S.Afr. Tydskr. Landbouvoorl./S. Afr. J. Agric. Ext., Abdu-Raheem & Worth
Vol. 41 2013: 1 – 15
ISSN 0301-603X (Copyright)

FOOD SECURITY AND BIODIVERSITY CONSERVATION IN THE CONTEXT OF SUSTAINABLE AGRICULTURE: THE ROLE OF AGRICULTURAL EXTENSION

Abdu-Raheem, K. A.[1] & Worth, S. H.[2]

ABSTRACT

Accomplishing household food security simultaneously with biodiversity conservation, particularly on communal farm lands, constitutes a great challenge in South Africa. This is because biodiversity species are being threatened on lands wherein agricultural production is done in the name of securing food availability. The general threats to biodiversity are in the forms of deforestation and habitat fragmentation, encroachment, pollution, invasion of alien species, wild fires, logging, and hunting. Over time, agriculture emerges the greatest threat to biodiversity. Using this framework, this paper presents a scientific argument, backed with empirical evidences, by exploring the role that agricultural extension can play to realise the goals of biodiversity conservation on South African communal and farm lands. Drawing on relevant published works, this paper argues that extension is particularly well positioned to address both food security and biodiversity conservation concerns through the instruments of linkages, local knowledge facilitation, social capital and education.

Keywords: Agricultural extension, Biodiversity conservation, Food security, Sustainable agriculture

1. INTRODUCTION

Reducing the threats of eradication of about a quarter of the total world's wild species and obliteration of important agro-biodiversity, while simultaneously seeking solutions to the plights of some 800 million and 1.2 billion people, respectively, suffering from under-nourishment and living in abject poverty, presents a difficult and overwhelming task (McNeely & Sherr, 2002). Environmental sustainability and food security are both parts of the Millennium Development Goals (MDGs) which must be achieved concurrently. Food and nutrition securities feature in Target 2 of Goal 1 which seeks to "halve the proportion of people who suffer from hunger", while biodiversity conservation features as Target 7 which seeks to "ensure environmental sustainability" (United Nations Development Programme, 2006: 4). Alleviating worldwide food insecurity without compromising natural biodiversity resources remains an elusive objective wherein further research is needed.

The fact that the extremely poor and food-insecure populations reside in countries with the largest biodiversity resources (World Summit on Sustainable Development, 2002; United Nations Division for Sustainable Development, 1992) suggests that efforts towards solving the problems of food security and biodiversity conservation should not be in isolation from each other. The Food and Agricultural Organisation (FAO) and the International Plant Genetic Resources Institute (IPGRI) are two international institutions immensely contributing to research works geared towards achieving both objectives concurrently. They have initiated a concept of biodiversity for food and nutrition in order to design and implement plans of action relating to food and nutrition securities while simultaneously encouraging the

[1] PhD Student at the University of KwaZulu-Natal (author of correspondence) and Lecturer, Department of Agricultural Economics and Extension Services, Ekiti State University, Nigeria. This article is part of the author's PhD Thesis.
[2] Supervisor, Senior Lecturer, Agricultural Extension and Rural Resource Management, University of KwaZulu-Natal.

sustainable use of biodiversity resources. Through this, they highlight the importance of biodiversity and the role it has to play in achieving sustainable development (Esquinas-Alcazar, 2005).

While food security is an issue of concern in all developing countries, it is of particular concern in Africa where food insecurity is severe. One major underlining factor severally reported in literature as warranting this is that the per capita food production in Africa grows at a declining rate; it is not keeping pace with population growth. In other developing countries food production is keeping pace with population growth (FAO, 1996). In South Africa, food security can be viewed in two levels: 'national food security' and 'household food security'. As a nation, according to National Food Security indicators, South Africa is food secure. In fact, South Africa has been food secured nationally for more than twenty years and is even an exporter of some foods. It excels in the production of some varieties of agricultural food products like maize and potatoes and it imports products which it lacks or produces inadequately; all contributing to meeting its national food requirements (Hirschowitz, 2000).

At the household level however, South Africa is not universally food secure; with some 14.3 million South Africans (about 35% of the total population) experiencing food insecurity (Hirschowitz, 2000). Many of these people are largely dependent on the natural resources available to them for their livelihoods. These resources are often used unsustainably. And it is in this context that the South African government has expressed its desire to ensure that food security is achieved at the household level (Altman, Hart and Jacobs; 2009) concomitantly with its conservation objectives (Botha, 2004).

South Africa is blessed in terms of biodiversity wealth. It is recognized as one of the 17 "mega diversity" nations of the world. Although South Africa covers 2% of the total world's land area, it is a home to not less than 10% of the total world's plants and 7% each of the mammals, reptiles and birds. While South Africa has several protected areas covering approximately 6% of the national territory, these protected areas do not give adequate representation of the full range of the biodiversity types that demand conservation. For example, out of 441 vegetation types found in the country, 110 are not protected at all. In addition, for 90 vegetation types, less than 5% of the area they cover is protected, and for more than 300 vegetation types less than half the area they cover is protected within statutory protected areas (Botha, 2004).

In the light of the food and conservation needs of South Africa outlined so far, there is an urgent need to explore solutions to fulfilling both objectives simultaneously. This paper is thus aimed at identifying possible contributions that agricultural extension could make to achieve this dual objective.

