Conservation of Insect Pollinators through Indigenous Traditional and Western Scientific Knowledge

Wisdom Harrison K. Hordzi
Department of Biology Education; Faculty of Science Education; University of Education, Winneba. P. O. Box 25, Winneba; Ghana

Abstract
Though useful indigenous knowledge systems are abound they are often overlooked by Western scientific research and development because of the oral tradition and certain inherent limitations in indigenous knowledge systems. This paper explores the usefulness of insect pollinators, harmful practices to the insect pollinators and their conservation, traditional indigenous knowledge that exists about insect pollinators, as well as the need for infusion of traditional indigenous knowledge and western scientific knowledge in the conservation and preservation of insect pollinators. The paper espouses the numerous benefits of insect pollinators right down from ecological to religious, financial and aesthetic. It also delved into some deliberate and inadvertent human practices that threaten the very existence of insect pollinators and the consequences. It is clear from the literature that though indigenous traditional knowledge about insect pollinators is in somewhat confused state its role and importance as a basis for participatory development is well recognized. Basically, several tacit indigenous traditional processes from diverse communities are in place to conserve insect pollinators. Some of such processes are facilitated by research scientists in the form of projects. Hence, more collaboration between indigenous traditionalists and research scientists in pollinator conservation is a step in the right direction and should be encouraged.
Keywords: Indigenous, traditional, insect pollinator, conservation, pesticidal, scientific knowledge

Introduction

Over the years traditional and locally accumulated knowledge have provided the foundations for thousands of years of agricultural development (GRAIN, 1990). Indigenous knowledge systems may be adaptive skills of local people usually derived from many years of experience that have been communicated through oral traditions and learned through family members over generations (Thrupp, 1989). They can also be time tested agricultural and natural resource management practices which gave way for sustainable agriculture (Venkatratnam, 1990). They can also be strategies and technologies developed by local people to cope with the changes in the socio-cultural and environmental conditions or they are practices that are accumulated by farmers due to constant experimentation and innovation (Venkatratnam, 1990) or trial and error problem-solving approaches by groups of people with an objective to meet the challenges they face in their local environments (Roling & Engel, 1992). They may appear simple to outsiders but they represent mechanisms to ensure minimal livelihoods for local people (Thrupp, 1989).

Indigenous knowledge systems often are elaborate, and they are adapted to local cultural and environmental conditions tuned to the needs of local people and the quality and quantity of available resources (Pretty & Sandbrook, 1991). They also pertain to various cultural norms, social roles, or physical conditions. The efficiency of indigenous knowledge system lies in the capacity to adapt to changing circumstances (Norguard, 1984).

Indigenous knowledge systems are often overlooked by Western scientific research and development because of their oral tradition (Warren, 1990). Therefore, as these systems are facilitated, outsiders can understand better the basis for decision making within a given society. Also, by comparing and contrasting indigenous knowledge systems with scientific technologies of international agricultural research and developmental and regional research stations, it is possible to see where technologies can be used to improve upon local systems. Despite the complex farming systems now being rediscovered by Third World farmers, where the knowledge of farmers and their role as experimentalists are increasingly being recognized, as a result of countless examples of farmers' innovations coming to light, still farmers' capacity to innovate is being ignored (GRAIN, 1990). According to GRAIN (1990), a particular innovation is invariably only part of a production system, often making sense only in its particular ecological and socio-economic context. The oral tradition of peasant societies means that rarely is there a written record of traditional innovations. But another reason is the widespread view that only the knowledge of experts has value - a view which became entrenched during the colonial period in Africa. Practices of traditional people were despised and sometimes even outlawed by colonial administrations and their agricultural extension agencies. Although sometimes based on sheer ignorance, many laws in colonial Africa were designed to maintain the supremacy of white farmers over their black rivals. This was done not only by restricting access to land, but also by downgrading indigenous techniques (GRAIN, 1990). Furthermore, certain inherent limitations in indigenous knowledge systems have strengthened the attitudes of outsiders that indigenous knowledge systems are primitive, unproductive and irregular. These are: (1) indigenous knowledge systems are oral in nature, (2) they are not formally recorded and documented, (3) each individual possesses only a part of the community's indigenous knowledge system, (4) they may be implicit within local people's practices, actions and reactions rather than a conscious resource (Reijintjes, Haverkort, & Waters-Bayer, 1992).

