; group-based approach; SG-2000; modified FSRE from Sokoine University of Agriculture's Centre for Sustainable Rural Development; private extension; decentralized Participatory District Extension; pluralism
Uganda	Pluralistic; National Agricultural Advisory Services (NAADS) is demand-driven, client-oriented, and farmer-led; SG-2000; FFS
Zambia	Participatory Extension Approach; FFS

Extension professionals are often seen as change agents, working closely with the farming community either as internal or external entity, and they play a process-facilitating role (Manning, 2013). To the extent that they are playing a much needed role in driving innovation and providing new knowledge, there are also authors who argue that extension workers are

largely engaged in knowledge transfer instead of knowledge exchange because there is no feedback loop in such a change-agent approach that is often characterized as a unidirectional information flow (van den Ban & Hawkins, 1996). Rogers (1995, p.27) describes extension professionals as "opinion leaders," whose mission in agricultural extension is to effect behavior change in the target audience, i.e., the farming community. A detailed discussion of extension approaches (guiding the structure, leadership, program, resources), models (schematic account of the system), and methods (such as visits, demonstrations) is given in Ponniah, Puskur, Workneh and Hoekstra (2008).

Increasingly the literature in this area focuses on how to reform and create a more robust, contextual, and lean extension model that places emphasis on education and engagement. For example, Linder and Dolly (2012) addressed this challenge head-on by offering the following ten ideas to create an effective extension and outreach service in developing countries: (a) be institutionalized, well defined, and well-funded; (b) address important and contemporary issues/problems; (c) be sufficiently nimble and flexible in order to address emerging issues; (d) be a credible and unbiased source for information and education and for solutions and research; (e) understand the needs of its customers; (f) embrace participatory and integrated approaches; (g) recognize that little happens in isolation and create regional/global sustainable partnership/ linkages with governments, NGOs, researchers, and educators; (h) be excellent stewards of resources acquired; (i) recognize that return on investment (ROI) from its research and outreach must be well documented; and (j) allow for decentralized decision making and action when warranted.

The lesson from what is known as "Research into Use – RIU," a program funded by the Department for International Development (DFID) of U.K. to help promote results from a suite of research carried out over a period of 11 years from 1995-2006 is worth noting here (Department for International Development [DFID], 2013). Under RIU, six countries from east and West Africa were selected. In each of these countries, a national innovation council was first established, through which relevant actors, stakeholders, scope and intervention strategies were defined. In the six countries involved, the approach was to use the knowledge and innovation capacity developed as a result of the 11 years suite of programmatic activities. After consultation with local and appropriate institutions and agricultural initiatives, specific commodity chains were identified as entry points that came to be known as 'innovation platforms (IP)'. Examples include: Cassava and aquaculture IP in Nigeria; poultry IP in Sierra Leone; and Potato IP in Rwanda. The key lesson from such an activity was that by bringing together different actors under specific IP's, success was achieved in building networks that develop trust and build social capital (DFID, 2013). In addition, there was not any single blueprint that worked across the countries selected supporting the need for contextual, situational, country and culture specific interventions. A similar notion was reflected by Rivera (cited in Linder & Dolly, 2012) that an appropriate extension model or system is situational in context, content, culture, and politics.

Translation science/research

RAND Corporation Europe (2011) defines translational research as "the new scientific methods and technologies, interdisciplinary approaches, and collaborative institutional arrangements being developed to narrow the gap between basic science and its application to product and process innovation."

As the evidence-based medicine (EBM) practice gained momentum, the knowledge-to-action (KTA) or knowledge transfer approach became more significant in healthcare. Repeated concerns that were reported include the effective transfer of knowledge to the intended audience, and the failure of researchers to address the most important problems facing clinicians, managers, and decision-makers (Bowen & Graham, 2013). The framework that is often cited to overcome the limitations of existing knowledge communication in healthcare is the integrated knowledge translation approach, one that engages knowledge users as partners in the research process (Bowen & Graham, 2013; Cargo & Mercer, 2008). Table 2 shows this same distinction between existing knowledge transfer paradigm and the integrated knowledge translation approach.

Table 2.

