Journal of Sustainable Development in Africa (Volume 15, No.5, 2013)
ISSN: 1520-5509
Clarion University of Pennsylvania, Clarion, Pennsylvania

ADOPTION OF AGRO-ECOLOGY PRACTICES IN SEMI-ARID ENVIRONMENT OF CHIMANIMANI DISTRICT, EASTERN ZIMBABWE

Clayton Mashapa[1], Patience Mhuriro-Mashapa[2], Patience Zisadza-Gandiwa[3] and Edson Gandiwa[4]

[1] Caritas International, Zimbabwe Mutare Diocese
[2] Ministry of Agriculture, Mechanization and Irrigation Development, Zimbabwe
[3] Zimbabwe Parks and Wildlife Management Authority
[4] Chinhoyi University of Technology, Zimbabwe

ABSTRACT
We assessed the adoption of agro-ecology practices under smallholder farming in semi-arid environment of Chimanimani District, Zimbabwe. Adoption of agro-ecology practices was examined in the context of factors that are argued as indicators of adoption and/or rejection of agro-ecology technologies and practices. Data were collected from farmers in Chikwakwa, Mhakwe and Shinja wards of Chimanimani District to examine adoption trends of agro-ecology production systems. Participatory action research was conducted from August 2011 to April 2013, where 200 smallholder farmers, inhabitants of the study area were interviewed. Our study revealed that local adoption of sustainable agro-ecology practices of direct seeding and mulch based cropping system was taking place within the study area. However, the adoption of crop residue management, crop rotation and agro-silviculture production technologies of agro-ecology, were relatively less adopted. What remains unclear is why adoption of certain agro-ecology practices assessed in the study has occurred.

Keywords: Semi-arid, agro-ecology, direct seeding, mulching, agro-silviculture, adoption.

INTRODUCTION

The last decades in Zimbabwe and the climate change induced aridity has seen increasing need to address agricultural development issues from the perspective that incorporates social and ecological dimensions. Participatory action research could hold the key and has relevance to raise the queries on the intuitive wisdom of stakeholders on sustainable agro-ecological practices (Tilman, 1998). The evolution of agro-ecology practices can be linked to the past when African tribes practiced minimum soil tillage using dibble stick or crude Iron Age tools for crop production purposes (Moyana, 1984). In Zimbabwe, agricultural production systems changed when Western European immigrants came to the then Rhodesia (now Zimbabwe) and introduced mechanized metal moldboard plows powered by animals that made it possible for smallholder farmers to farm larger tracts of land (Alvord, 1936; Moyana, 1984), with higher soil disturbance subject to erosion and subsequent land degradation as demonstrated by Boardman, Foster & Deering (1990). In that regard, the then government of Rhodesia enacted the Land Husbandry Act of 1951, which intended to provide for good husbandry farming methods and protection of natural resources by smallholder farmers (Moyana, 1984). Scholars and concerned citizens continued to raise questions about the impact of high scale conventional agriculture practices on land, water resources, food security and the environment at large (Elwell & Stocking, 1988; Nyagumbo, 1998; Oldrieve, 1993; Smith, 1988; Zimbabwe Conservation Agriculture Task Force (ZCATF), 2009), thus, advocacy for agro-ecology practice in Zimbabwe began. Agro-ecology is a whole system approach to agriculture that is inspired by the natural ecological ecosystem for agricultural development in order to improve food production, resource management, the fight against desertification and human well-being through food security (Benites, Vaneph & Bot, 2002). It links ecology, culture, economics, and society to sustain agricultural production, ecological healthy ecosystem services and viable communities (Food & Agriculture Organisation (FAO), 2002).

Semi-arid area of Chimanimani District, eastern Zimbabwe is experiencing a silent revolution that is changing conventional agriculture practices and is directed towards sustainable agro-ecology production systems. Since the early 2000s, in search of a more sustainable long-term commitment to smallholder agricultural development, a broad based partnership has brought together state actors and non-state actors in partnership with the lead Ministry of Agriculture, Mechanization and Irrigation Development of Zimbabwe, to provide technical assistance to promote agro-ecology practice to vulnerable smallholder farmers across the study area and related semi-arid areas of Zimbabwe (FAO, 2002; Twomlow *et al*., 2007; ZCATF, 2009). Many views are highlighted by researchers on sustainable agriculture, which range from low use of external inputs (Altieri, 1995; Ouedraogo, Mando & Zombre, 2001), enhancing agricultural productivity (De Jager et al., 2001), soil water and soil nutrient management (Conway, 1990; Pretty & Hine, 2000) , proactive concern to maintain the ecological health and sustainable ecosystem services (Edwards, Grove, Harwood. & Colfer, 1993; Heller & Zavaleta, 2009), biodiversity enhancement (Stobbelaar, Kuiper, van Mansvelt & Kabourakis, 2000), land quality (Rigby & Caceres 2001) as prerequisites for conservative agro-ecology and economic agricultural development. However, these sustainability indicators are ambiguously used by many researchers unlike the views of farming community of smallholder farmers. Likewise, the challenge is the aggregation of ecological, social and economic indicators, which are incommensurable to arrive at overall assessment of smallholder farms (King et al., 2000) and their adoption trends of agro-ecology principles for sustainable agricultural development.

Participatory action research as an adaptive social research through the integration of scientific and indigenous knowledge of agro-ecology basis as an approach to improve the overall sustainable agricultural development by stakeholders was used to address the integral objective of linking sustainable agriculture initiatives as part of the socio-economic agricultural development at local scale, so as to highlight adoption trends of agro-ecology practices and further discuss the merits of agro-ecology practices in agricultural development. Our study aimed at analyzing inter-linked concepts relevant to address the sustainability issues in agro-ecology at the interface of socio-ecological perspective of agricultural development within a context of vulnerable communities practicing rain-fed agriculture as a livelihood activity in a semi-arid environment. Our study assessed experiences and adoption trends of agro-ecology practices in a relief context that targeted the most vulnerable communities in semi-arid environment. Implications for future ecological and agricultural policies to encourage adoption of agro-ecology production systems at smallholder level were noted and discussed. Our study findings are discussed in the context of sustainable agricultural development to inform agro-ecology efforts for the vulnerable smallholder farmers within semi-arid environments.