The woes of traditional indigenous knowledge systems have been made worse where westernized scientists hold claims to findings of indigenous people. For example, Andean small farmers are responsible for an important technical innovation which is often credited to scientists working at the International Potato Centre (CIP). The scientists noticed that these farmers, like those in Kenya and Nepal, stored potatoes in diffused light rather than in darkness. They tested and refined the technique, and successfully passed it on back to the farmers (GRAIN, 1990). GRAIN (1990) stated further that farmers have also played a major role in the selection and diffusion of new varieties originally developed in research stations. An example is a case in which a new paddy rice variety, 'Mahsuri,' rejected by official researchers after poor performance on their experimental stations somehow reached farmers in the Indian state of Andra Pradesh. Farmers tried it and found its performance to be excellent under their conditions, and its use spread to other states. It is now the third most popular variety in India.

The narratives so far point to the level of contributions indigenous traditional knowledge systems have made to the development of knowledge, the agricultural sector and development as a whole despite the attempt to bastardize it by westernized scientific researchers. Considering all these facts as stated earlier it

is fair to consider the fact that there should be indigenous traditional knowledge from local people related to insect pollinators and their conservation. Hence, the writer thought it necessary to explore the literature to find out the usefulness of insect pollinators, harmful practices to the insect pollinators and their conservation as well as traditional indigenous knowledge that exist about insect pollinators. The paper also made the attempt to explore the need for infusion of traditional indigenous knowledge and western scientific knowledge in the conservation and preservation of insect pollinators.

Usefulness of insect pollinators

Pollination is an essential link in the ecological global chain (API, 2003). Hence more than 100,000 species of wild plants depend upon insects for pollination and reproduction (Teale, 1957). Cross-pollination by insects is very essential to the survival of many flowering plants. Roubik (2002); Klein, Steffan-Dewenter and Tscharntke (2003) observe that the fruit set of highland coffee increases with cross-pollination by bees. About 75% of the world's food crops depend at least in part on pollination (IPBES, 2016). Also, it is documented that US$235 billion–US$577 billion annual value of global crops are directly affected by pollinators. In the past 50 years there has been 300% increase in volume of agricultural production dependent on animal pollination. Almost 90% of wild flowering plants depend to some extent on animal pollination (IPBES, 2016). Gyasi and Enu-Kwasi (2001) observe that small holder farmers in West Africa recognize and value wild bees as principal pollinators of tree crops such as mangoes, citrus and pawpaw. They also recognized ants as pollinators. Because insects have become so adept at finding and identifying individual flowering plants, even rare plants may persist so long as pollination occurs (API, 2003).

In addition to food crops, pollinators contribute to crops that provide biofuels such as canola and palm oils; fibers such as cotton; medicines, forage for livestock and construction materials. Some species also provide materials such as beeswax for candles and musical instruments, and arts and crafts. Pollinators, especially bees, have also played a role throughout human history as inspirations for art, music, religion and technology. They are important in seed and fruit formation, making it a critical determinant in food production and on farmers' incomes (Frimpong-Anin, Kwapong & Gordon, 2013). Therefore, the worldwide decline of pollinators can cause decline in crop yield (Kevan & Philip, 2001). Just as pollination is pivotal to agriculture for quantity, quality and diversity of foods, fibres and medicines, it is also essential for maintaining biological diversity (Ahmad, *et al.*, 2006). The Norwegian Biodiversity Information Centre (2013) observes that the seed production of probably nearly 80 % of wild plant species in Norway is favoured by insects visiting their flowers.

With the lofty benefits of insect pollinators espoused it stands to reason that pollinators for that matter pollination is very important in the food chain in the ecological systems, socioeconomic development and sustenance of mankind. These submissions point to the need for African for that matter Ghanaian farmers and various communities that interact with the ecosystem in one way or the other to be knowledgeable in the usefulness of insect pollinators. Such knowledge would have been useful for the community members and farmers to identify and differentiate useful insects such as pollinators from insect pests and make deliberate efforts to conserve them through their various ecosystem practices. But is that what we often see? The answer is no because there are several practices that take place in the environment that are detrimental to the very existence of insect pollinators.

Harmful practices to insect pollinators and their conservation

A number of processes negatively affect pollinator populations, especially insect pollinators. Although genetically modified (GM) crops are usually either tolerant to herbicides or resistant to insect pests, they reduce the availability of weeds, which supply food for pollinators. As such lower use of insecticides is encouraged, which reduces pressure on beneficial insects including pollinators. However, the sub-lethal and indirect effects of GM crops on pollinators are poorly understood and not usually accounted for in risk assessments. Pollinators are also threatened by the decline of practices based on indigenous and local knowledge. These practices include traditional farming systems; land fragmentation, maintenance of diverse landscapes and gardens; kinship relationships that protect specific pollinators; and cultures and languages that are connected to pollinators (IPBES, 2016). The abundance of bees and other pollinators is drastically reduced by intensive agriculture and urban development (Ellis, Bazendale & Keith, 1998).