Two paradigms in knowledge translation (Bowen & Graham, 2013)

Knowledge Transfer Paradigm	**Engagement Paradigm**
● Evidence-based medicine	● Evidence-informed decision-making
● Biomedical roots	● Social science roots
● Researchers do research	● Researchers and users select questions
● Researchers communicate results effectively	● Researchers and users bring different expertise
● Recipients use the results	● Joint interpretation, application in context
● 1-way knowledge transfer by expert	● Multidirectional learning
● Goal: more use of research	● Goal: better quality, relevant research
● Communication and dissemination	● Genuine partnership mutual respect
● Focus on single issue	● Focus on change in how business done
● Focus on content	● Focus on process
● Increasing user capacity	● Change management
● Information sharing	● Power sharing

In agriculture, RAND Corporation in Europe (2011) produced a comprehensive report to promote translational research and knowledge exchange in the U.K. agricultural sector, using wheat production as a test case. The report provided a conceptual framework to guide investigation of the entire value chain in agriculture that spans from what they call "upstream activities," in research to "downstream activities," in application and development (RAND Corporation, 2011). In The long arc of the value chain system depicted by the conceptual framework, the study identified three key actors viz. knowledge producers, knowledge intermediaries, and knowledge users. In addition, borrowing a significant insight from translational research in healthcare, the report lists the following enablers of translational research and knowledge exchange:

- Targeting end-user
- Involving key actors
- Multi-disciplinarity
- Fora to facilitate knowledge exchange and translational research
- Policy, legislation, and regulation
- Availability of funding for translational research

The key findings from the RAND Corporation Europe (2011) technical report is that the main impediment for effecting translational research is the lack of synthesized and useful information, communication challenges, and fragmentation of different types of actors across the value chain. Started in healthcare practice as a means to bridge the gap between scientists and clinicians, there is a growing interest in translational research to take advantage of advances made in plant breeding and genomics to improve crop productivity (Delmer, 2005; Reynolds & Tuberosa, 2008). Relevant points that emerge from the discussion of translational research are the idea of 'knowledge translation' and 'knowledge synthesis.' According to the Canadian Institutes of Health Research (CIHR, 2004), Knowledge translation is defined as:

"...the exchange, synthesis and ethically-sound application of research findings within a complex set of interactions among researchers and knowledge users... In other words, knowledge translation can be seen as an acceleration of the knowledge cycle; an acceleration of the natural transformation of knowledge into use. Within the context of health research, KT therefore aims to 'accelerate the capture of the benefits of research. . . through improved health, more effective services and products, and a strengthened health care system'..."

Knowledge synthesis, on the other hand, is (CIHR, 2004):
"…the integration of research findings into the larger corpus body of knowledge in a given discipline. A knowledge synthesis must be reproducible and transparent in its methods and use quantitative and/or qualitative methods. It can take the form of a systematic review and follow methods established by the Cochrane Collaboration; or, it can be developed as a result of a consensus conference, expert panel, qualitative or quantitative study. Realist synthesis, narrative

synthesis, meta-analysis, meta-syntheses and practice guidelines are all forms of knowledge synthesis."

ICT and Agricultural Knowledge Diffusion in SSA

Information and communication technology (ICT) has the potential to play a significant role in the agricultural innovation effort in Africa. Under the general catchphrase 'ICT for development, ICT4D,' information and communication technology is increasingly used for development activities, including in agriculture sector in Africa. In a time when agricultural innovation is required to be more nimble and adapt to changing local and global situations, the role of ICT to track, analyze, communicate, and follow new developments is enormous. For example, the World Bank is funding a program called "infoDev," through which African countries are receiving support to create technological applications in climate change, mobile technology, and agribusiness entrepreneurship (Ventures Africa, 2013). More examples of innovative use of ICT in African agricultural activities include: the use of an e-voucher system in Zimbabwe; electronic wallets in Nigeria where farmers receive fertilizer and seed support through their mobile phone; or a similar mobile app called 'iCow' that allows dairy farmers in Kenya to track the gestation periods and progress of their cows (Ventures Africa, 2013).

In any knowledge diffusion model, the communication channel holds a central role. Given the discussion above that current paradigm in extension service requires engaging farming communities to understand their needs and priorities, the role of communication technologies such as mobile phones to collect data from the farming community and/or push information back to the farmers is substantial. According to a World Bank report (2012), there were about 650 million mobile phone subscribers in Africa at the beginning of 2012. The figure below taken from the same World Bank report shows the exponential growth of mobile phone penetration in sub Saharan Africa - the second highest growth in the world exceeded only by south Asia. In regards to mobile phone utilization, there were several case studies that were documented in this same eTransform Africa report and some of the examples include – mFarmer initiative fund aimed at supporting development of mobile phone-enabled communications and advisory services in the agricultural value chain; and Africa Scan that documented several success stories from ICT use in multiple SSA countries (World Bank and African Development Bank, 2012).