2. AGRICULTURAL BIODIVERSITY: THE LINK BETWEEN BIODIVERSITY AND FOOD SECURITY

That South Africa is a mega-diversity nation (Botha, 2004) with agricultural production constituting 50% of the source of threats to its biodiversity (Biggs, Reyers and Scholes, 2006), highlights the inextricable link between realizing food security and biodiversity conservation within the country. Biodiversity implies the disparity among genes, species and ecosystems, and variation in organization, role and composition at each of these cadres (Biggs, *et al.,* 2006 citing Noss, 1990). Food security, on the other hand, refers to "a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 2010:8).

The two objectives overlap in the concept of "agricultural biodiversity". Agricultural biodiversity – henceforth referred to as 'agro-biodiversity'– encompasses the variety and variability of animals, plants and micro-organisms which are necessary for sustaining key functions of the agro-ecosystem, its structure and processes that are associated with food production and food security (FAO, 1999). Wild biodiversity, which is equally exploited for variety of uses by man, is the variety and variability of non-domesticated plant and animal species (McNeely & Scherr, 2003), and the ecosystems comprising these species (Dollacker and Rhodes, 2007). This indicates that biodiversity, both agro and wild, supplies the food we consume and the means to produce it. It is the conglomerate of the different components of this biodiversity wealth that are becoming extinct, thereby creating food shortages in the world.

It is posited that achieving food security is hardly realistic in the context of the unprecedented rate at which the agro-biodiversity resources are being lost. Pimm and Raven (2000) note that between 10000 and 10 million species become extinct globally each decade. They further warn that up to 40% of biodiversity species in Myer's 25 hotspots could disappear if deforestation continues at the present rate. The International Union for Conservation of Nature (IUCN) (2007) also indicates that 31%, 12% and 20% respectively of amphibian, bird and mammal species, are currently facing extinction; while plant species are simultaneously undergoing rapid disappearance in Central and West Africa, Central and South America, and Southeast Asia. Similarly, Hughes, Byrnes, Kirnbro & Stachowicz (2007) forecast that between 0.1% and 0.3% (14,000 to 40,000) of tropical forest species become extinct every year. Furthermore, BirdLife International (2000) also envisages that 13% of the global bird species, 99% of which would be as a result of hunting and deforestation, would disappear within a century.

In the context of South Africa as well, the impact on biodiversity sustainability of wild biodiversity removal and trade is considerable (Shackleton, 2009). Millions of household rely on biodiversity for medicinal and cultural purposes (Shackleton, 2005), fuel wood (Twine, Moshe, Netshiluvhi & Siphugu, 2003), foods (Clark, Hauck, Harris, Salo & Russell, 2002; UNDP, 2006), veterinary medicine (Dold & Cocks, 2001) and for general livelihood (Shackleton & Shackleton, 2004). The pressure biodiversity faces in South Africa coupled with the world-wide threats to biodiversity forewarns of a serious decline in biodiversity and highlights the enormity of the challenge ahead if achieving food security at the grass root, both globally and nationally, is to be realized.

Apart from the fact that human existence depends on food derivable from biodiversity, it is important to note that biodiversity resources also serve a source of numerous raw materials which enhance survival and development of the human world. Such materials include fibre for clothing, materials for fuel, medicine, transportation, fertilizer, shelter, to mention only a few (Shand, 1997). Notwithstanding these physical benefits, biodiversity also serves as the centre-piece upon which the smooth functioning of the planet earth depends. This is implied in essential role in maintaining balances in atmospheric gases and generation of oxygen, regularization of climatic conditions, maintenance of regular supply and quality of water, pollination, regularization and protection of top soil, conversion of solar energy to planet matter, decomposition of organic materials and nutrients recycling, and curbing outbreaks of pests and diseases (Hooper, Chapin, Ewel, Hector, Inchausti, Lavorel, Lawton, Lodge, Loreau, Naeem, Schmid, Seta, Symstad, Vandermeer & Wardle, 2005).

3. FOOD SECURITY AND SUSTAINABILITY: THE NEED TO CLARIFY THE GOAL

As more efforts need to be geared towards abating the ever-increasing challenge of global food insecurity particularly at the household level, greater attention and focus should be directed towards sustainability (FAO, 2009). Globally, sufficient food is produced to make it possible to achieve food security (Islam, 1995; FAO, 2002: 9), but the number of the undernourished has risen from about 840 million in 1996 (FAO, 1996) to about 925 million in 2010 (FAO, 2010). The World Bank (2011) indicates that due to food price increases in 2011, an additional 44 million people have fallen below the poverty line of USD1, 25 per person per day. The global maize price increased by 17% in the first quarter of 2011 as compared to the last quarter of 2010, with the impact more felt and localized in the Sub-Saharan Africa (World Bank, 2011).

The increase in food prices is attributed to the recent increase in the prices of crude oil by 10% in March, 2011 (WBFPW, 2011). The WBFPW also noted that the increase in crude oil prices impacts on food prices in three ways: increased promotion for the use of food products like corn, vegetable oil and sugar for biofuels production (which creates greater competition for food); increased cost of food production based on higher prices of fertilizer, irrigation and other farm inputs; and increased cost of crop transportation to destination markets.