Richard (1996) observes that the poisoning of honeybees and other beneficial insects by pesticides can be a serious problem. Analysis of pesticide residues on vegetable samples from Accra, Kumasi and Tamale all in Ghana was undertaken by Amoah, Drechisel, Abaidoo, & Ntow (2006). The results indicated that Chlopyrifos (Dursban) was detected on 78% of the lettuce, lindane (Gammalin 20) on 31%, endosulfulfan (Thiodan) on 36%, lambdacyhalothrin (Karate) on 11% and dichloro-diphenyl trichloroethane (DDT) on 33%. Insecticidal dusts and encapsulated insecticides such as Penncap-M are especially dangerous because they adhere to foraging bees and may be collected and stored in the hive with pollen. Such materials can cause serious bee kills within the hive for many months (Richard, 1996).

Judging from the discourse so far it is obvious that though insect pollinators play very useful roles in the lives of mankind and for ecological balance there are number of threats posed by human activities knowingly or inadvertently to the detriment of these useful insects. Obviously the solution lies in how much knowledge farmers have about the existence, nature and conservation of these useful insects. Here, traditional indigenous knowledge about these insect pollinators may become a worthy weapon to reverse their decline as a result of detrimental farmer activities.

Traditional indigenous knowledge about insect pollinators

It is said that for lack of knowledge my people perish. This saying is akin to the problems that insect pollinators face in various ecological systems in the world. However, it is the considered opinion of this writer that the level of understanding of the issues of pollination and pollinators would enable various ecosystem players to conserve pollinators, especially insect pollinators. It is in the light of this that the literature on traditional indigenous knowledge about insect pollinators is being explored in this work to serve as a useful source of information for pollinator biologists.

The role and importance of local knowledge as a basis for participatory development is well recognized. The potential to build socially and ecologically sound approaches to agricultural development by understanding, respecting and utilizing local knowledge systems is great. Though, information from the literature points to mixed indigenous traditional knowledge about pollinators and for that matter insect pollinators, there exists a modest body of documentation of local knowledge in indigenous bee management (FAO, 2008). According to Césard and Heri (2015), in Indonesia forest collectors have comprehensive knowledge of various bee species, especially those they observe in their regular practices and use for wax or honey. They give names to bees, to their offspring and to their products, and distinguish honeybees from other bees, including more solitary species. However, the level of knowledge may be different from one social group to the other and from one individual to another. Honey collectors associate the main migrations of the giant Asian honeybee colonies to their nesting sites to seasonal massive blooms, an ecological phenomenon (known in the scientific literature as General Flowering events) in which most tree species flower simultaneously at more or less random times of the year (Césard & Heri, 2015).

Norwegian Biodiversity Information Centre (2013) observes that little is known in Norway about the importance of pollination as an ecosystem process. In Norway, there are just a few examples of such highly specialized interactions. One is the globeflower (*Trollius europaeus*), which is pollinated by flies in the *Chiastocheta* genus (Diptera, Anthomyiidae), the females of which lay eggs in the ovaries of the flower. Another is the northern wolf's-bane (*Aconitum lycoctonum*), which is pollinated by a single bumblebee (*Bombus consobrinus*), and a third is the fly orchid (*Ophrys insectifera*), which is pollinated by a digger wasp in the *Argogorytes* genus.

An assessment of the state of indigenous knowledge of pollination carried out through visits to selected areas of Bolivia, New Zealand and South Africa in 1998, had a common trend: indigenous knowledge of pollination varies markedly even within a single community (Mayfield 2004 cited in FAO, 2008). In the Yungas region of the Andes in Bolivia, the range of beliefs and understanding amongst the Ayamara people who inhabit this area were very wide. Some farmers believed that bees were detrimental to flowers because they sucked energy from them, whereas some others had a complex, and very accurate knowledge of what the bees do when they visit flowers and how important bees are for production in certain crops. Despite this, the farmers as a whole did not take measures explicitly to protect pollinator populations in the region.

Amongst Brazil nut collectors on the Amazonian frontier of Bolivia, in the state of Pando, knowledge of pollination services also varied widely. Some believed that the bees visiting Brazil nut flowers were responsible for making the flowers fall and thus were detrimental to the production. Others asserted that they knew that the trees needed bees to visit the flowers for fruit to be produced and that the most common bee visitors relied on orchids in the forest when the Brazil nut trees were not blooming (FAO, 2008). The description of the common bee visitors by these people were consistent with the Eulema bee species that have been observed in scientific studies of nut flowers (Nelson, Absy, Barbosa, & Prance, 1985).