MATERIALS AND METHODS

Study area

The study area covered the south western wards of Chimanimani District, eastern Zimbabwe, marked by an international border with Mozambique (Figure 1). The south-western parts of Chimanimani District, falls in the semi-arid agro-ecological zone, with a hostile crop environment caused mainly by variable annual rainfall with a range of 450-800mm, which usually comes in infrequent heavy storms (Moyo, O'Keefe & Sill, 1993; Vincent &Thomas, 1960). The study area covered Shinja ward 9, Mhakwe ward 18 and Chikwakwa ward 19, in the southwest foot-slopes of Chimanimani Mountain Range of Zimbabwe. Soils are mainly red sand loams with medium to low fertility and organic matter. The study area is dominated by red clay soils known as *rhodic ferralsols* and these soils have a good water holding capacity (Nyamapfene, 1991). The gentle undulating landscape of the study area is often broken by bornhardts, usually upstanding, bare rocks and smaller kopjes, isolated granite hills, which make cultivation difficult. In this drought prone semi-arid area, drought resistant maize, sorghum and millet varieties are grown; with most people relying upon subsistence farming and development relief from humanitarian organizations in collaboration with the government of Zimbabwe.

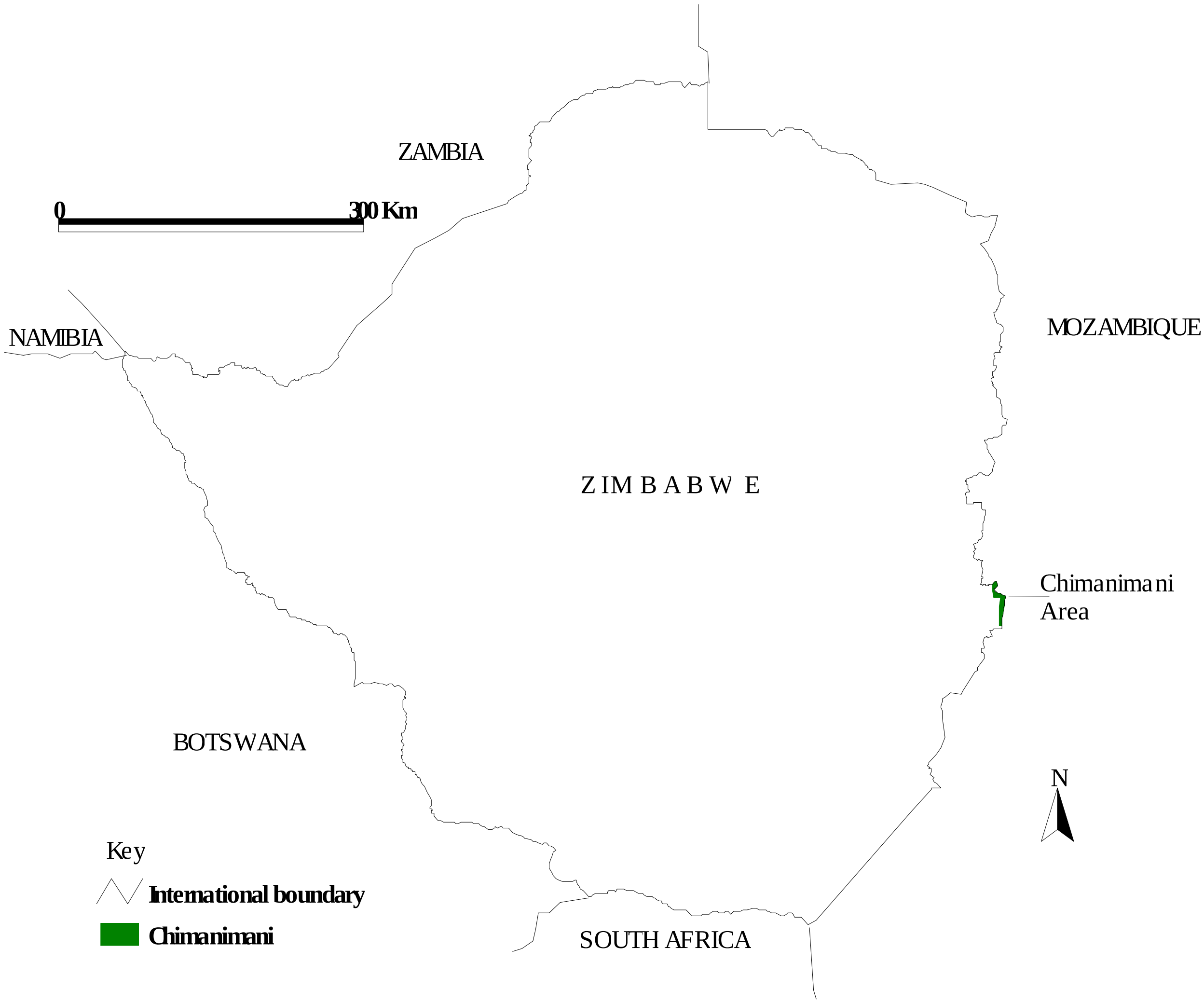

Figure 1: Shows the study area location, Chimanimani District, eastern Zimbabwe

Study design and data collection

The investigation of agro-ecology practices adoption trends of Chimanimani District farmers was conducted from August 2011 to April 2013 period, in which 200 smallholder farmers in three wards of Mhakwe, Chikwakwa and Shinja were asked to indicate their types of smallholder farm production practices of agro-ecology concepts and related conventional agriculture practices. Our study used a cyclic data collection process of participatory action research approach which included observational, reflective thinking, experimental actions and co-evolution through network reciprocity (Gliessman, 2009). Participatory action research and mapping of the agro-ecological health indicators in smallholder farms was used in identification of key agro-ecological issues at local scale (Smyth & Dumanski, 1995). From about 2000 inhabitant households of the study area (Zimbabwe Central Statistics Office, 2000), a sample of 200 smallholder farmers was randomly selected using random number tables based on the community household register intercept system, in relation to the defined study sites.