The FAO (2010) argues that the second of the factors identified by the WBFPW (the cost of food production) is directly related to the current extensive agricultural practices which rely on external inputs. The FAO further argues that this extensive farming systems need to be substituted by a low external input production system (FAO, 2010). The external inputs pose great threats to biodiversity and essential ecosystem services (MEA, 2005). Nellemann (2009) indicates that unless and until sustainable agricultural practices are adopted widely, food prices will continue to soar high. Thus it can be argued that the extensive system contributes to maintaining persistent unsustainable production of food and the consequent food security crisis.

The depletion effect on significant biodiversity of most agricultural production systems currently in use have left major agricultural lands impoverished and at the mercy of perpetual use of external inputs for appreciable production. If this trend continues, about 1 billion hectares of natural ecosystems would have to be converted for agricultural uses (FAO, 2010). Tilman, Fargione, Wolff, D' Antonio, Dobson, Howarth, Schindler, Schlesinger, Simberloff & Swachhamer (2001) add that this will amount to between 2.4 and 2.7-fold increase in eutrophication of fresh water, terrestrial and near-shore marine ecosystems and increased uses of nitrogen and phosphorus. However, as a note of caution on the current rate of phosphorus' usage, Vaccary (2009) warns that phosphorus will be a limiting factor to agricultural production by the end of this century, as Vaccary suggests, the present stock of phosphorus is nearing exhaustion.

Many management practices have been developed and identified as ways forward from the *status quo*. These include integrated pest management, improved soil and water management, eco-agriculture, conservation agriculture, and organic agriculture (FAO, 2010). All these practices are intended towards enhancing biological processes such as nutrient cycling, pest control, pollination, carbon sequestration (Power, 2010), and involve increased but more efficient use of biodiversity for food and agriculture (FAO, 2010).

4. FARMERS: BEDROCK TO CONCURRENT ACHIEVEMENT OF BIODIVERSITY CONSERVATION AND FOOD SECURITY

Developing an efficient agricultural system that embodies natural resource sustainability concurrently with food security solutions, requires holistic, interdisciplinary, ecosystem and biologically-based interventions; and this should necessarily consider the social, economic, and cultural aspects of agriculture (Millenium Ecosystem Assessment (MEA), 2005; IAASTD, 2008). In addition, such an agricultural system needs to recognize the multifunctional role of agriculture, the broad-range services including provisioning, regulating, supporting, and socio-cultural services supplied by agro-biodiversity, and the importance of smallholder farmers as one of the major stakeholders that could bring about the desired change (FAO, 2010).

About 50% of rural populations in developing countries are smallholder farmers (United Nations Conference on Trade and Development - UNCTAD, 2010) while another 20% are landless (FAO, 2010). These farmers engage in different forms of agricultural production ranging from pastoralism, aquaculture and artisanal fishing (FAO, 2010). Morton (2007) indicates that the farming systems used by smallholder farmers are often complex and diverse which may even assist them to cope better with risks. These smallholder farmers, as may be deduced, play vital roles in the management of vast agricultural landscapes in the developing nations and are, therefore, central to the management of the biodiversity resources of these countries. Thus, it is suggested that improvement in farming systems needs to be relevant to the context of these smallholder farmers if significant progress is to be achieved in terms of reducing the number of the food-insecure while saving biodiversity from extinction.

Shand (1997) indicated that the hunt for a long-lasting food security measures has to begin with the regions where diversified food materials are produced and with the people behind the production, as they are best suited to innovating new technologies and farming systems that best suit their varied biological environments. Shand furthermore notes that, instead of accentuating external technologies and other production inputs, sustainable food security for the globe is better achieved by improving on the local knowledge, resources and strength of the rural farming communities. In the light of this logical reasoning, attention to the needs and enhancement of the capabilities of the major stakeholders that are in charge of conservation and exploitation of agro biodiversity resources, the rural farmers, should constitute the focus of all agricultural policies being created to tackle the current state of world's food insecurity.

5. HOW CAN AGRICULTURAL EXTENSION CONTRIBUTE IN THIS CHALLENGE?

As South Africa sets out to combat degradation and unsustainable exploitation of its biodiversity species in the context of enhancing food security at household level, agricultural extension emerges a potentially influential tool to achieve this. This is evidenced through the skills and approaches that extension possesses, and which it can use to create and facilitate necessary instruments of change as may be required by sustainable agricultural practices.

Understanding the general objectives and approaches of agricultural extension will better shed light on the role that extension can play in addressing South African biodiversity conservation and household food security concerns. Swanson (2009) identified four categories or models of agricultural extension: technology transfer; advisory services; non-formal education; and facilitation extension. Groot and Roling (1998) described a similar range of extension approaches. Worth (2006) suggests a fifth approach: facilitated learning. Table 1 provides a brief comparison of four of these approaches using eight critical factors: purpose, assumptions, source of innovation, promoter's role, farmers' role, supply/demand, orientation and target.