Assessing farmer knowledge of the roles of cowpea insect flower visitors and effects of pesticide control measures on them in three districts in the Central Region of Ghana Hordzi (2014) found out that 59.6% (62) and 67.3% (70) of the farmers considered bees and Lepidopterans respectively as pollinators of cowpea whereas 63.5% (66), 46.2% (48) and 34.6% (36) of them considered beetles, ants and flies (Dipterans) respectively as pests. Majority of the farmers (98.0%) claimed to have some knowledge of pollinators and 98.1% (99) of these indicated that pollinators transfer pollen grains from the anther to the stigma. While 98.0% of the farmers considered insects as pollinators, 2.9% (3) of them were of the opinion that pollinators harm or destroy flowers. From the findings of that study it was clear that respondents had varied opinions about pollinators and that depended largely on the level of education of respondents.

In similar research in Ghana about cocoa farmers' awareness of pollination and its implication for pollinator-friendly practices, Frimpong-Anin, Kwapong and Gordon (2013) found out that the majority of farmers (87.6%) were ignorant of the general scientific concept of pollination. They perceived pollination to be one of the intrinsic physiological mechanisms of trees. Farmers familiar with pollination attributed dropping of unpollinated flowers off the tree to failure of fertilization while those ignorant of pollination likened it to leaf flush, referring particularly to the high flower drop observed in February to April. It is clear from this study also that responses were mixed and respondents with the right information went through some education (Frimpong-Anin *et al.,* 2013).

Clearly, the general indigenous traditional knowledge about pollinators throughout the world is mixed depending on the individuals' level of education related to pollinators, specifically on insect pollinators. It appears that on large scale those involved in bee keeping and harvesting of honey appear to gain some knowledge in the process as a result of long association with the bees and related to flowering and blossoming of the flowers to attract insects to themselves in order to make honey. As such, bee farmers and wild honey harvesters have a lot of knowledge about insect pollination biology by default. However, for local people to be able to put deliberate efforts in place to conserve insect pollinators it is important for them to understand the operations and biology of such insect pollinators.

Conservation of insect pollinators through traditional indigenous knowledge and Western scientific knowledge

Local knowledge of promoting pollination services may be embedded in a more holistic appreciation of the role of biodiversity on-farm, including its multiple benefits for natural pest control and provision of medicinal plants, as well as providing alternate forage to attract pollinators (FAO, 2008). Thus, perhaps planting of other crops or plants in-between rows to attract pollinators into the farm may be a useful practice. However, Agricultural scientists with the appropriate knowledge should make deliberate efforts to make such technology available to farmers under a suitable condition where they will feel comfortable to adopt or adapt the best practices. Some of the practices recommended by FAO (2008) include the use of local management practices supporting pollination services and indigenous bee management to serve as the foundation of future recommendations for pro-pollinator management practices; and in-situ management of plant genetic resources by greater consideration of the role of pollination in the conservation of plant genetic diversity. These also imply that advantage should be taken of what the farmers already know and help them improve upon them for pollinator conservation. For genetic resource management, simple experiments involving transfer of useful genetic traits that will enhance pollination will be appreciated.

Though many farmers are not conversant with the scientific terminologies pertaining to pollination and pollinator conservation, friendly interactions with them will make them apply their practical indigenous traditional knowledge and thereby working with research scientists to conserve pollinator biodiversity. This is probably in line with a Norwegian recommendation that the effort ahead should be directed at 1) mapping pollinators and which species of plants they visit, 2) the availability of pollinators for rare species of plants, 3) the importance of pollen limitation for seed production and population growth in rare species of plants, 4) Norwegian contributions to global knowledge on pollination, and 5) the education of competent pollination ecologists (Norwegian Biodiversity Information Centre, 2013).

The work of Frimpong-Anin *et al.* (2013) in Ghana points to the fact that lateral information flow (farmer-

farmer) was common, and therefore equipping influential farmers will ensure the dissemination of the right information. For instance, farmers enquire from colleague farmers whose trees are doing well and may go to the extent of collecting planting seeds from them, contrary to the recommendation that all seeds should be sourced from cocoa seed production unit. This is because current varieties are hybrid and therefore yields and vigour of the offspring are low. The focal farmers are being given additional training through frequent interactions with the researchers and pollinator-management workshops. The model has been developed through the survey and field experiments. The foregoing is an interesting finding which can help African farmers to quickly adopt modern scientific methods from a revered farmer. For instance, in Africa, seniority and leadership positions are well respected and an elderly person is well adored irrespective of whichever knowledge he/she has. Therefore, the use of a matured farmer with the requisite knowledge will be a useful weapon to reverse pollinator population decline. This is because once such focal person understands the rudiments of all the agronomic practices he/she will inadvertently transmit the knowledge to others informally without much effort from research scientists.