For the purpose of this study, factors used to predict adoption of agro-ecology practices were adopted from Napier, Thraen & McClaskie (1988), thus follows: perceived relevance of agro-ecology practices to the existing smallholder conventional agricultural operation, anticipated transfer of smallholder agricultural plot to descendants, access to agro-ecology information, awareness of soil erosion problems, size of land usually farmed, size of land severely eroded, perceived increase in investments to effectively use agro-ecology practices, experience in farming, willingness to assume risk, use of existing conventional agriculture practices on smallholder agricultural plot. The overall research methodology comprised of both qualitative and quantitative techniques to data collection.We used a multi-method approach to gather data: i) we examined agro-ecology records kept at Chimanimani Agritex District-Ward Office of the Ministry of Agriculture, Mechanization & Irrigation Development, Zimbabwe, to gather statistics on trends in adoption of agro-ecology in the study area; (ii) we stayed for one agricultural season of 5 months and undertook strategic field visits within the study area for observational data collection, and (iii) we interviewed key informants using protocols outlined by Gandiwa (2012). Our study observed/recorded and analyzed the agro-ecological value chain and issues relevant to address the sustainability issues in agro-ecology productivity at the interface of socio-economic development and adoption trends of agro-ecology practices by vulnerable communities in semi-arid areas

RESULTS AND DISCUSSION

Characterization of the farmers and their experience in farming

The sustainability of agro-ecology is discussed in response to concerns about the adverse ecological and socio-economic impacts of conventional agriculture (Hansen, 1996) and the adoption trends of agro-ecology principles aimed at sustainable agricultural development. Farmers dis-engage technology practices, adopt the most relevant practices initially, and then follow additional components over time, as also noted by Byerlee & Hessel de Polanco (1986). The old paradigms of conventional agriculture being dis-adopted were related to the findings of Derpsch & Moria (1999), that is: 1) soil tillage was thought to be necessary to produce crops, 2) crop residue was regarded as waste product, 3) burning crop residue was permissible, 4) bare soil on fallow fields was permissible, 5) there was strong focus on soil chemical processes, 6) chemical pest control was the first option, and 7) soil erosion was accepted as an unavoidable risk associated with farming. The old paradigms generally result in soil resource exploitation and sustainable land use is not possible ecologically, socially or economically. There were many variations in the agro-ecology techniques practiced within the study area (Table 1). With time an increasing proportion of farmers are likely to adopt a number of agro-ecology techniques. Farmers are expected to realize importance of agro-ecology as they gain experience with the technology over time. Farmers practicing agro-ecology practice of maize production generally has a gross margin five times greater than those earned by conventional agriculture (Mazvimavi & Twomlow, 2009). Households interviewed in our study had experience with some agro-ecology practices and technologies with the majority of farmers having at least a minimum of ten years of practice with the technology.

An increasing number of non-governmental organizations (NGOs) through funding from multiple donors have been promoting agro-ecology and the package has recently been accepted by the Zimbabwean government as a group of technology interventions that have the potential to sustainably increase yields of a wide range of crops produced by resource-poor farmers even in drier agro-ecological regions (Nyagumbo, 1998; Twomlow *et al*., 2007). Farmers across Zimbabwe have shown a growing interest in agro-ecology practice with evidence of crop yield gains of between 10 and more than 100% depending on input levels and the experience of the farming household (Mazvimavi & Twomlow, 2009). Cases of spontaneous adoption of agro-ecology techniques are being observed in areas where agro-ecology farmer field school demonstrations and training programs have been well supported by non-state actors and state actors (Nyagumbo, 1998). Spontaneous adoption trends of agro-ecology practices was well observed in areas where water gravity fed micro-irrigation schemes were developed by state actors and non-state actors for vulnerable households as an adaptation strategy to climate change induced aridity. A number of water gravity fed micro-irrigation schemes of low maintenance and low operating cost were developed by state actors and donor funded non-governmental organisations within the study area. The observed water gravity-fed micro-irrigation schemes are namely; Dembweni and Nechirinda in Mhakwe ward 18 and Muroti, Tumbanyai, Chikware, Chibasani and Makandwa in Chikwakwa ward 19, as well as Zimunda micro-irrigation scheme in Shinja ward 9. The technological packaging of improved market-led agro-ecology production systems under low cost gravity fed irrigation scheme, within a supportive stakeholder institutional environment for agricultural transformation and development could likely lead to local rapid rural sustainable economic productivity growth and food security.

Apart from digging the planting basins and thatch grass mulch based cropping techniques, followed by at least 70% (n = 200) of the interviewed farmers are manure application, topdressing and weed management (Table 1). Whilst manure is readily available from livestock pens, nitrogen fertilizers for top dressing were provided by local NGOs to selected relief recipients (Twomlow, Urolov, Jenrich & Oldrieve, 2008; ZCATF, 2009). The least implemented techniques were crop residue application, basal fertilizer application, crop rotation and agro-silviculture (Table 1).

Table 1: Proportion of farmers to variable components studied (%) and adoption level

Agro-ecology practice of conservation agriculture techniques & other studied variables	Cropping season (n=200) 2011/12 (%)	Cropping season (n=200) 2012/13 (%)	Adoption level
Perceived relevance of agro-ecology practice to the existing conventional smallholder agricultural production	70	80	High
Anticipated transfer of agro-ecology technology to descendants	80	85	High
Household land usually farmed	80	75	High
Perceived increase in investments to effectively use agro-ecology practices	75	80	High
Application of thatch grass as mulch	85	90	High
Digging planting basins	95	100	High
Application of manure	80	85	High
Application of Top dressing fertiliser	80	75	High
Willingness to assume risk	55	60	Medium
Weed management	70	70	Medium
Access to agro-ecology information	70	60	Medium
Hectares of land severely eroded	25	30	Low
Awareness of soil erosion problems	45	45	Low
Agro-silviculture (tree-crop interaction)	25	25	Low
Use of existing conventional agriculture practices on smallholder agriculture plots.	45	40	Low
Application of crop residue	30	40	Low
Application of basal fertilizer	45	35	Low
Crop rotation	15	20	Low

Notes: High – means high positive impact & adoption; Medium – means intermediate impact & adoption and Low - means low impact & adoption. Source: Fieldwork, years 2011/13

Planting basins are holes dug in a field into which a crop is planted. The advantage of using basins was observed that they enhance the capture of water from the first rains of the wet season and enable precision of both organic and inorganic fertilizers application. The practice of applying nitrogen fertilizer, thus, top dressing has been followed by at least 75 percent (n = 200) of the interviewed farmers (Table 1). Ammonium nitrate (AN) is the most common inorganic nitrogen fertilizer used in Zimbabwe and is available in prill form. The nitrate fertilizer, through micro-dosing is spot applied in basins in cereal crop production and this has led to better water harvesting and infiltration and this improves nitrogen use efficiency which likely translates to better crop yield especially in semi-arid areas where moisture is limiting (Mashingaidze, Belder, Twomlow & Hove, 2007). Application of basal fertilizer was likely less adopted and this could be attributed to readily availability of substitute soil nutrient source in the form of manure from livestock pens. A gradual increase in soil-water productivity during the soil aggradation phase as promoted by manure application to improve soil organic matter, could be the result of two interrelated processes that are classically ascribed to agro-ecology practice of soil management: (a) Enlargement of the soil moisture reservoir: No-tillage and inter-cropping with cover crops may often result in an effective enlargement of the rootzone in space and time, as well as an increased soil moisture holding capacity as a consequence of the build-up of soil organic matter. In particular for degraded sandy/coarse soils, this may amount over time to an additional increase of soil moisture holding capacity of 40% (Scopel et al., 1998). b) Increased rainwater infiltration and reduced evaporation losses: The application of mulch can drastically increase the infiltration and storage of rainwater up to 50% (Scopel et al., 1998) and reduce unproductive soil water evaporation losses up to 25% (Allen et al., 1998), particularly during the initial and development stages of the crop development. These effects may in some situations take long to induce substantial crop yield advantages that could motivate small-holder farmers to adopt and implement agro-ecology practices. Weed management was fairly adopted. One strategy was to weed in a timely manner (i.e., when the weeds are still small) preventing the weeds from setting seed. Timely weeding in combination with mulching could eventually lead to effective weed management.

