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Legume-based diversification; lessons learned from the small-scale farmers in the semi-arid Tanzania

Diversifikasi tanaman berbasis legume yang dapat dipelajari dari petani skala kecil pada kawasan semi-arid di Tanzania

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Banjarnahor D, Scholberg J, Almekinders C. 2015. Legume-based diversification; lessons learned from the small-scale farmers in the semi-arid Tanzania. Pros Sem Nas Masy Biodiv Indon 1: 667-672. For generations, the small-scale farmers in the Mbeya highlands of semi-arid Tanzania had been cultivating maize (*Zea mays*) and beans (*Phaseolus vulgaris*). The major constraints were drought and water shortage, soil fertility degradation, and financial restriction to purchase fertilizers. The introduction of conservation agriculture (CA) which was based on minimum soil disturbance, permanent soil cover, and crops diversification was expected to provide a solution. Despite the almost two-decades of CA introduction, the adoption rate seemed to be rather low. In this study, the local implementation of diversification strategy was assessed to understand this low adoption. To this end, we interviewed and visited 46 farmers who were joining the local CA training through the local farmer's group, 4 group leaders, and 6 CA promoters/trainers. Several highly nitrogen-fixing legumes had been introduced and promoted in the Mbeya rural district. They functioned as nutrient suppliers, soil cover, and sources of organic matter. The adoption of mucuna (*Mucuna pruriens*), pigeon pea (*Cajanus cajan*), and lablab (*Dolichos lablab* L.) was mostly terminated after 1-3 cropping seasons. Farmers witnessed the effectivity of mucuna and lablab to conserve soil moist and suppress weeds but they ceased growing those legumes due to the absence of market. Most farmers did not observe the direct benefits of mucuna and lablab. They could consume pigeon pea but seeds were not available after household consumption. The free-grazing animal husbandry had led to the short life-span of lablab and pigeon pea on the field. Eventually, farmers maintained the previous combination of maize and beans. The effort to diversify the small-scale farming systems must anticipate the pragmatic challenges in order to be compatible with the local context. The agroecosystem diversification design might potentially improve crop production and overcome farmers' limitations. Nonetheless, its successful implementation will require comprehensive local assessment and active participation of local farmers to evaluate the empirical challenges and perpetually redesign the most locally-fitted diversification practices.

Keywords: adoption, diversification, legume, conservation agriculture
Abbreviations: Conservation Agriculture (CA)

Banjarnahor D, Scholberg J, Almekinders C. 2015. Diversifikasi tanaman berbasis legume yang dapat dipelajari dari petani skala kecil pada kawasan semi-arid di Tanzania. Pros Sem Nas Masy Biodiv Indon 1: 667-672. Dari generasi ke generasi, petani skala kecil di dataran tinggi semi-arid Mbeya Tanzania Afrika Timur bertanam jagung (*Zea mays*) dan kacang (*Phaseolus vulgaris*). Kendala utama yang mereka hadapi adalah kekeringan dan kelangkaan air, penurunan kesuburan tanah serta hambatan finansial untuk membeli pupuk. Penerapan pertanian konservasi berbasis reduksi pengolahan tanah, penutupan permukaan tanah, dan diversifikasi tanaman diharapkan dapat menjadi solusi. Meskipun introduksi pertanian konservasi oleh promotor telah dilakukan selama hampir dua dekade, laju adopsi oleh petani lokal masih rendah. Di dalam studi ini, implementasi prinsip diversifikasi tanaman dikaji untuk memahami adopsi yang tersendat. Sebanyak 46 petani peserta pelatihan pertanian konservasi, 4 pimpinan kelompok tani, dan 6 promotor menjadi narasumber studi kualitatif berbasis wawancara dan kunjungan lapangan ini. Beberapa tanaman legume berkemampuan fiksasi nitrogen tinggi telah diperkenalkan dan dipromosikan di kecamatan Mbeya pedesaan. Fungsinya adalah sebagai penyedia hara nitrogen, penutup tanah, serta sumber bahan organik. Adopsi kara benguk (*Mucuna pruriens*), kacang gude (*Cajanus cajan*), dan kacang komak (*Dolichos lablab* L.) oleh petani lokal ternyata tidak bertahan lama; hanya 1-3 musim tanam. Petani menyaksikan keefektifan kara benguk dan komak dalam konservasi tanah dan menekan pertumbuhan gulma tetapi tidak melanjutkan pertanaman karena absennya pasar. Mayoritas masyarakat tidak melihat manfaat praktis kara benguk dan komak. Petani mengkonsumsi gude tetapi ketersediaan benih habis setelah konsumsi. Sistem pertanian campuran berbasis ternak yang merumput bebas (*free-grazing mixed farming system*) mengakibatkan gude dan komak tidak berumur panjang di lahan. Mayoritas petani akhirnya mempertahankan kombinasi jagung dan kacang. Sangat nyata bahwa upaya penganekaragaman dalam sistem pertanian skala kecil harus mengantisipasi tantangan pragmatis, sehingga dapat cocok dengan konteks lokal. Desain keanekaragaman agroekosistem tertentu berpotensi meningkatkan produksi tanaman dan mengatasi keterbatasan petani. Akan tetapi, kesuksesan implementasinya memerlukan kajian lokal yang komprehensif dan partisipasi aktif petani untuk mengevaluasi permasalahan empirik di lapangan dan secara terus menerus merancang praktik diversifikasi yang sesuai lokalitas wilayah.