IPBES (2016) suggests specific options of maintaining or creating greater diversity of pollinator habitats in agricultural and urban landscapes such as: supporting traditional practices that manage habitat patchiness, crop rotation, and cooperation between science and indigenous local knowledge; education and exchange of knowledge among farmers, scientists, industry, communities, and the general public; decreasing exposure of pollinators to pesticides by reducing their usage, seeking alternative forms of pest control, and adopting a range of specific application practices, including technologies to reduce pesticide drift; and improving managed bee husbandry for pathogen control, coupled with better regulation of trade and use of commercial pollinators (IPBES, 2016; Fagen, 2016).). For education, there is no other weapon more powerful than it. Invariably, all the processes being discussed in this paper hinge on education, formal, informal or non-formal. Hence, recommendations such as that of the landmark United Nations report on pollinator decline suggesting policies that could be adopted by governments, including encouraging farmers to protect and manage wildlife that underpin crop production; mixing up monocultures to cut down on ‘green deserts’; and creating ‘bee highways’, providing habitat that links together to allow them to move across landscapes when put to use may make the desired impact.

Farmers can be helped to undertake their own restoration projects to improve the health of the land, animals, plants and the people by bringing together the knowledge and practices of pollinator restoration and conservation of thousands of farmers. Farmer-promoters can be given workshops and classes in their local grammar schools and high schools. Students will classify local pollinators and their associated plants, and mount them in glass-case displays. They will then learn conservation and restoration practices and implement them on a small scale on their family farms. As parents and other villagers follow the progress of the experiments, everyone will learn and share knowledge about agro-ecosystems, climate resilience, pollinator restoration, and soil and water conservation. Workshops in the classroom and in the field will engage participants in both theory and practice, encouraging them to test practices first, before adopting them. This will help to adapt the practices to local conditions and build the methodology of experimentation into the learning process so that farmers can address future agro-ecological challenges. This proposition is similar to Chile pepper and long handle-hoe project of University of Development Studies (UDS) in the Northern and Upper East Regions of Ghana. These projects were studied by this writer and other two people where farmers initiated the projects and sought technical knowledge from researchers of the UDS. It so happened that the best practices were shared by the farmers who took part in the projects with farmers who did not take part. By so doing there were cascading effects of the positive impacts of the projects.

Another important thing worth mentioning is the use of pesticidal plants in insect pest control and its beneficial effects on pollinators in general and specifically insect pollinators. The use of pesticidal plants is gaining priority in developing countries where massive poisoning as a result of the use of pesticides is increasing and posing environmental and health risks (Isman, 2008). It is documented that for long time now small holder farmers have been knowledgeable in the use of pesticidal plants in pest control. According to Dubey, Srivastava and Kumar (2008); Sola, Mvumi, Ogendo, Mponda, Kamanula, Nyirenda, *et al*., (2014), pesticidal plants are being used as alternative to synthetic pesticides because of the non-cytotoxicity, easy of biodegradability and simulator nature of host metabolism of such pesticidal plants. Pesticidal plants break down rapidly, making them more environmentally friendly (Grzywacz, Stevenson, Mushobozi, Belmain & Wilson, 2014) and thus can naturally degrade easily in the environment rendering them less persistent (Dubey, et al., 2008). As such they are better alternatives in crop production.

Africa is endowed with numerous plants with pesticidal effects (Gakuya, Itonga, Mbaria, Muthee & Musau, 2013; Van Andel, Croft & van Loon, 2015). Their growth, proliferation and cheap availability encourage their use (Gakuya *et al.,* 2013). It is refreshing news that many African smallholder farmers have been using various botanical pesticides to control insect pests. For example, in the Victoria basin in Uganda, farmers have used *Capsicum frutescens*, *Tagetes* spp., *Nicotiana tabacum*, *Cypressus* spp., *Tephrosia vogelii*, *Azadirachta indica*, *Musa* spp., *Moringa oleifera*, *Tithonia diversifolia*, *Lantana camara*, *Phytollacca dodecandra*, *Vernonia* *amygdalina*, *Aloe* spp., *Eucalyptus* spp., (Mugisha-Kamatenesi, Deng, Ogendo, Omolo, Mihale, Otim, et al., 2008). Other plants used are *Tephrosia vogelii, Vernonia amygdalina, Tithonia diversifolia* and *Lantana camara, Tephrosia vogelii, Vernonia amygdalina, Tithonia diversifolia,* etc. In Ghana, farmers have been using ashes, neem tree extracts, *Crotalaria*, soapy water, plant extracts, etc to control pests. In addition to the pesticidal plants, farmers in Tanzania have been using other products such as cow's urine, cow dung, and ashes (Mihale, Deng, Selemani, Mugisha-Kamatenesi, Kidukuli & Ogendo, 2009).