One critical problem faced by agro-ecology adopters in the study area was ensuring that enough crop residues remained in the field to meet threshold of mulching. Research evidence elsewhere has shown that with increasing mulch density, farmers are likely to obtain additional crop yield benefits in agro-ecology practiced plots than plots where conventional agriculture is practiced (Nyagumbo, Mbvumi & Mutsamba, 2009). Agro-ecology plots that were not adequately protected or fenced were likely to be invaded by animals destroying basins and at times eating most of the crop residue left for mulch. Some farmers would place higher value to feeding crop residue to livestock, a source of manure, than reserving it for mulching. In particular, smallholder African farmers often face serious tradeoffs in resource allocation or in biomass valorization within their smallholder farm, especially between cropping and livestock activities. The short term economic value obtained from livestock (e.g. milk production) represents a relevant criterion which influences farmers' decision given that livestock production is more resilient than crop production under semi-arid environments. Also when crop residue is left in some fields, it becomes susceptible to free ranging animals and termite damage. Harvested thatching grass remained the main source of mulching material as farmers appreciates and adopt the mulching technique of agro-ecology. Over 85% (n = 200) of household interviewed apply readily available thatching grass as their mulching material. However, various other materials can also be used as mulch including leaf litter and stones which are readily available in the study area. Stone bunds may also be a viable option since they help in moisture conservation and erosion control through reduction of runoff and allow more water to infiltrate as noted by Donovan & Casey (1998).

Rotating crops is one of the key principles of agro-ecology practice which is currently lowly adopted. The advantages of crop rotation include soil fertility improvement, weed control, integrated pests and diseases management, and production of different types of crop outputs, which reduce the risk of total crop failure in cases of drought and disease outbreaks (Nyagumbo, 1998). Crop rotation is the agro-ecology component that has hardly been adopted by farmers across the study sites. Only less than 21% (n = 200) of the respondents practiced crop rotation on their plots. The reasons for not practicing crop rotation varied with many farmers preferring to continue growing the staple cereal crops (maize/ sorghum/ millet) on their most fertile plots, which is the agro-ecology plot. Some claimed ignorance of the importance of the recommended practice of crop rotation. Other farmers said they had not been taught how to incorporate legumes in basins as the basin spacing seemed more suitable for cereals whereas legumes required smaller spacing and a higher plant population. Some, however, were practicing a cereal–cereal rotation where they planted maize one year, followed by sorghum and/or pearl millet the following year with intercropping of legume crops like cucumber, pumpkins and water melons. Legume seed shortage was another reason cited for not practicing crop rotations and intercropping in Chimanimani District of Zimbabwe.

Rural poverty, poor soils and land degradation in developing countries have been linked as a ‘downward spiral’ by many, with population growth, economic marginalization, and more recently climatic variability and change leading to vulnerability of rural livelihoods who depend on rain-fed agriculture for food security (Scherr, 2000). These processes are particularly severe in semi-arid areas, where rainfall variability exacerbates crop failure risks and resource degradation. Agro-ecology as a sustainable agriculture practice is increasingly promoted and adopted through direct seeding and mulch based technology as an alternative to address soil degradation resulting from conventional agricultural practices that deplete the organic matter and soil nutrient content (Kassam et al., 2009). In areas of climatic variability in Zimbabwe and elsewhere, agro-ecology may represent a low-investment strategy to increase soil-water productivity and mitigate risks, by breaking the vicious cycle of low rainfall, poor crop yields, and soil degradation. In spite of experimental evidence elsewhere showing increased soil-water productivity and crop yields under agro-ecology practice, its adoption by smallholder farmers in Chimanimani, Zimbabwe and related areas of sub- Saharan Africa seems to be hampered by (Giller et al., 2009): (i) lack of sufficient biomass for effective mulching due to poor crop productivity or to competing uses for crop residues in crop-livestock systems; (ii) increased labour requirements when herbicides are not used, putting an extra burden on household labour for weeding. A fundamental challenge with the adoption of agro-ecology is its promotion as an indivisible package that farmers find hard to adopt in full, ignoring farmers’ participation in the design/selection of agro-ecology alternatives, overlooking the fact that the process through which innovation emerges are complex and non-linear. Our study findings were that farmers adopt and dis-engage various agro-ecology practices. It has become evident that agro-ecology technologies and practices has to be tailored to local conditions to make it more suitable to resource-constrained smallholder farmers in sub-Saharan Africa if ever it is to be perceived relevant and to promote stewardship of community sustainable agriculture development (Giller et al., 2011). So-called ‘one-size-fits-all’ technologies and policies might not provide adequate solutions to human poverty and land degradation problems in sub-Saharan Africa (Ruben & Pender, 2004). There seemed no universally significant factors that influence agro-ecology adoption and therefore tailored approaches to promote this practice are needed (Knowler & Bradshaw, 2007). Such approaches could contain the following elements: education and technical assistance, build socio-ecological capital and financial assistance if appropriate.

Agro-silviculture practice of agro-ecology

Agro-silviculture practice adoption was low and lacking in the study area, where only 25% (n=200) of the interviewed farmers practiced woody species-crop production interactions (Table 1). Traditionally, agro-silviculture systems are the result of a long evolutionary process during which an association between natural elements such as trees and shrubs share the same stands with crops and sometimes with households (Montambault & Alavalapati, 2005). These systems are full of indigenous woody species that provide important ecosystem services or economically valuable products traditionally obtained from natural forest (Leakey & Simons, 1998). Indeed, wild food plants and fodder trees play a very important role in the livelihoods of rural communities. They serve as alternatives to staple food during periods of food deficit (Asfaw & Tadesse, 2001; Vodouhê, Coulibaly, Greene & Sinsin, 2009) and are also one of the primary alternative sources of income for many rural communities (Fandohan *et al*., 2010; Shrestha & Dhillion, 2006). Where trees can exploit resources that are unavailable to crops, agro-siviculture can increase productivity per unit area of land through the efficient use of resources (Cannell, van Noordwijk & Ong, 1996), thus, through spatial complementarities. It is suggested that to reduce the negative effects of competition, tree spacing could be increased to minimise competition for water with crops (Singh, Ong & Saharan, 1989). An extension of this idea is that to further minimise negative effects of trees on crops they could be matched to appropriate niches within the farm (Van Noordwijk & Ong, 1996). In reconciling this information with the vast agro-ecological literature on tropical savannas we suggest that it is useful for farmers in Chimanimani District, eastern Zimbabwe and elsewhere semi-arid environments to consider agro-silviculture practice of agro-ecology as an opportunity for temporal and spatial resource complementarities.