Table 1: Comparison of Extension Approaches

Characteristics	EXTENSION MODELS/APPROACHES			
	Linear	Advisory	Facilitation	Learning
Purpose	Production increase through transfer of technology Government policy	Holistic approach to farm entrepreneurship	Empowerment and ownership	Awakening desire and building skills in learning for advancement as jointly defined by partners
Source of Innovation	Outside innovations	Outside innovations and by farm manager	Local knowledge and innovations	Synergistic partnership of farmers, researchers and extension
Promoter's Role	Extending knowledge	Providing advice	Facilitating	Promoting learning skills and facilitating partnerships for learning
Farmer's Role	Passive: others know what is best Adopting recommended technologies	Active: problem solving Asking for advice Taking management decisions	Active: problem solving; owns the process Learning by doing Farmer-to-farmer learning	Considering all possibilities Contributing to own and others' learning; partner in learning
Assumptions	Research corresponds to farmer's problem	Farmer knows what advisory services he needs	Farmer willing to learn to interact and to take ownership	Farmer less powerful in learning relationship; needs support in developing desire and skill to learn
Supply/ Demand	Supply	Demand	Demand	Supply to evoke dynamic relationship of supply and demand
Orientation	Technology	Client	Process	Client and process and 'right' placement of technology
'Target'	Individuals Farmer organisations Projects	Individuals Groups with common problems	Groups and organisations, interaction of stakeholders, networking	Farmers in context of a learning partnership Others in partnership in context of facilitated learning

Derived from Blum, 2007 and Worth, 2006; and adapted by Abdu-Raheem and Worth, 2011

Figure 1 shows the intervention instruments available to agricultural extension to achieve biodiversity conservation in the context of promoting food security, through sustainable agricultural production and management. The key instruments are linkages, local knowledge facilitation, social capital and education.

5.1 Linkages

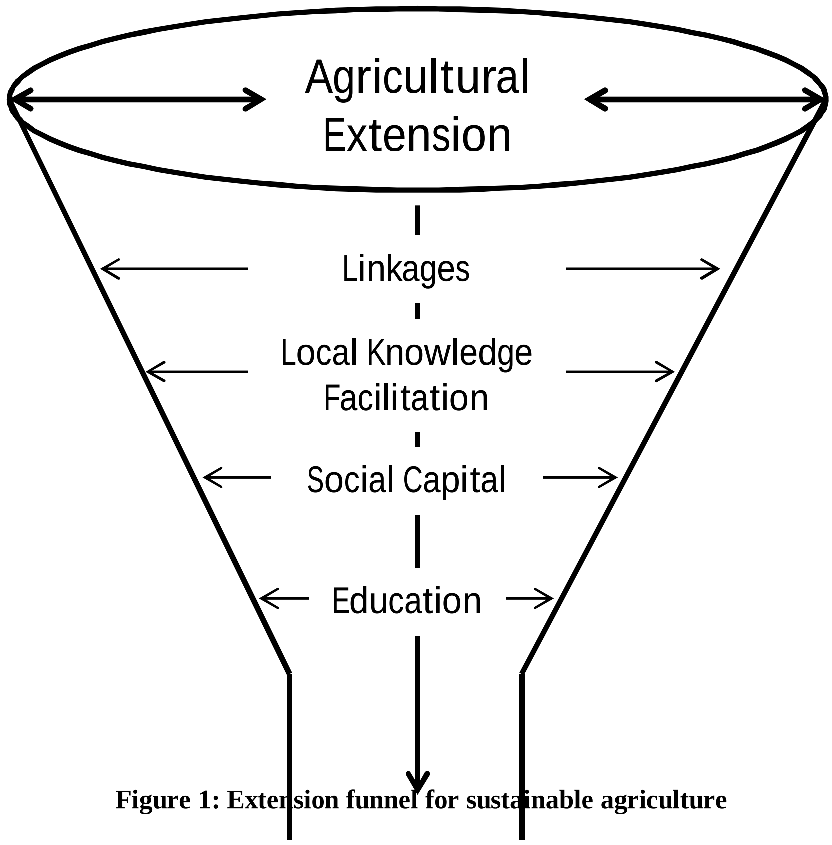

Figure 1: Extension funnel for sustainable agriculture

As indicated in Figure 1, the first instrument available to extension to enhance promotion and adoption of sustainable agriculture among rural landholders is 'linkages'. This indicates that extension can assist rural landholders to set up a two-way relationship with biodiversity conservation institutes, in order to facilitate free flow of information between both parties. Swanson (2006) indicates that 'linkages' has an association with building social capital. This is because all parties involved combine efforts towards achieving a common goal. Putnam (2000) however suggests terminologies like "bonding" and "bridging" in the description of possible linkages that extension may build for success to be achieved by farmers in any innovation adoption exercise. "Bonding", the creation of a network of people that aim at achieving a common goal, relates to the creation of partnerships between landholders and different groups within the community so that all relevant stakeholders are purposefully engaged in achieving their common goal. For example, rural landholders can be linked with other rural groups like marketing, credit and consumer groups to facilitate participation in the different stages of food supply chain, thereby resulting in synergy where they derive greater strength from working together than they would by working individually.
"Bridging", entails linkages created by extension between rural landholders and external organizations in order that problem identification and solution seeking efforts will not be

pursued in isolation from each other. For example, suppliers of sustainable agriculture inputs can be linked (bridged) with rural farmers so that access to such inputs by farmers is facilitated. These linkages will help farmers receive advice that is relevant to their local conditions, secure favourable deals with both the input and output markets, and be better placed to adopt new technology of minimum disturbance to biodiversity. Swanson (2006:12) indicates that extension is well positioned to assist farmers with establishing relationships with relevant and important groups. He suggests four ways through which this responsibility is better achieved, namely: "helping farmers get organised"; "determining their interests based on accessible market opportunities"; "training these groups in how to produce specific crops/products" and "working with them to develop supply chains in marketing their products".