Researchers have come up with some application techniques. This includes: the use of the freshly ground leaves, mixed and soaked overnight (Paul, 2007; Amoabeng, Geoff, Catherine & Philip, 2014). Also, boiling plant parts and adding soap for extraction has been practiced. Paul (2007) used fresh leaves pounded and mixed with water and 0.1% soap to make 3% w/v of the extract. Mekonnen *et al.* (2014) used another technique where sun dried plant materials were soaked in acetone and stirred for 30 minutes. The mixture was left for 24 hours, filtered and stored under 4˚C temperature before use. All mentioned application techniques demonstrated positive results in controlling certain insect pests. These efforts have been done in few parts of developing countries despite presence of pesticidal plants in diverse areas. These call for diverse research on plants with pesticidal properties coupled with indigenous knowledge from people of different backgrounds and cultures in collaboration with research scientists and development of tangible solutions on the use of pesticidal plants to control insect pests.

Conclusion

It is an undeniable fact that insect pollination is an essential link in the ecological global chain and several thousands of species of wild plants depend upon insects for pollination and reproduction. It is further established that cross-pollination by insects is very essential to the survival of many flowering plants and thousands of dollars accrue to farmers per annum as a result of cross-pollination by insects. However, a number of processes negatively affect pollinator populations not excluding insect pollinators. Some of such processes include traditional farming systems such as land fragmentation, maintenance of diverse landscapes and gardens; kinship relationships that protect specific pollinators; and cultures and languages that are connected to pollinators; changes in land use, intensive agricultural practices, alien invasive species, diseases and pests, and climate change. In some cases pesticide misuse has driven beekeepers out of business, though this can affect native wild bees even worse due to the fact that they have no humans to move or protect them.

There exists a modest body of documentation of indigenous traditional knowledge concerning the management of insets for pollination and honey production. It is also evident that there are several attempts to involve the local people in promoting pollination services in a more holistic appreciation of the role of biodiversity on-farm, including its multiple benefits for natural pest control and provision of medicinal plants, as well as providing alternate forage to attract pollinators. In some cases western scientific research officers get involved in collaborative works with traditional people to blend indigenous knowledge with western scientific knowledge in solving the problem of pollinator decline. Some refreshing examples come from West Africa, East Africa, Mexico, Brazil, and others which serve as examples of best practices. What is important is that such useful intercourse between indigenous knowledge systems and western scientific knowledge systems is an encouraging phenomenon which should be pursued to its logical conclusion.

Recommendations

In order to reverse traditional farming systems and practices that are harmful to insect pollinators, research scientists and extension officers should help farmers to acquire the knowledge of modern farming practices that are friendly to insect pollinators. Such training should be targeted at reducing land fragmentation, changes in land use, intensive agricultural practices, alien invasive species, diseases and pests, and climate change. Since, most of the indigenous traditional knowledge practitioners with the right knowledge about insect pollinators appeared to have obtained the information through some education, there is the need for research scientists and extension officers to intensify projects that are focused on providing education on insect pollinators to local people. Also, there should be more collaboration between western research scientists with local people in promoting pollination services in a more holistic appreciation of the role of biodiversity on-farm, including its multiple benefits for natural pest control and provision of medicinal plants, as well as providing alternate forage to attract pollinators. The already existing collaborative processes between western scientific research officers and traditional people to blend indigenous knowledge with western scientific knowledge in solving the problem of pollinator decline should be continued and pursued more vigorously.

Research scientists should work with custodians of indigenous traditional knowledge and help them to document such indigenous knowledge about insect pollinators. That way, the research scientists will get to understand the custodians of indigenous scientific knowledge and the holders of indigenous traditional knowledge also appreciate the work of research scientists. This will help build harmonious collaboration between practitioners of indigenous traditional knowledge and research scientists to make concerted efforts to conserve insect pollinators. Plant based pesticides should be exploited more by farmers as a substitute for synthetic pesticides

There is the need for farmers to be helped by agricultural extension officers and scientists to identify and be conversant with biological biodiversity of useful insects that can bring about pollination and if it becomes unavoidably necessary to apply insecticides it should be done when such insect pollinators are not actively foraging, either in the late evening or early morning. This helps to conserve the insect pollinators for pollination purposes. In such a situation farmers should use insecticides that are less toxic to insect pollinators when the choices are consistent with pest control recommendations. Furthermore, farmers should choose the least hazardous formulations of pesticides where possible.