Agro-silviculture practice of agro-ecology could allow the regeneration of smallholder farmers' plots and lead to the successional development and patch dynamics of an agro-ecosystem that is akin to natural ecological succession (Leakey, 1996). Furthermore, it could probably take a long time for the beneficial effects of microclimate and soil improvements of mature savanna trees to be realised (Leakey, 1998). Economic gains from marketable woody species products could compensate for any loss in crop yield (Kessler, 1992). It is perhaps not surprising that farmers elsewhere are already beginning to experiment with such agro-silviculture systems of agro-ecology practice. For example, in the dry-lands of eastern Kenya, farmers have recently developed an intensive parkland system using a fast-growing indigenous species, *Melia volkensii* (Meliaceae). This woody species provides high value timber in five to eight years plus fodder during the dry season, without an apparent loss in productivity in associated crops (Stewart & Bromley, 1994). Consequently, International Centre for Research of Agro-Forestry (ICRAF) is currently investigating the woody species-crop interactions in the *Melia* system in farmers' fields. Rhoades (1995) reported increased soil water (40–53% greater than in the open) in the crop root zone beneath *Faidherbia albida* canopies in Malawi. In theory, trees can increase soil water content underneath their canopies, if the water saved by shading effects on soil evaporation and rainfall redistribution (e.g., funnelling of intercepted rainfall as stem flow), exceeds that removed by the root systems beneath tree canopies. In systems like this, the physiological interactions between the tree and crop components of the agro-ecosystem are more likely to mimic those of natural ecosystems, e.g., involving a

Leucaena leucocephala/ Pennisetum americanum (millet) alley cropping system. Similar investigations in semi-arid Kenya confirmed that, on deep alfisols, alley cropping *leucaena*/ maize has the potential to increase light interception and to double water use as compared to sole maize stands (Howard, Ong, Rao, Mathuva & Black, 1995).

Agro-ecology information and adoption

As similarly noted by Derpsch & Moriya (1999), the old paradigms of conventional agriculture are giving way to the new paradigms in agro-ecology practices, thus, 1) tillage is not necessary for crop production as indicated by over 95% (n =200) of the study sample involved in digging of planting basins, 2) over 85% (n =200) apply thatch grass as mulch which remain as permanent soil cover, 3) burning of crop residue and mulch is prohibited and there is a focus on biological soil processes, and 4) integrated pest and disease control was considered the first option. However, the new paradigms of agro-ecology practices in the study area lacked awareness of soil erosion (water and wind) as a symptom of unsuitable methods of farming that are likely practiced in the study area and the semi-arid environments. About 25% (n = 200) households interviewed had their plots severely eroded (Table 1). The study group had moderate knowledge of agro-ecology practice; however, the anticipation to pass it on to future generations was high. Lack of site-specific knowledge of agro-ecology practices like agro-silviculture and crop rotation has likely been one of the main limitations to the spread of the technology in the study area. Factors that could contribute to low adoption were the general dearth of technical expertise of some agro-ecology practices among farmers, mainly on agro-silviculture and crop rotation. In order to avoid failures, farmers, researchers and agriculturists need to have an adequate knowledge of agro-ecology and make sure that all adaptive and sustainable practices of the technology are implemented. A mind-set change of farmers, researchers, agricultural extensionists, away from natural resource base degrading operations towards sustainable agro-ecology practice is necessary to change the attitude of all stakeholders. The agro-ecology technology is said to be acceptable to those who have an innovative mind-set and who engage in a lifelong process of learning and it is complex for those who give up when the first problems appear and for those accustomed to conventional agriculture (Derpsch, 2008). As smallholder farmers adopt agro-ecology practice, new questions always come up with the changing climate induced aridity. To speed up adoption, collaboration from all stakeholders is therefore needed.

The emergence and diffusion of agro-ecology knowledge elements (technical, scientific) and their translation into agricultural development processes and practices describe feedback mechanisms of participation action research and interactions between science, learning, policy and technology demand (Edquist, 1997). This opposes the traditional linear model of knowledge transfer in agriculture, the research-extension-farmer continuum, through which most technologies are promoted. The participation of farmers in technology development through participatory action research, with a solid involvement of researchers in iteration (co-innovation), is suggested as a prerequisite to the adoption of agro-ecology technologies and practices aimed at sustainable agriculture development (Misiko & Tittonell, 2011; Misiko et al., 2011). Stakeholders could adopts a definition of co-innovation platform which is a flexible and informal, dynamic, multi-stakeholder partnership working together to develop and use agro-ecology technologies and processes to improve livelihoods. One of the forms of co-innovation platform suggested is the Learning Centre Approach, a concept developed by the Soil Fertility Consortium for Southern Africa (Chikowo et al., 2011). Learning Centre Approach revolve around participatory adaptive experimentation with smallholder farming communities and a range of stakeholders, emphasizing on enhancement of crop productivity and other robust risk-management practices for sustained resilience to different shocks of agricultural development, livelihoods restoration with environmental protection objectives (Mapfumo et al., 2008). Also core to the approach is that the activities have to align with or recognize farmer experiences. Learning Centre Approach is defined as 'field-based interactive. Successful mobilization of farmers and service providers in Zimbabwe resulted in a rapid increase of climate change adaptation Learning Centres from six to 42 over three seasons, reaching out to over 3000 farmers (Chikowo et al., 2011). These committees then spearhead effective learning by organizing field-days, experimental demonstration plots, learning tours and related events where farmers and stakeholders are able to evaluate different technical options for agro-ecology practices for sustainable agriculture development.