Although the attempt in this section is to review the potential of ICT for agriculture in SSA, the role of ICT globally in the agriculture sector is vast. A quick scan of the iPhone Apps store or looking into resources from major university agricultural extension programs (such as Cornell University Cooperative Extension or Iowa State Extension and Outreach), for example, have extensive examples of technology use in agriculture in areas such as geographic information system, weather forecast, weeds identification, and agricultural price alerts.

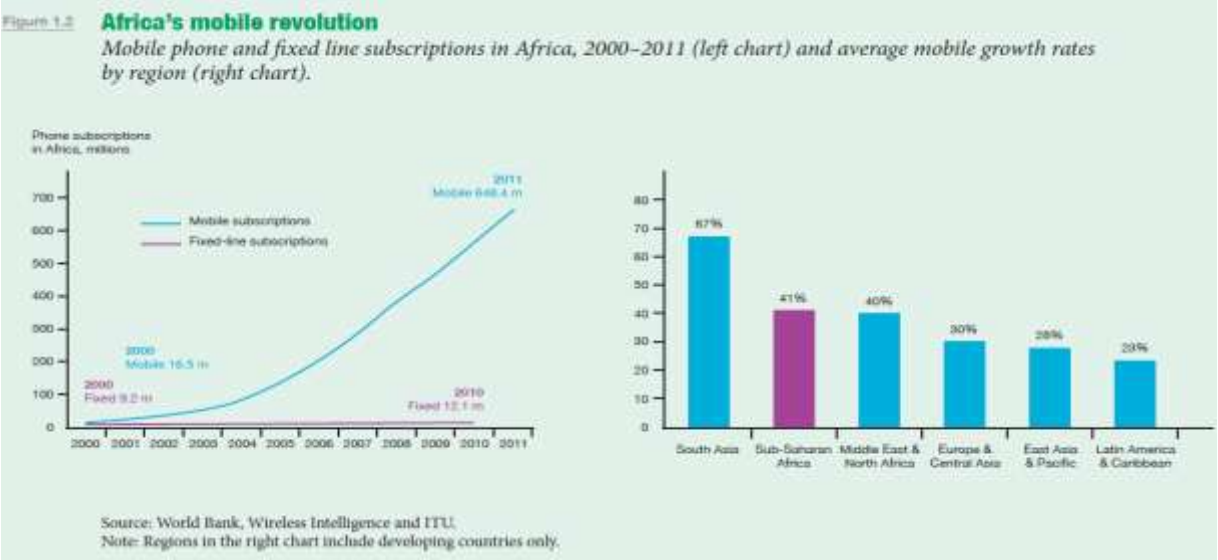

Figure 2. Exponential growth of Africa's mobile phone subscribers data

METHODS

This study is exploratory in nature. We reviewed relevant articles and resources from pertinent sources. We first searched AGRICOLA, web of science (WOS) and Science Direct databases using different combinations of terms/phrases: Agriculture, Africa, knowledge - diffusion, transfer, innovation, exchange; translational research, and extension service. In addition, Websites and resources from appropriate regional and international organizations such as Forum for Agricultural Research in Africa (FARA), Consultative Group on International Agricultural Research (CGIAR), Food and Agricultural Organization (FAO), West Africa Centre for Crop Improvement (WACCI), Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), Alliance for a Green Revolution in Africa (AGRA), and African Union–New Partnerships for Africa's Development (AU–NEPAD)'s Comprehensive Africa Agriculture Development Program (CAADP) were consulted.

As shown in the related works section above, the extant literature is synthesized and categorized into the following areas to help answer the questions put forward in the Introduction: (1) scientific knowledge diffusion, exchange, transfer, innovation adoption – in agriculture in Africa; (2) extension service in SSA countries; and (3) translation research, and (4) ICT use for agriculture in Africa. From the outset, we set out to explore the potential of translational research to bolster knowledge exchange and knowledge diffusion in agricultural practices in Africa as a way to augment existing extension services.