References

African Pollinator Initiative (API) (2003). *Plan of Action of the African Pollinator Initiative*. Nairobi: African Pollinator Initiative

Ahmad, E., Banne, S., Buchman, S, Castro, M, Chavarria, G, Clarke, J, Collete, L., Eardley, C., Fonseca, V.L.I, Freitas, B.M., Gemmill, B., Griswold, T., Gross, C., Kevan, P., Kwapong, P., Lundall-Magnuson, E., Medellin, R., Partap, U., Potts, S., Roth, D., Ruggiero, M. and Urban, R. (2006). *Pollinators and Pollination: A resource book for policy and practice*. Pretoria: African Pollinator Initiative.

Amoabeng, B.W., Geoff, M.G., Catherine, W.G. and Philip, C.S. (2014). Cost: Benefit Analysis of Botanical Insecticide Use in Cabbage: Implications for Smallholder Farmers in Developing Countries. *Crop Protection*, **57**, 71-76. http://dx.doi.org/10.1016/j.cropro.2013.11.019

Amoah, P, Drechisel, P, Abaidoo, R. C. and Ntow, W. J. (2006). Pesticide and Pathogen Contamination of Vegetables in Ghana's Urban Markets*. Archives of Environmental Contamination and Toxicology, 50(1)*. Retrieved from http://www.springerlink.com/content/7575km06652224q3/ on 20/04/2007

Césard, N. and Heri, V. (2015). Indonesian forest communities: Indigenous and local knowledge of pollination and pollinators associated with food production. In P. Lyver, E. Perez, M. Carneiro da Cumba and M. Carneiro (eds.), *Indigenous and Local Knowledge about Pollination and Pollinators associated with Food Production*. Paris, France: United Nations Educational, Scientific and Cultural Organization

Dubey, N.K., Srivastava, B. and Kumar, A. (2008). Current Status of Plant Products as Botanical Pesticides in Storage Pest Management. *Journal of Biopesticides*, *1*, 182-186.

Ellis, M. D., Bazendale, F. P. and Keith, D. I. (1998). *Protecting Bees When Using Insecticides*. Lincoln: Cooperative Extension Institute of Agriculture and Natural Resources, University of Nebraska

Fagen, K. (2016). *Protecting our pollinators through Indigenous knowledge*. IPBES. Retrieved 24/9/2017 from https://blog.csiro.au/protecting-our-pollinators-indigenous-knowledge

Food and Agriculture Organisation **(**FAO) (2008). *A contribution to the international initiative for the conservation and sustainable use of pollinators rapid assessment of pollinators' status.* Rome: FAO

Frimpong-Anin, K., Kwapong, P. K. and Gordon, I (2013). Cocoa farmers' awareness of pollination and its implication for pollinator-friendly practices. *BioSciences, 7(12*): 504-512

Gakuya, D.W., Itonga, S.M., Mbaria, J.M., Muthee, J.K. and Musau, J.K. (2013). Ethnobotanical Survey of Biopesticides and Other Medicinal Plants Traditionally Used in Meru Central District of Kenya. *Journal of Ethnopharmacology*, 145, 547-553. http://dx.doi.org/10.1016/j.jep.2012.11.028

GRAIN (1990): *Building on farmers' knowledge*. Retrieved on 09/10/2007 from (Internet-http://www.grain.ord/seedling/?id=350)

Grzywacz, D., Stevenson, P.C., Mushobozi, W.L., Belmain, S. and Wilson, K. (2014). The Use of Indigenous Ecological Resources for Pest Control in Africa. *Food Security*, 6, 71-86. http://dx.doi.org/10.1007/s12571-013-0313-5

Gyasi, E.A and Enu-Kwasi, L. (2001). *Managing Agricultural Resources for Biodiversity Conservation. Policy Dimension Final Report: A Case Study of Experience with managing Agricultural Resources for African Region with a Special Reference to Ghana; for Environmental Liaison Centre International* (ELCI); July, 2001.

Hordzi, W. H. K. (2014). Knowledge of the Roles of Cowpea Insect Flower Visitors and Effects of Pesticide Control Measures on them by Farmers in Three Districts in the Central Region of Ghana. *International Journal of Research Studies in Biosciences (IJRSB), 2 (5):* 38-50

IPBES (2016*). Pollinators Vital to Our Food Supply Under Threat: Assessment Details Options for Safeguarding Pollinators*; Fourth Plenary, 22nd - 28th February 2016 – Kuala Lumpur. IPBES civil society Dialogue for progress

Isman, M.B. (2008) Botanical Insecticides: For Richer, for Poorer. *Pest Management Science*, *64:* 8-11. http://dx.doi.org/10.1002/ps.1470

Kevan, P.G. & Phillips, T.P. (2001).The economic impacts of pollinator declines: an approach to assessing the consequences. *Conserv. Ecol. 5*, 8 (online). URL. http://www.consecol.org/vol5/iss1/art8 .