CONCLUSION

The dividends from the ongoing adoption of agro-ecology practice in semi-arid environments of Chimanimani District, eastern Zimbabwe are expected to be immense. Our findings revealed that adoption of agro-ecology practice of direct seeding and mulch based cropping system was highly taking place within the study area. Agro-ecology has demonstrated great potential in increasing crop productivity for farmers in the drought prone areas in Zimbabwe (Nyagumbo, 1998). The widespread adaptation and adoption of agro-ecology practice of planting basin, mulch based cropping systems and related conservation agriculture techniques in rain-fed agriculture in the study area is likely to tackle complex issues of households food security, vulnerability, degraded natural resources and lack of diversification. As state actors and non-state actor institutions of research, agricultural extension service providers grow stronger and policies shift towards improved food security and nutrition, integrated natural resource management, water security and climate resilience; the institutional environment for agro-ecology adaptation and adoption would likely improve progressively. Moreover, the merits of agro-ecology adoption over conventional agriculture systems are likely to grow as fresh water becomes scarcer in irrigated systems, as volatility increases in rain-fed agriculture systems as climate change impact become a reality in semi-arid environments. However, it seemed difficult for the targeted smallholder farmers to fully adopt the wider package of agro-ecology practice under current circumstances. Agro-silviculture, crop rotation and management of crop residues remain a challenge in terms of knowledge constraint and community organization to protect crop residues and household woody species from livestock.

Our study findings, discussion and initiative places strong emphasis on local farmer selection and adaptation of agro-ecology technologies and principles. This does not guarantee that all technical, ecological and socio-economic constraints to sustainable agro-ecology in semi-arid environments would be automatically solved. The few examples of typical tradeoffs highlighted by our study, from crop rotation practice, information access to agro-ecology and agro-silviculture, to the village scale impact of crop residue allocation to mulching or live-stock feeding, indicate that challenges are multi-dimensional. The filters through which farmers select suitable technologies, however, are more complex than their sheer technical performance and therefore sensitive to wider scale constraints. While our study suggested engaging with local smallholder farming communities and other stakeholders through Learning Centres, we also aimed at creating local awareness of such constraints to seek compromise solutions to sustainable agriculture development through agro-ecology practices. Some of such solutions will require a conducive policy environment, as seen in other parts of the world.

We recommend state actors and non-state actors to consider vulnerable households for assistance towards provision of fencing agro-ecology plots and above all, the priority could be to harness more water from available perennial rivers for the purpose of developing gravity fed low cost irrigation schemes in semi-arid environments as an adaptive strategy towards climate change induced aridity. Despite the noted setbacks, agro-ecology practice is regarded a more viable option compared to conventional agriculture system, and the benefits of adopting agro-ecology practices are evident in future in the face of changing climate. What remains unclear is why adoption of agro-ecology practices assessed in the study area has occurred. Research is needed to determine what motivates some smallholder farmers to adopt some agro-ecology practices while others reject adoption of certain production systems. Until we are able to determine with considerable confidence what motivates farmers to adopt agro-ecology practice at smallholder level, public sustainable conservation agriculture policy in Zimbabwe is likely to be misdirected and at best only marginally successful. Agro-ecology remains a part of challenges that are on the world wide agendas, such as conventions on desertification, biodiversity, and climate change (carbon sequestration) and on water resources (Benites *et al*., 2002). Within this wider perspective, our research article could be another paper trying to promote agro-ecology in sub-Sahara Africa, and a platform through which some of the positive aspects of agro-ecology innovations that may fit within smallholder systems can be put to work in its semi-arid regions.

ACKNOWLEDGEMENTS

We are indebted to the Ministry of Agriculture, Mechanisation & Irrigation Development, Zimbabwe for supporting this study, and the people who assisted in fieldwork; namely; Mr T. Mugani, Mr T. Chikukwa, Mr G. Manzou, Miss C. Tendeke, Mr L. Mufute, Mr A. T. Simbi, Mr C. Mufudza, Miss T. Mukonya, Mr D.T. Nyanhete, Mr B. Mutunzi, Mr T. Matanga, Mrs L. Chinengundu, Mr D. Kazhanje, Mr M. Tholana, Mr M. Jerekete and Mr S. Mudenga. We also thank Caritas International Zimbabwe, Roman Catholic Diocese of Mutare for promoting agro-ecology in the study area. CM acknowledges Lista-Bianca, Leonce-Beverlino and Sister Euphrasia Chaza for their support.

REFERENCES

Altieri, M. 1995. *Agroecology: The scientific basis of alternative agriculture*. West View Press, Boulder.

Alvord, E. D. 1936. *Annual Report to the Agriculturalist*. Native Department, Unpublished report on file of the Ministry of Agriculture, Mechanisation & Irrigation Development, Harare. 35 pp.

Asfaw, Z. & Tadesse, M. 2001. Prospects for sustainable use and development of wild food plants in Ethiopia. *Economic Botany*, 55, 47–62.

Benites, J., Vaneph, S. & Bot, A. 2002. *Planting concepts and harvesting good results*. LEISA Magazine on Low External Input and Sustainable Agriculture, 18 (3): 6-9.

Boardman, B., Foster, I. D. L. & Deering, J. A. 1990. *Soil Erosion on Agricultural Land*. New York: John Wiley and Sons.

Byerlee, D. & Hessel de Polanco, E. 1986. “Farmers’ stepwise adoption of technological packages: evidence from the Mexican Altiplano. *American Journal of Agricultural Economics*, 68(3): 519-527.

Cannell, M. G. R., van Noordwijk, M & Ong, C. K. 1996. The central agroforestry hypothesis: the trees must acquire resources that the crop would not otherwise acquire. *Agroforestry Systems*, 34: 27–31.

Chikowo, R., Mtambanengwe, F & Mapfumo, P. 2011. *Going through paces: Empowering communities to use improved crop production practices to adapt to climate change and variability through field-based Learning Centres in Zimbabwe*. A SOFECSA technical annual report for the sub-Saharan Africa Challenge Program (SSA-CP) prepared for the Forum for Agricultural Research in Africa (FARA). Soil Fertility Consortium for Southern Africa (SOFECSA), CIMMYT-Zimbabwe, Harare.

Conway, G.R. 1990. Agriculture and the environment: Concept and issues. In: Huq, S., Rahman, A. and Conway, G.R. Eds., *Environmental Aspects of Agricultural Development in Bangladesh*, University Press, Dhaka.

De Jager, A., Onduru, D., van Wijk, M.S., Vlaming, J & Gachini, G.N. 2001. Assessing sustainability of low- external input farm management systems with the nutrient monitoring approach: A case study in Kenya. *Agri-culture Systems*, 69, 99-118.