RESULTS AND DISCUSSION

Best Practices for Scientific Knowledge Diffusion– in SSA Agriculture

For the translation and diffusion of scientific knowledge to bear fruit and for it to be effective, first and foremost, seamless partnerships between researchers (and their institutions/organizations) and practice constituencies must be built, implemented, nurtured, evaluated, and improved upon. Our first research question is meant to assess the nature of such partnerships in the agricultural sector in Africa and identify best practices.

It is easier to confuse knowledge - diffusion, - exchange, - transfer, - translation, -synthesis, and - integration. However, a closer look into the relevant literature shows that marked differences exist between these concepts. When we consider models and frameworks that are based on participatory, peer-to-peer, and collaborative communication, knowledge diffusion and/or knowledge exchange is the appropriate strategy to pursue. Even in situations where we want to avoid a linear top-down information flow and embrace feedback in the model, knowledge users are usually providing feedback about the outcome rather than the process (RELU, 2007). This calls for participatory and collaborative knowledge production where both the research and farming communities interact from the start on the planning and priorities of the research process. In addition, effective utilization of knowledge with a view to narrow the gap from knowledge to action requires activities in knowledge synthesis, translation, and integration.

The current understanding and best practices in scientific knowledge diffusion in agricultural practices, therefore, demands a multi-stakeholder, multi-disciplinary, public-private-NGO partnership, and integrated framework (Adekunle et al., 2012; FARA, CGIAR Science Council, 2007). For example, the Integrated Agricultural Research for Development (IAR4D) concept is aggressively promoted by FARA as a multi-stakeholder and multi-disciplinary participatory approach (CGIAR Science Council, 2007). In this regard, there are already several initiatives that have transformed agriculture in SSA. The effort now needs to focus on integrating all national and regional level activities towards a common shared knowledge base in order to develop a better knowledge diffusion approach. At a more general and abstract level, we envision the current understanding of knowledge diffusion as depicted in Figure 3 spanning activities from upstream (R&D) to downstream (application and use) via an intermediary (information system, or extension service) of some kind. In Figure 3, our goal is to show that R&D activities need not be done in isolation but rather with the end-users at the downstream level. Thus, the arrows entering into the R&D and the arrows coming out of the downstream activities are meant to illustrate the cyclical flow of information. It is to be noted that the double-arrowed line at the top shows the bi-directional flow of information/knowledge in the overall continuum of the model.

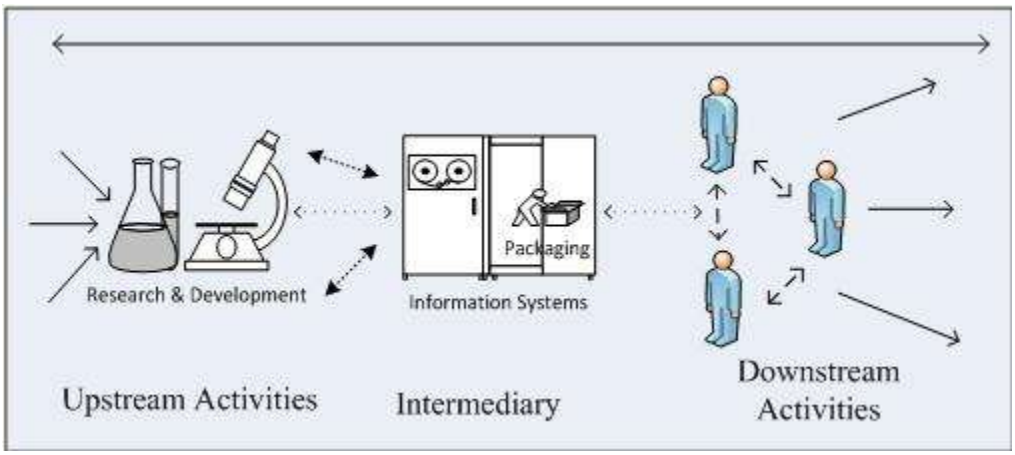

Figure 3. General overview of knowledge diffusion model.

The model is intended to present the results of best practices in scientific knowledge diffusion as reviewed in the extant literature in a form of a diagram, albeit with much of the detail hidden. For example, in the intermediary stage, information systems are used to loosely represent what the extension agent is doing by transferring knowledge and new ideas from the R&D community to the farming community. At the intermediary level, what SSA countries need is a network of national and regional knowledge exchange systems that offer a platform to deposit, manage, package, re-package, mirror, and share new discoveries, insights, and innovations across the agriculture value chain. We present a more specific and detailed model in the discussion section below.