Klein, A. M., Steffan-Dewenter, I. & Tscharntke, T. (2003). Bee pollination and fruit set of Coffea arabica and C. canephora (Rubiaceae). Am. J: 153-157

Mekonnen, M., Begashaw, M. and Beemnet, M. (2014) Screening of Botanical Extracts for the Control of Spearmint Leaf Rust in Greenhouse and Field Conditions. *World Journal of Agricultural Sciences*, *10*, 42-47.

Mihale, M.J., Deng, A.L., Selemani, H.O., Mugisha-Kamatenesi, M., Kidukuli, A.W. and Ogendo, J.O. (2009). Use of Indigenous Knowledge in the Management of Field and Storage Pests around Lake Victoria Basin in Tanzania. *African Journal of Environmental Science and Technology*, *3:* 251-259.

Mugisha-Kamatenesi, M., Deng, A.L., Ogendo, J.O., Omolo, E.O., Mihale, M.J., Otim, M., Buyungo, J.P. and Bett, P.K. (2008) Indigenous Knowledge of Field Insect Pests and Their Management around Lake Victoria Basin in Uganda. *African Journal of Environmental Science and Technology*, *2*: 342-348.

Nelson, B. W., Absy, M. L., Barbosa, E. M. and Prance, G.T. (1985). Observations of flower visitors to Bertholletia excelsa H.B.K. and Couratari tenuicarpa A.C. (Lechythidaceae) *Acta Amazonica, Suppliment 15(102):*225-234.

Norguard, R. B. (1984).Traditional Agricultural Knowledge: Past Performance, Future Prospects and Institutional Implications. *American Journal of Agricultural Economies 66*: 874 – 878.

Norwegian Biodiversity Information Centre (2013). *The state of knowledge about insect pollination in Norway – the importance of the complex interaction between plants and insects.* Trondheim: Norwegian Biodiversity Information Centre. Retrieved from www.biodiversity.no on 23/9/2017.

Paul, V.P. (2007). *Bean Pest Management in East Africa: A Scientific Evaluation of Organic Insect Control Practices Used by Tanzanian Farmers*. Doctoral Thesis, Swiss Federal Institute of Technology, Zurich.

Pretty, J. and Sandbrook, R. (1991). *Operationalising Sustainable Development at the Community Level: Primary Environmental Care*. Paper presented at the DAC Working Party on Development assistance and the Environment. London, October, 1991.

Reijintjes, C, Haverkort, B, and Waters-Bayer, A. (1992). *Farming for the Future: An Introduction to Low-External Input and Sustainable Agriculture*. London: Macmillan.

Richard, F.D. (1996). Protecting Honey Bees. *In Field Crops*. Retrieved on 4th October, 2017 from http://webipm.ento.vt.edu/ipm-www/nipmn/VA-IPM/PMG/field/1bHoneyb.pdf

Roling, N. and Engel, P. (1992). The development of the concept of agricultural Knowledge Information System (AKIS): Implication for Extension. In W. M. Rivera and D. J. Gustafson (Eds.). *Agricultural Extension: Worldwide Institutional Evolution and Forces for Change*. New York: Elsevier Science Publishing Company.

Roubik, D.W. (2002). The value of bees to the coffee harvest. *Nature 417*:708

Sola, P., Mvumi, B.M., Ogendo, J.O., Mponda, O., Kamanula, J.F., Nyirenda, S.P., Belmain,

S.R. and Stevenson, P.C. (2014). Botanical Pesticide Production, Trade and Regulatory Mechanisms in Sub-Saharan Africa: Making a Case for Plant-Based Pesticidal Products. *Food Security*, **6**, 369-384. http://dx.doi.org/10.1007/s12571-014-0343-7

Teale, E. (1957). *Insect Friend*. London: Mead Dodd Co.

Thrupp, L. (1989). Legitimizing local knowledge: Schematized Packages or Empowerment for Third World People. In D.M. Warren, L.J.S. Knowledgekerver and S.O. Titilola (Eds.) *Indigenous knowledge systems: Implications for Agriculture and International Development Studies in Technology and Social Change No 11*. Ames: Iowa State University

Van Andel, T.R., Croft, S. and van Loon, E.E. (2015). Prioritizing West African Medicinal

Plants for Conservation and Sustainable Extraction Studies Based on Market Surveys and Species Distribution Models. *Biological Sciences*, *181:* 173-181.

Venkatratnam, L. (1990). Farmers' wisdom for Sustainable Agriculture. *Kisanworld 7(12*): 22

Warren, D.M. (1990). *Indigenous Knowledge Systems and Development*. Background paper for seminar series on Sociology and Natural Resource Management. Washington DC: The World Bank. December 3, 1990.