5.2 Local knowledge facilitation

Also indicated in Figure 1 is 'local knowledge facilitation' as one of the viable tools available to extension to facilitate adoption of sustainable agricultural systems by rural farmers. Stanley, Clouston and Baker (undated) indicate that landholders often do not share the same views with scientists who propose land-uses on the basis of scientific researches. They claim that this situation springs up from the experiences of landholders that often go in contradiction to scientific claims over time. Supporting this view is the submission by Richards, Lawrence and Kelly (2003) which indicates that landholders' strong attachment to local knowledge and experiences affects their decisions relative to adopting new scientific innovations. With this in view, extension practitioners seriously need to acknowledge local knowledge and put it into perspectives when finding solutions to some of the problems that landholders experience on their farms.

Stanley, Clouston and Baker (undated, quoting Khanna, 2001) also argue that inadequate knowledge of the derivable benefits from a particular innovation has a strong correlation with non-adoption of such technology by landholders. Therefore, extension practitioners need to seek suitable media that can adequately facilitate the exchange and collaborative sharing of knowledge and skills between landholders and scientists. Seeking improved media for knowledge sharing may also help solve the challenge of inaccessibility identified by Byron, Curtis and MacKay (2004) that landholders face relative to professional advice on new technologies. Furthermore, Byron, Curtis and MacKay indicate that inaccessibility challenge constitutes a major constraint towards changing land management practices by landholders. While some resistance may ensue from landholders towards new technologies on the basis of inadequate knowledge (Stanley, Clouston & Baker, undated, citing Khanna, 2001), Pannell, Marshall, Barr, Curtis, Vanclay and Wilkinson (2006) note that landholders' confidence and possibility of adoption of new technology increase with increased knowledge and experience. Thus in order to significantly improve receptivity to new technologies by landholders, extension practitioners will have to provide access to dependable, practical and understandable information to landholders (Lockie and Rockloff, 2004).

This is not to suggest that knowledge sharing should only be one-sided, that is from researchers to landholders. Rather, there should be collaboration between both groups wherein the different skills and knowledge of each group is shared with the other, thereby complimenting one another. Many researchers like Reijntjes and Waters-Bayer (2001), Saad (2002), Hoffmann, Probst and Christinck (2007) have pointed out the importance of local knowledge and the ability and capacity demonstrated by landholders to experiment and innovate successfully on their own. However, Hoffmann, Probst and Christinck (2007) suggest that, the mutual comparative advantages of both farmers and researchers are more optimally harnessed and relevant agricultural knowledge and innovation are more efficiently generated when landowners and researchers collaborate. They further argue that successful collaboration is based on the following principles:

> “there are complementary roles for farmers and researchers in setting research priorities”;
>
> “there is a need for decentralized community-based technology testing that makes use of the farmers’ experimentation and dissemination capacity”;
>
> “formal research should be more open to farmers’ informal experimentation”;
>
> “more attention needs to be paid to the externalization of expert farmers’ tacit knowledge”; and
>
> “opportunity costs should be respected if farmers dedicate time to research”.

5.3 Social capital

Social capital, also indicated in Figure 1, is another instrument that extension can adopt to facilitate promotion and adoption of sustainable agricultural practices among rural landholders. One of the numerous contributions it can make is that different rural groups such as producers, marketing, credit and consumer groups can be convinced to work together and accommodated within the new innovation programme; thereby facilitating the processes involved in all the different phases of production through to selling farm produce. Gray, Phillips & Dunn (2000) indicate that landholders’ decisions on land use has a correlation with the relationships that exist among themselves and the context of the society within which decisions are being taken.

Adoption of new innovations on a large scale within a community has been found out to be greatly dependent on strong social capital (Serageldin and Grootaert, 2000; Pretty & Smith, 2004). Relative to natural resource management, Stanley, Clouston and Baker (undated) indicate that communities exploiting their social capital can contribute physical resources, human resources and information resources towards successful development, adoption and implementation of any innovation that will assist them to generate common benefits from their natural resources. In addition, Ostrom and Ahn (2001) assert that the importance of social capital in solving problems which require collective action, particularly natural resource management, cannot be overemphasised.

Pretty and Ward (2001: 211) identify that social capital comprises of four core aspects: (a) relations of trust, (b) reciprocity and exchanges, (c) common rules, norms, and sanctions, and (d) connectedness in networks and groups. Wu and Pretty (2004) further note that the importance of social capital to innovation is often underestimated. Their research in marginal locations of China, Wu and Pretty demonstrated the importance of social capital to innovation development and adoption by identifying the positive impacts that the various levels of organizational arrangements, ranging from household communication networks, inter-household technology learning groups, and inter-village innovative links have on agricultural and natural resource innovation, which translated to improved rural incomes.