Extension Service in SSA Agriculture

As noted in the literature review, the extension model in SSA is predominantly linear, hierarchical, centralized, poorly funded, and government led. The problem with the existing extension model is widely documented (Bembridge, 1987; Linder & Dolly, 2012; Marsh, Pannell, & Lindner, 2004) and at the same time what needs to be done to overcome the bottlenecks were also suggested (DFID, 2013; Linder & Dolly, 2012). What was attempted under the Research in Use (RIU) program in the six participating African countries was a good example of success in knowledge re-use and knowledge diffusion. The results of 11 years of research work on a whole host of programs on Renewable Natural Resources (RNRRS) was implemented to benefit select African countries. Instead of embarking on new initiatives, the RIU African countries program were given the opportunity to uptake already tested ideas through which countries showed marked success.

We observe that there are a multitude of initiatives and practices that are happening in SSA countries. In the RIU report (DFID, 2013), we find established practices such as – farm input promotions (Africa); Learning, Innovation, Knowledge (LINK); national innovation council; partnership for agricultural innovation and development (Sierra Leone); national agricultural

research system (Nigeria); crop intensification program (Rwanda); and many more. While all these initiatives are very encouraging, it is now time to move towards integration of efforts at national and regional levels. We argue that integration is a necessary condition for knowledge diffusion

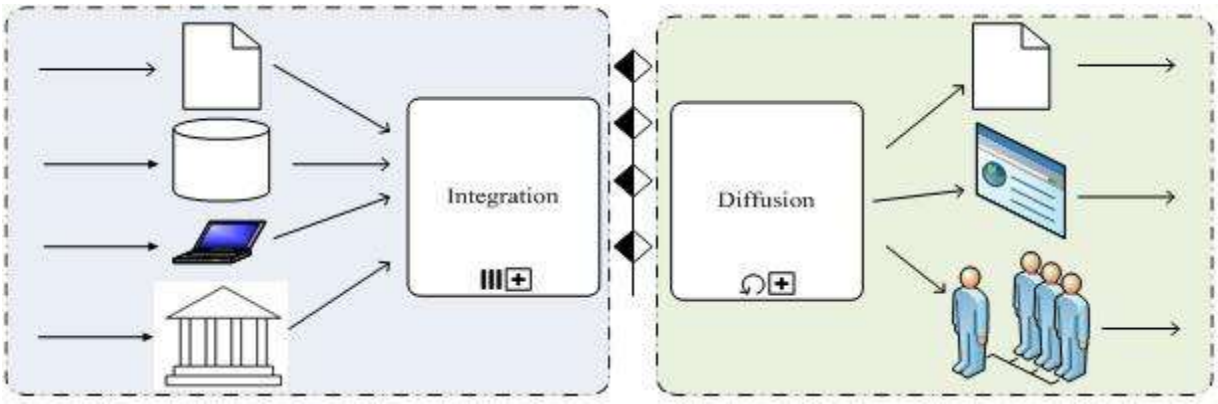

Figure 4. Knowledge integration and diffusion model.

In general the major findings in extension service related to pertinent contemporary understanding include the following:

- Instead of the public and government controlled extension services, the national innovation systems approach is gaining more foothold (Adekunle et al., 2012; Ayele et al., 2012; Hall, 2005; Johnson & Segura-Bonilla, 2001; Ponniah et al., 2008).
- The significance of public private partnerships, integrated knowledge exchanges that engage multi-stakeholder and multi-disciplinary actors are emphasized across the board (Marsh et al., 2000; Delmer, 2005).
- Training and visit (T&V), farm field schools (FFS) focused on training, mentoring, and education are preferred methods of contacts to reach farmers (Blanckenburg, 1982; Davis, 2008; Manning, 2013).
- Extension needs to be designed with the farmer but not for the farmer – requiring participation in both research and extension, including the use of technological solutions (Bembridge, 1987; Blanckenburg, 1982).
- When national and regional level knowledge networks and extension services are built - country, culture and politics-specific situational factors need to be taken into account. (Davis, 2008; DFID, 2012; Linder & Dolly, 2012; Ponniah et al., 2008).
- Extension agents/professionals are considered knowledge brokers, linking farmers and researchers and when designed properly extension services played a positive role (Marsh et al, 2000; Marsh et al., 2004; RELU, 2007).
- Educational function of the extension service should be given more priority (Blanckenburg , 1982; Navarro, 2006).
- One-on-one consultation, coaching, group advice, peer-to-peer learning, face-to-face extension, learning networks, and the use of community radio are found to be relevant

and appropriate methods of contacts (Lwoga, 2010; RAND Corporation, 2011; Riddell, 2001; Scarborough et al., 1997; Topping, 2005).