Derpsch R. 2008. *No-tillage and conservation agriculture*: A progress report. Pages 7–42 in *No-till farming systems* (Goddard T, Zoebisch MA, Gan YT, Ellis W, Watson A and Sombatpanit S, eds.). Special Publication No. 3. Bangkok, Thailand: World Association of Soil and Water Conservation.

Derpsch, R. & Moriya, K. 1999. *Implications of soil preparation as comparedto no-tillage, on the sustainability of agricultural production*. Experiences from South America. *In* Reddy, M. V. (ed.) *Management of Tropical Agroecosystems and the Beneficial Soil Biota.* Science Publishers Inc., Enfield, NH, USA, 1999, pp. 49-65.

Donovan G. & Casey F. 1998. *Soil fertility Management in Sub Sahara Africa*. World Bank Technical Paper No 408, World Bank, Washington D C, 44pp.

Edquist, C. 1997. Systems of Innovation – Technologies, Institutions and Organizations. Printer Publishers, London/Washington.

Edwards, C.A., Grove, T., Harwood, R.R & Colfer, J. 1993. The role of agroecology and integrated farming systems in sustainable agriculture. *Agriculture Ecosystems Environment*, 46, 99-121.

Elwell, H. A. & Stocking, M., 1988, ‘Loss of soil nutrients by sheet erosion is a major hidden farming cost’, *Zimbabwe Science News*, 22, 7/8, 79–82.

Fandohan, B., Assogbadjo, A. E., Glèlè Kakaï, R., Kyndt, T., De Caluwe, E., Codjia, J. T. C. & Sinsin, B. 2010. Women's traditional knowledge, use value and the contribution of tamarind (Tamarindus indica L.) to rural households' cash income. *Economic Botany*, 64, 248–259.

Food & Agriculture Organisation (FAO), 2002. Conservation agriculture website. http://www.fao.org/waicent/faoinfo/agricult/ags/AGSE/agsee/general/OBJECT.htm

Gandiwa, E. 2012. Local knowledge and perceptions of animal population abundances by communities adjacent to the northern Gonarezhou National Park, Zimbabwe. *Tropical Conservation Science*, 5(3), 255-269.

Giller, K.E., Corbeels, M., Dercon, G., Jenrich, M., Nyamangara, J., Triomphe, B., Affholder, F., Scopel, E & Tittonell, P. 2011. A research agenda to explore the role of conservation agriculture in African smallholder farming systems. *Field Crop Research*, 124, 468–472.

Giller, K.E., Witter, E., Corbeels, M &Tittonell, P. 2009. Conservation agriculture and smallholder farming in Africa: the heretics’ view. Field Crop Research, 114, 23–24.

Gliessman, S. 2009. Community-based participatory action research with agro-ecology. *Journal Sustainable Agriculture*, 33, 799-800.

Hansen, J.W. 1996. Is agricultural sustainability a useful concept? *Agricultural Systems*, 50, 117-143.

Heller, N.E & Zavaleta, E.S. 2009. Biodiversity management in the face of climate change: A review of 22 years of recommendations. *Biological Conservation*, 142, 14-32.

Howard, S. B., Ong, C. K., Rao, M. R., Mathuva, M & Black, C. R. 1995. *Partitioning of light and water in leucaena/maize agroforestry systems*. In: Sinoquet, H and Cruz, P. (eds). *The Ecophysiology of Tropical Intercropping*, pp 175–187. INRA Editions, Paris.

Kassam, A., Friedrich, T., Shaxson, F & Pretty, J. 2009. The spread of conservation agri-culture: justification, sustainability and uptake. *International Journal of Agriculture and Sustainability* **7**, 292–320.

Kessler, J. J. 1992. The influence of karité (*Vitellaria paradoxa*) and néré (*Parkia biglobosa*) trees on sorghum production in Burkina Faso. *Agroforesty Systems*, 17: 97–118.

King, C., Gunton, J., Freebarin, D., Coutts, J & Webb, I. 2000. The sustainability indicator industry: Where to from here? A focus group study to explore the potential of farmer participation in the development of indicators. *Australian Journal of Experimental Agriculture*, 40, 631- 642.

Knowler, D & Bradshaw, B. 2007. Farmers' adoption of conservation agriculture: a review and synthesis of recent research. *Food Policies.* 32, 25–48.

Leakey, R. R. B. & Simons, A. J. 1998. The domestication and commercialization of indigenous trees in agroforestry for the alleviation of poverty. *Agroforestry Systems*, 38, 165–176.

Leakey, R. R. B. 1996. Definition of agroforestry revisited. *Agroforestry Today*, 8: 5–7.

Leakey, R. R. B. 1998. *Agroforestry for biodiversity in farming systems*. In: Collins W and Qualset, C. (eds). *The Importance of Biodiversity in Agroecosystems*, pp 127–145. CRC Press, New York, USA.

Mapfumo, P., Chikowo, R., Mtambanengwe, F., Adeji-Nsiah, S., Baijukia, F., Maria, R., Mvula, A and Giller, K.E., 2008. Farmers' perceptions lead to experimentation and learning. LEISA Mag. 24, 30–31.

Mashingaidze, N., Belder, P., Twomlow, S. & Hove, L. 2007. *Put Your Plants on a Nitrogen Pill – An Alternative Micro-dosing Strategy*: *Preliminary Results from Zimbabwe*. Paper presented to the SADC Land and Water Management Applied Research and Training Programme, 2nd Symbosium, 20-22 February 2007. Gaborone.

Mazvimavi K. & Twomlow S., 2009. "Socioeconomic and Institutional Factors Influencing Adoption of Conservation Farming by Vulnerable Households in Zimbabwe". *Agricultural Systems*, 101:20–29.

Misiko, M & Tittonell, P. 2011. *Counting eggs? Smallholder experiments and tryouts as success indicators of adoption of soil fertility technologies.* In: Bationo, A., Waswa, B.S., Okeyo, J.M., Maina, F. (Eds.), Innovations as Key to the Green Revolution in Africa: Exploring the Scientific Facts. Springer, The Netherlands.

Misiko, M., Tittonell, P., Giller, K.E & Richards, P., 2011. Strengthening understanding of mineral fertilizer among smallholder farmers in western Kenya. Agricultural. *Human Values*, 28, 27–38.

Montambault, J. R. & Alavalapati, J. R. R. 2005. Socioeconomic research in agroforestry: a decade in review. *Agroforestry Systems* 65, 151–161.

Moyana, H.V. 1984. The Political Economy of Land in Zimbabwe, Harare: *Mambo Press*.

Moyo, S., O'Keefe, P. & Sill, M. 1993. *The Southern African Environment.* Profiles of the SADC Countries, London: Earthscan Publications.