5.4 Education

The last instrument indicated in Figure 1 as being available to extension to influence adoption of sustainable agricultural practices by smallholder farmers is ‘education’. Educational activities can be carried out through different combinations of the numerous extension methods of teaching, ranging from workshops, field trainings, field visits, to demonstrations. Pierotti and Wildcat (2000) note that substantial knowledge of an intervention and literacy affect the readiness of individual landholder to engage in collective action to achieve collective gains. However, Abadi Ghandim and Pannell (1999) note that adoption is achieved through two phases of a learning process. The first entails the collection, integration and evaluation of available information in order to make an informed decision about a new innovation; and the second, borders on improvement in skills of landholders through practice for better adaption of new innovations to their local circumstances.

The first phase indicates that landholders are frequently unsure of the usefulness and benefits embedded in new innovations; hence the explanation behind their reservations towards adoption. With education however, Marra, Pannell & Abadi Ghandim (2003) indicate that farmers’ uncertainties reduce and they become better informed as to what decisions to make on newly introduced innovations. The second phase of the learning process indicates that full adoption of an innovation is often based on a higher degree of knowledge, which is mostly acquired through landholders’ experience when testing adoption on a small scale. This assists landholders to identify the best-suited methodology of application of the innovation in the context of their environment. Reiterating the importance of education on adoption and successful implementation of an innovation, Pretty and Smith (2004) submit that the farmer field schools for rice management that is innovated in Asia, has resulted in substantial reduction in the use of pesticides among farmers. Various researchers such as Pannell, (1999), Barr and Cary (2000), Rogers (2003), and Pannell, Marshall, Barr, Curtis, Vanclay and Wilkinson (2006) have helped to identify the dynamism and stages involved in a learning process that priors adoption of any innovation.

However, an important challenge is that of educating the biodiversity and agricultural researchers to genuinely engage with local knowledge. Norman and Snyman (1996:121) argued that agricultural research has failed in Africa precisely because of the failure of research scientists to understand, relate to and work with African farmers and their particular knowledge set; “...they find themselves not particularly well adapted to the research needs of the African farmer. This stems primarily from (1) the crop-specific or input-specific approaches commonly used by these institutions, (2) poor understanding of the African farmer and his farming practices by research scientists, (3) doubt by Western agricultural research experts whether the complex African farming systems can be transformed for increased food production, and (4) the arrogance and unwillingness of agricultural scientists to learn from the traditional African farmer”. This suggests that research scientists need to understand the dynamics of how things work in a typical rural environment and be ready to acknowledge and build upon local knowledge. It also suggests that experts should adopt a more participatory approach with landholders rather than treating them as mere recipients of externally innovated technology.

6. CONCLUSION

This paper has highlighted various means by which agricultural extension can help address innovation, development, and adoption of sustainable agricultural practices among rural landholders. Its chief instruments of linkages, local knowledge facilitation, social capital and education are effective means of addressing food security challenges simultaneously with biodiversity conservation. The paper acknowledges that while the approach (as depicted in the Extension Funnel) is relatively straightforward, it is a complex process that one should not attempt to over-simplify. It will require deliberate, conscious effort sustained over time. The paper demonstrates that, by focusing on enhancing sustainable agricultural production and management practices, both objectives of food security and conservation of biodiversity can be achieved on rural farm lands. Thus, it is vital that agriculture remains an integral part of any government's strategy to address food insecurity and biodiversity conservation challenges on rural farm lands. Whatever approach or combination of approaches used – technology transfer, advisory, facilitation, or learning – agricultural extension programmes should be re-examined and adjusted so that they are made to contribute to creating and maintaining food security as well as biodiversity conservation on lands beyond the fences of officially designated protected areas.

REFERENCES

ABADIGHANDIM, A. K. & PANNELL, D. J. 1999.A conceptual framework of adoption of agricultural innovation. *Agricultural Economics*, 21: 145-154.

ALTMAN, M; HART, T. G. B & JACOBS, P. T. 2009. Household food security status in South Africa. *Agrecon,* 48 (4): 345-361.

BARR, N. & CARY, J. 2000. Influencing improved natural resource management on farms: a guide to factors influencing the adoption of sustainable natural resource management practices. Bureau of Rural Sciences, Canberra.

BIGGS, R., REYERS, B. & SCHOLES, R. J. 2006. A biodiversity intactness score for South Africa. *South African Journal of Science* 102: 277- 283.

BIRDLIFE INTERNATIONAL. 2000. *Threatened birds of the world*. Barcelona, Spain and Cambridge, UK: Lynx Edicions and BirdLife International.

BOTHA, M. 2004. *Implementing laws for conservation action: Partnerships in the Biodiversity and Protected Areas Acts.* [Online] Available from: http://www.botanicalsociety.org.za/ccu/ downloads/reports/Implementing%20laws%20for%20conservation%20action.doc (Accessed: 14/10/10).

BYRON, I., CURTIS, A. & MACKAY, J. 2004. *Providing social data to underpin catchment planning in the Queensland Murray-Darling region,* Bureau of Rural Sciences, Canberra. [Online] Available from: http://www.affashop.gov.au/product.asp?prodid=13217. (Accessed: 14/10/10).

CLARK, B. M., HAUCK, M., HARRIS, J. M., SALO, K. & RUSSELL, E. 2002. Identification of subsistence fishers, fishing areas, resource use and activities along the South African coast. *South African Journal of Marine Science* 24(1):425 - 437.