Translational Research

As noted above, the goal of this paper was to investigate the existing knowledge diffusion model with a view to address its inherent limitations by augmenting it from lessons in translational research in healthcare. There were few studies, especially in biotechnology, genomics, and plant biology that looked into the role of translational science for agriculture (Delmer, 2005; RAND Corporation, 2011; Reynolds & Tuberosa, 2008). The relevance of incorporating translational research in the overall knowledge diffusion activity in agriculture can be seen from the perspective of bridging the gap and speeding the diffusion, use, and impact of scientific knowledge in the entire agricultural value chain. The gulf between what is known in the research labs and what is actually practiced in the field is one reason that gave rise to translational research in medicine. For example, Delmer's (2005) testimony from her personal experience in academia and food security at the Rockefeller Foundation is quite telling: " …there exists a high degree of disconnect between those who work at the lab bench and those who work in the field."

Translational research in healthcare offers significant insights into agricultural practices in various ways: (1) offers a methodological approach to translate knowledge and findings from research to application so it can be readily used by the intended audience, the end-users, (2) offers an awareness across the agricultural value chain on how to package and re-package knowledge, and (3) offers an opportunity for training in translational research methods for agricultural scientists and extension agents (CIHR, 2004; Davis, Jadad, & Perrier , 2003; RAND Corporation, 2011). Driven by evidence-based medicine practices, translational research has given healthcare professionals tools to synthesize knowledge gained through research in order to support their intervention with certain degree of confidence. Commonly used synthesized knowledge products in evidence-based medicine include – practice guidelines, systematic reviews, and the tools and methods used to create such resources include meta-analysis, and other quantitative or qualitative studies (Davis, Jadad, & Perrier , 2003; Grol & Grimshaw, 2003).

In order to implement a successful translational program to aid knowledge diffusion in the field of agriculture, it is very critical for us to prepare and create the awareness about translational research across relevant stakeholders. One way this can be affected is by sensitizing the whole range of scientists (new to experienced) on the principles and methods of translational research. Technical schools, universities, and research centers, NGOs, government agriculture departments/ministries, and the entire value-chain system should work towards a goal of achieving translational research. In healthcare where translational research is widely used, training on tools such as meta-analysis and systematic reviews are regularly offered. Researchers and scientists are expected to disseminate their knowledge outputs in prescribed outlines and

deposit their work in openly accessible repository systems. For example in a typical systematic review, the **ABSTRACT** section alone is divided into the following outlines - Background, Objectives, Search methods, Selection criteria, Data collection and analysis, Main results, Author's conclusion. This structure helps to later perform statistical analysis on a body of work in similar topics to understand the evidence better, on aggregate.

ICT and Knowledge Diffusion in African Agriculture

Africa, especially sub Saharan Africa is leapfrogging to embrace advances in information and communication technology. With about 650 million subscribers, SSA is registering the second highest growth globally in mobile phone use, exceeded only by south Asia. By September 2011, Africa had already rolled out some 676,739 km of fibre-optic backbone infrastructure under sea and inland in an effort to connect the entire continent (World Bank & African Development Bank, 2012, p.27). National level innovation councils were established that spearhead new ICT applications in climate change, crop insurance, market information, etc. More and more national, regional, and international funding agencies are creating opportunities for SSA countries to take advantage of the ICT revolution. There is no doubt the literature is indicative of the potential of ICT for development activities, including agriculture. Given the high adult illiteracy rate and shortage of electricity, we believe community information centers tied to the agriculture extension service model would be an appropriate solution. In the effort we are proposing in this paper to build a national and regional network of agricultural knowledge clearinghouses, ICT will definitely play a significant role to connect and exchange information between and among these independent systems. It is fitting to restate RAND Corporation's (2011) three key findings that were considered as barriers to the implementation of translational research and knowledge exchange in agriculture: (1) lack of synthesis and useful information, (2) communication challenges, and (3) fragmentation of different types of actors across the value chain (RAND Corporation, 2011).