Napier, T. L., Thraen, C. S. & McClaskie, S. L. 1988. Adoption of soil conservation practices by farmers in erosion-prone areas of Ohio The application of logit modeling. *Society and Natural Resources*, 1: 109-129.

Nyagumbo I. 1998. *Experiences with conservation tillage practices: A regional perspective for Eastern and Southern Africa*. Pages 1–18 in *Conservation tillage for sustainable agriculture*: Part II (Annexes). Proceedings of an international workshop, Harare, Zimbabwe, 22–27 June 1998 (Benites T, Chuma E, Fowler R, Kienzle J, Molapong K, Manu J, Nyagumbo I, Steiner K and van Veenhuizen R, eds.). Germany: GTZ.

Nyagumbo, I., Mbvumi, B. M. & Mutsamba, E., 2009, '*Conservation agriculture in Zimbabwe: socio-economic and biophysical studies*', a paper presented at the SADC Regional Conference on Sustainable Land Management, Windhoek, Namibia, 7–11 September.

Nyamapfene, K. 1991. Soils of Zimbabwe. *Nehanda Publishers*, Harare, Zimbabwe, 179pp.

Oldrieve B. 1993. *Conservation farming for small-scale resettlement and co-operative farmers of Zimbabwe*. A farm management handbook. Harare, Zimbabwe: Rio Tinto Foundation.

Ouedraogo, E., Mando, A & Zombre, N.P. 2001. Use of compost to improve soil properties and crop productiv-ity under low input agricultural system in West Africa. *Agriculture Ecosystems Environment*, 84, 259-266.

Pretty, J.N & Hine, R. 2000. The promising spread of sustainable agriculture in Asia. *National Research Forum*, 24, 107-121.

Rhoades, C. C. 1995. Seasonal patterns of nitrogen mineralisation and soil moisture beneath *Faidherbia albida* (syn *Acacia albida*) in central Malawi. *Agroforestry Systems*, 29: 133–145.

Rigby, D., Woodhouse, P. Young, T. and Burton, M. 2001. Constructing a farm level indicator of sustainable agricultural practice. *Ecological Economics*, 39, 463-478.

Ruben, R & Pender, J., 2004. Rural diversity and heterogeneity in less-favoured areas: the quest for policy targeting. *Food Policies*. 29, 303–320.

Scherr, S.J. 2000. A downward spiral? Research evidence on the relationship between poverty and natural resource degradation. *Food Policies*, 25, 479–498.

Scopel, E., Muller, B., Arreola-Tostado, J.M., Chavez Guerra, E & Maraux, F., 1998. *Quantifying and modeling the effects of a light crop residue mulch on the water balance: an application to rainfed maize in Western Mexico.* In: World Congress of Soil Science, July 1998, Montpellier.

Shrestha, P. M. & Dhillion, S. S. 2006. Diversity and traditional knowledge concerning wild food species in a locally managed forest in Nepal. *Agroforestry Systems* 66, 55–63.

Singh, R. P., Ong, C. K. & Saharan, N. 1989. Above and below-ground interactions in alley cropping in semiarid India. *Agro forestry Systems*, 9: 259–274

Smith, R. D. 1988. *Tillage trials in Zimbabwe*: *1957 to 1988*. Consultancy report, November 1988. Institute of Agricultural Engineering (AGRITEX and GTZ), Harare.

Smyth, A.J & Dumanski, G. 1995. A framework for evaluating sustainable land management. *Canadian Journal of Soil Science*, 75, 40-406.

Stewart, M and Bromley, T. 1994. Use of *Melia volkensii* in semiarid agroforestry systems in Kenya. *Commonwealth Forestry Review*, 73: 128–131.

Stobbelaar, D.J., Kuiper, J., van Mansvelt, J.D & Kabourakis, E. 2000. Landscape quality on organic farms in the landscape. *Agriculture Ecosystems Environment*, 77, 79-93.

Tilman, D. 1998. The greening of the green revolution. *Nature*, 396, 211-212.

Twomlow S, Rohrbach D, Rusike J, Mupangwa W, Dimes J. & Ncube B. 2007. *Spreading the word on fertilizer in Zimbabwe*. Pages 6–21 in *Land and water management for sustainable agriculture*: Proceedings of the EU/SADC Land and Water Management Applied Research and Training Programmes Inaugural Scientific Symposium, Malawi Institute of Management, Lilongwe, Malawi, 14–16 February 2006 (Mapiki A and Nhira C, (eds.).

Twomlow S., Urolov J. C., Jenrich, M. & Oldrieve B. 2008. "Lessons from the Field Zimbabwe's Conservation Agriculture Task Force". *Journal of SAT Agricultural Research,* 6, 1-10.

Van Noordwijk, M. & Ong, C. K. 1996. Lateral resource flow and capture – the key to scaling up agroforestry results. *Agroforestry Today*, 7: 29–31.

Vincent, V. & Thomas, R. G. 1960. *An agricultural survey of Southern Rhodesia*: Part I: Agro-ecological survey. Salisbury: Zimbabwe Government Printers.

Vodouhê, G. F., Coulibaly, O., Greene, C. & Sinsin, B. 2009. Estimating the local value of non-timber forest products to Pendjari Biosphere Reserve Dwellers in Benin. *Economic Botany*, 63, 397–412.

Zimbabwe Central Statistical Office (2000). *Zimbabwe Demographic and Health Survey 1999*, Macro International: Calverton, Md. Allen, R.G., Pereira, L.S., Raes, D & Smith, D. 1998. *Crop Evapotranspiration*; Guidelines for Computing Crop Water Requirements. FAO, Rome.

Zimbabwe Conservation Agriculture Task Force (ZACTF), 2009. *"Farming for the future". A Guide to Conservation Agriculture in Zimbabwe.* Zimbabwe Ministry of Agriculture, Mechanisation & Irrigation Development, Harare, Zimbabwe Conservation Agriculture Task Force, 57pp.

ABOUT THE AUTHORS:

Clayton Mashapa is an Agricultural Ecologist affiliated with Caritas International, Zimbabwe Diocese of Mutare, under the auspices of the Zimbabwe Catholic Bishops Conference

Patience Mhuriro-Mashapa is an Agricultural Economist affiliated with Zimbabwe Ministry of Agriculture, Mechanization and Irrigation Development

Patience Zisadza-Gandiwa is an International Coordinator for Greater Mapungubwe Transfrontier Conservation Area affiliated with Zimbabwe Parks and Wildlife Management Authority

Edson Gandiwa is an Associate Professor affiliated with Chinhoyi University of Technology, Zimbabwe