DOLD, A. P. & COCKS, M. L. 2001. Traditional veterinary medicine in the Alice district of the Eastern Cape Province, South Africa. *South African Journal of Science,* 97:375-379.

DOLLACKER A. & RHODES, C. 2007. Integrating crop productivity and biodiversity conservation pilot initiatives developed by Bayer Crop Science. *Crop Protect*, 26(3):408–16.

ESQUINAS-ALCAZAR, J. 2005. Science and society: Protecting crop genetic diversity for food security: political, ethical and technical challenges. *Nature Review Genetics* 6:946-953.

FOOD AND AGRICULTURAL ORGANIZATION (FAO). 1996. *World food summit: synthesis of the technical background documents*. Rome: Food and Agriculture Organization of the United Nations.

FAO. 1999. *Multifunctional Character of Agriculture and Land: Conference Background Paper No. 1*, Maastricht Sept.

FAO. 2002. *Reducing Poverty and Hunger, the Critical Role of Financing for Food, Agriculture, and Rural Development*. Rome, Italy.

FAO. 2009. *Declaration of the World Summit on Food, Rome, 16-18 November 2009*. Rome, Italy.

FAO. 2010. Biodiversity for Food and Agriculture: contributing to food security and sustainability in a changing world. Rome, Italy.

FAO. 2010. The State of Food Insecurity in the World: Addressing food insecurity in protracted crises. Rome.

GRAY, I., PHILLIPS, E. & DUNN, T. 2000. Aspects of rural culture and the use of conservation farming, in Shulman, A. and Price, R. (eds) *Case studies in increasing the adoption of sustainable resource management practices*, LWRRDC, Canberra.

HIRSCHOWITZ, R. 2000. Measuring Poverty in South Africa. Pretoria: Statistics South Africa.

HOFFMANN, V., PROBST, K. & CHRISTINCK, A. 2007. Farmers and researchers: how can collaborative advantages be created in participatory research and technology development? *Agr Hum Values*. 24: 355–68.

HOOPER, D. U., CHAPIN, F. S., EWEL, J. J., HECTOR, A., INCHAUSTI, P., LAVOREL, S., LAWTON, J. H., LODGE, D. M., LOREAU, M., NAEEM, S., SCHMID, B. H. SETA, L. A., SYMSTAD, A. J., VANDERMEER, J. H. & WARDLE, D. A. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological Monographs* 75(1): 3–35.

HUGHES, A. R., BYRNES J. E., KIRNBRO D. L. & STACHOWICZ, J. J. 2007.Reciprocal relationships and potential feedbacks between biodiversity and disturbance. *Ecol Lett*, **10**: 849–64.

INTERNATIONAL ASSESSMENT OF AGRICULTURAL KNOWLEDGE, SCIENCE AND TECHNOLOGY FOR DEVELOPMENT (IAASTD). 2008. Agriculture *at a Cross-road. Global Report*. Island Press, Washington, DC, USA.

ISLAM, N. (Ed). 1995. Population and food in the early twenty-first century: meeting future food demands of an increasing population. Intl Food Policy Research Inst. Washington, DC.

IUCN (International Union for Conservation of Nature). 2007. *IUCN red list of threatened species*. Gland, Switzerland: World Conservation Union.

LOCKIE, S. & ROCKLOFF, S. 2004: *Landowner attitudes to wetlands and wetland conservation programs and incentives*, Draft Report for Coastal CRC.

MARRA, M., PANNELL, D. J. & ABADIGHANDIM, A. 2003. The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve? *Agricultural Systems*, 75: 215-234.

MCNEELY, J. A & SCHERR, S. J. 2003. *Ecoagriculture: strategies to feed the world and save wild biodiversity*. Washington, DC: Island Press.

MEA. 2005. Ecosystems and Human Well-being. Millennium Ecosystem Assessment. Island Press, Washington DC, USA.

MORTON, J. F. 2007. The impact of climate change on smallholder and subsistence agriculture. PNAS, 104(50): 19680–19685.

NELLEMANN, C., MACDEVETTE, M., MANDERS, T., EICKHOUT, B., SVIHUS, B., PRINS, A.G. & KALTENBORN, B. P. (Eds). 2009. *The Environmental Food Crisis –*

The Environment's Role in Averting Future Food Crises. A UNEP Rapid Response Assessment. United Nations Environment Programme, GRID-Arendal, Norway.

NORMANN, N. & SNYMAN, I. 1996. *Indigenous knowledge and its uses in southern Africa*. Pretoria: HSRC Press.

OSTROM, E. & AHN, T. 2001. A social science perspective on social capital: social capital and collective action, a paper presented at the *Social capital: interdisciplinary perspectives*, European Research Conference, Exeter, United Kingom, 15-20 September 2001.

PANNEL, D. J. 1999. Social and economic challenges in the development of complex farming systems. *Agroforestry Systems*, 45: 395-409.

PANNELL, D., MARSHALL, G., BARR, N., CURTIS, A., VANCLAY, F. & WILKINSON, R. 2006: Understanding and promoting adoption of conservation practices by rural landholders. *Australian Journal of Experimental Agriculture,* 46: 1407-1424.