Overall, the most frequently recurring themes in the extant literature that received repeated mention and that have relevance to effective diffusion and utilization of research knowledge are: (1) engage knowledge users in prioritization, definition, interpretation, and application of research (105; 106); (2) the significance of starting with indigenous knowledge, (3) the critical role of packaging and re-packaging new ideas, findings, and innovation to produce readily-usable guidelines and manuals (knowledge synthesis), (4) the need for national and regional integrated knowledge networks, innovation platforms, (5) continuous professional development of the extension agent and re-conceptualizing their role as effective knowledge brokers, (6) taking advantage of the existing relevant and appropriate information and communication technologies, including mobile and social communication tools, (7) the need to create lean and robust communication infrastructure that serves both vertical and horizontal interactions. In addition, we add to the above synthesis (often overlapping) Linder and Dolly's (2012) ten ideas to create effective extension and outreach services in developing countries. We propose the

revitalization of existing extension and knowledge diffusion model by incorporating knowledge integration and translation at its core. Using business processing modeling notation (as in the other models above), we offer the following detailed framework that incorporates the results of our exploratory investigation thus far.

In the model (Figure 5) we use what is called swim lane diagrams (or cross-functional flowcharts) to show the actors, roles, activities, and interactions within and between the lanes. There are three pools – one for each of the major entities viz. upstream activities, intermediary system, and downstream activities. Within each pool, there are two lanes representing the functions of the major actors in each. For example, upstream activities have 'public-private partnership' and 'Research and Development' lanes. Within each lane, what is shown is a start event (the small blue circle) and series of activities/tasks (represented by the squares) to be executed by the designated actor/entity at the top. The activities/tasks boxes have additional icons to signify the task types (user, service, script, send, receive, and reference). For example, the person icon is for 'user,' the gear icon is for 'service,' etc. Also, some of the boxes have a round pointing arrow to represent a standard loop where the particular task can be executed repeatedly, and the three vertical bars indicate a task that is multiple instances of a loop. While the solid arrow connectors represent sequence flow within each pool, the dashed connectors between pools are meant to indicate message flow. Models or frameworks (no matter how detailed they may be) always tend to abstract the complex reality. However, given the discussion above, we believe the basic architecture provided in the model below captures the idea of participatory, integrated, knowledge diffusion where knowledge translation and synthesis is at its core. Because of this, we believe the idea of 'agricultural knowledge clearinghouse (AKC),' at national and regional level is an idea that is worth considering.

For the initial implementation, it can be realistically assumed to build one regional agricultural knowledge clearinghouse. As shown in the framework (Figure 5), the major activities of the AKC involve knowledge work - including evaluating and managing existing knowledge; synthesizing knowledge to create ready-to-use knowledge packages, storing and sharing these resources with other regional clearinghouses. Following knowledge products from evidence-based healthcare such as clinical practice guidelines (CPG), systematic reviews, we propose the following knowledge products to come out of the AKC activities:

- Agricultural practice guidelines – e.g., for specific crop or for specific input.
- Farming factsheet – e.g., for pesticide or spray application.
- Expert panel reports – e.g., no-till or tillage.
- Systematic reviews – e.g., literature review of genetically engineered crops.
- Extension demonstration/experiment registries together with the results – e.g., reports from field experiments, tests.
- Systematic documentation of indigenous knowledge – e.g., externalizing or documenting local knowledge.

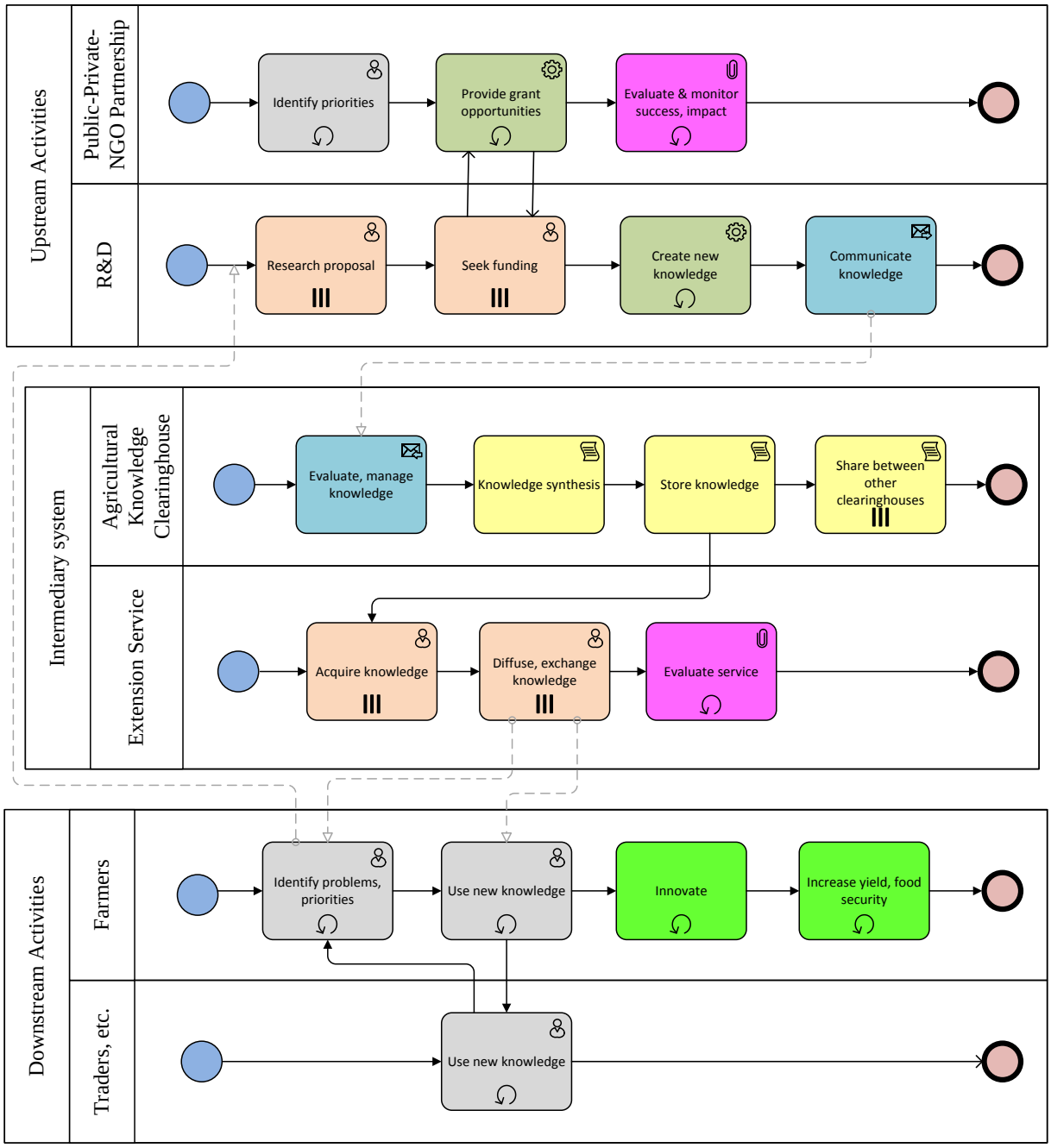

Figure 5. Detailed framework of knowledge diffusion in African agriculture.

CONCLUSION

It is true that tremendous advances have been made in the agriculture sector – spanning crop, livestock, dairy, fruit, vegetable, and organic farming. As a result, knowledge (both indigenous and scientific) is stored in knowledge bases globally. We argue that the most important task is not to re-create new knowledge, but to acquire and effectively use existing knowledge to fuel further knowledge creation and spur more innovation. Because of this view and based on what

the literature in the field shows, we believe translational research will play a role in strengthening traditional extension service in the effort to disseminate refined, synthesized, and ready to use knowledge in the hands of the farmer. This not only helps to streamline and standardize processes and agricultural practices, it also repositions the role of the extension agent as an effective knowledge broker, thereby creating trust and long-term sustainability. As indicated above, knowledge translation speeds the knowledge to action/decision gap. In healthcare, where knowledge translation is very active, the knowledge to evidence-based gap is characterized by sub-optimal usage of evidence between what we know and what is done in practice (Davis et al., 2003).

In summary, we believe more effort needs to be expended towards creating national and regional level "agricultural knowledge clearinghouses," where knowledge synthesis and knowledge translation of existing stock of knowledge form the core of the activities. These clearinghouses can be nested under the current national level innovation councils or knowledge networks that SSA countries are building or have built and may not require much investment other than having designated personnel (research scientist or extension agent) with a translational research background. Another important element to consider is to establish a robust network between national level and regional level clearinghouses as well as between one region (east, west, south, and central) and all the other regions. This is critical to mirror the knowledge repository between one another and avoid duplication of effort.

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