PieROTTI, R. & WILDCAT, D. 2000. Traditional ecological knowledge: the third alternative (commentary). *Ecological Applications*, 10: 1333-1340.

PIMM, S. L & RAVE, P. 2000. Extinction by numbers. *Nature*, 403: 843-45.

POWER, A. G. 2010. Ecosystem services and agriculture: tradeoffs and synergies. *Phil. Trans. R. Soc.* 365, 2959-2971.

PRETTY, J. & WARD, H. 2001. Social capital and the environment. *World Development* 29(2): 209–227.

PRETTY, J. & SMITH, D. 2004. Social capital in biodiversity conservation and management, *Conservation Biology*, 18(3):631-638.

PUTNAM, R. D. 2000. *Bowling alone: the collapse and revival of American community*. New York: Simon & Schuster, 541p.

REIJNTJES, C. & A. WATERS-BAYER (Eds.) 2001. *Farmer Innovation in Africa. A source of Inspiration for Agricultural Development*. London, UK: Earthscan Publications.

RICHARDS, C., LAWRENCE, G. & KELLY, N. 2003. *Is it hard to be green when you are in the red? A sociological account of primary production and environmental sustainability,* paper presented to the 'New times, new worlds, new ideas: sociology today and tomorrow', Conference of the Australian Sociological association, University of New England, Armidale, December.

ROGERS, E. M. 2003. *Diffusion of innovations*. 5th edition. Free Press, New York.

SAAD, N. 2002. Farmer processes of experimentation and innovation – A review of literature. Cali, Colombia: Participatory Research and Gender Analysis Program, PRGA Working Document No. 21.

SERAGELDIN, I. & GROOTAERT, C. 2000. Defining social capital: an integrating view. In: Serageldin, I. and Dasgupta, P. (Eds) *Social Capital: a multifaceted perspective,* World Bank, Washington.

SHACKLETON, C. M. & SHACKLETON, S. E. 2004. The importance of non-timber forest products in rural livelihood security and as safety-nets: evidence from South Africa. *South African Journal of Science* 100:658–664.

SHACKLETON, S. 2005. The significance of the local trade in natural resource products for livelihoods and poverty alleviation in South Africa. Dissertation, Rhodes University Grahamstown, South Africa.

SHACKLETON, C. 2009. Will the real custodian of natural resource management please stand up? *South African Journal of Science*, 105:91-93.

SHAND, H. 1997. Human Nature: Agricultural Biodiversity and Farm-based Food Security. RAFI, Ottawa, Canada.

STANLEY, J., CLOUSTON, B. & BAKER, R. (Undated). Understanding Land Manager Constraints to the Adoption of Changed Practices or Technological Innnovations:

Literature Review. Working Paper No: 1, from the Project "Impediments to the Uptake of Market Based Instruments".

SWANSON, B. 2006. The changing role of agricultural extension in a global economy, *JIAEE*, 11(3):5–17.

SWANSON, B. E. 2009. Changing Extension Paradigms within a Rapidly Changing Global Economy. In: Paffarini, C. and F.M. Santucci (Eds), *Proceedings of the 19th European Seminar on Extension Education: Theory and Practice of Advisory Work in a time of Turbulences*, pp. 113-17.

TILMAN, D., FARGIONE, J., WOLFF, B., D'ANTONIO, C., DOBSON, A., HOWARTH, R., SCHINDLER, D., SCHLESINGER, W. H., SIMBERLOFF, D. & SWACKHAMER, D. 2001. Forecasting Agriculturally Driven Global Environmental Change. *Science,* 292:281-284.

TWINE, W. C., MOSHE, D., NETSHILUVHI, T. & SIPHUGU, V. 2003. Consumption and direct-use values of savanna bio-resources used by rural households in Mametja, a semi-arid area of Limpopo Province, South Africa. *South African Journal of Science* 99:467-473.

UNCTAD. 2010. Enhancing food security in Africa through science, technology and innovation. Technology and Innovation Report 2010. United Nations Conference on Trade and Development, Geneva, Switzerland. USA.

UNITED NATIONS DIVISION FOR SUSTAINABLE DEVELOPMENT. 1992. AGENDA 21. [Online] Available from: http://www.un.org/esa/sustdev/publications/water_for_life.pdf. (Accessed: 17/10/2010).

UNITED NATIONS (UN). 2005. Millennium Development Goals. [Oline] Available from: http://www.un.org/milleniumgoals. (Accessed: 17/10/2010).

UNITED NATIONS DEVELOPMENT PROGRAMME. 2006. *South Africa Showcase.* Global Environment Facility. New York, United States of America.

WORLD BANK. 2011. Food Price Watch. [Online]; Available at: http://siteresources.worldbank.org/INTPOVERTY/Resources/335642121085959103O/FPW_April2011.pdf. (Accessed: 05/01/2012).

WORLD SUMMIT ON SUSTAINABLE DEVELOPMENT. 2002. Summaries of the partnership events. [Online] Available from: http:// www.johannesburgsummit.org. (Accessed: 05/01/2012).

WU, B. & PRETTY, J. 2004 Social Connectedness in Marginal Rural China: The Case of Farmer Innovation Circles in Zhidan, North Shaanxi. *Agr Hum Values*, 21: 81-92.