Kata kunci: adopsi, diversifikasi, legume, pertanian konservasi

INTRODUCTION

Conservation agriculture (CA) is increasingly promoted in semi-arid Africa as a technological package to combat soil degradation and increase agricultural production. The Food and Agriculture Organization (FAO) defines it as an approach to managing agroecosystems with three underlying principles: (i) minimum soil disturbance, (ii) permanent soil cover, and (iii) effective use of crop diversification. The implementation of these linked principles is considered to promote soil properties, ecosystem services, farm productivity and farm economics (Scopel et al. 2005; Bescansa et al. 2006; Rocktrom et al. 2008; Kassam et al. 2009; Castellanos-Navarrete et al. 2012; Flower et al. 2012; Thierfelder and Wall, 2012; Moitzi et al. 2013; Nguema et el., 2013; Ngwira et al. 2013). These anticipated benefits are therefore incentives offered by CA proponents (Giller et al. 2011).

In Tanzania, CA has been introduced since the late 1990. One region with long history of CA dissemination is the Mbeya rural district in the southern highlands zone. It lies at the altitude of 500-2981 meters above sea level (m. asl) (NSCA 2007). Its climate is semi-arid to sub-humid. Arable land, predominantly managed by smallholders, covers 70% of the region (Mkomwa et al. 2007). Average annual temperatures range between 16°C in the highlands and 25°C in the lowlands with annual rainfall between 650-2600 mm. Poor and shallow soils are found on mountain summits and slopes while more fertile clay soils may occur in the valleys (Tittonell et al. 2012). Potential evapotranspiration exceeds rainfall thus results in moisture stress. Due to scarce vegetation, the soil is bare and high intensity rainfall on slopes may result in erosion (Lugandu et al. 2012). In this context CA appears to be promising in reverting soil degradation.

Crop diversification as one pillar of CA is one subject to which particular attention has been given. Diversification, either as intercropping or rotation, has been widely integrated in cropping system to enhance nutrient cycle, prevent pest explosion and establish self-reliant farms. The introduction of new cover crops, usually highly nitrogen-fixating legumes, is one diversification strategy included in CA. Nonetheless, various studies had shown that such approach may not always satisfy farmers' circumstances and interests. While maize-pigeon pea intercropping in Mozambique worked perfectly due to the functional market (Rusinamhodzi et al. 2012), the shortage of seeds, absence of immediate benefits and the dysfunctional market had triggered legumes disintegration in other African regions (Mazvimavi and Twomlow, 2009; Lahmar et al. 2012; Thierfelder et al. 2013b).

In this study we investigated the current progress of legumes integration among the smallholders in Mbeya rural district as resulted from CA promotion. We sought to understand the key factors leading farmers to approve legumes. The result shall be useful to building better comprehension on the potentially supporting or hindering factors of adoption and to developing a more effective mechanism to upscale agroecosystem diversification.

MATERIALS AND METHODS

Study sites

The study sites were four neighboring villages whose farmers groups were currently learning CA through the Farmers Field Schools. These remote villages lay on the foothill of Mbeya range forest (22,260 ha) and expand up to Songwe valley (1000-1500 m. asl). They were Mshewe, Muvwa, Njelenje, and Mapogoro. Mshewe was approximately 18 km away from town. The distance from one village to the subsequent one ranged from 5-8 km.

Methods

Data collection took place from November 2013 to January 2014. The main tools used were survey, interview, and farm visitation. There were 85 farmers registered in the CA training group. A face-to-face individual survey was conducted with 46 members who represented 43 households. Semi-structured interviews were conducted with key informants: 4 group leaders, and 6 officers from the Agricultural Research Institute Uyole, the District Agricultural and Livestock Development Office (DALDO), and the African Conservation Tillage Network who acted as the promoters and trainers. Subsequently, farm visitation were conducted to document what and why farmers had been conducting with respect to the newly introduced legumes. An open interview and casual conversation were carried out to this end.

Data analysis

Descriptive statistical analysis was performed to understand the adoption trend among farmers since their initial engagement with newly introduced legumes. Qualitative analysis was carried out to understand farmer's rationales in approving or rejecting particular legumes. Crop yield data based on information provided by farmers could not be evaluated in an accurate manner. This was due to data inaccuracy after reconfirmation. Nonetheless, this shall not disrupt the aim of this study.

RESULTS AND DISCUSSION

Local farming system

The biophysical characteristics and local livelihood of the four villages were similar (Table 1). All inhabitants were smallholder farmers with an average landholding of 1.52 hectare. Combination of crop and animal production was prevalent. The main cropping season ran from November to June with maize (*Zea mays*) and beans (*Phaseolus vulgaris*) as the major crops. The seeds used by farmers were mostly local. Some farmers also cultivated other crops (sunflower, vegetables, tubers, coffee) but in a confined area. The arable lands and homesteads were fallow during the dry season. Very few farmers could access the springs on the foothill of Mbeya range forest for the off-season farming.

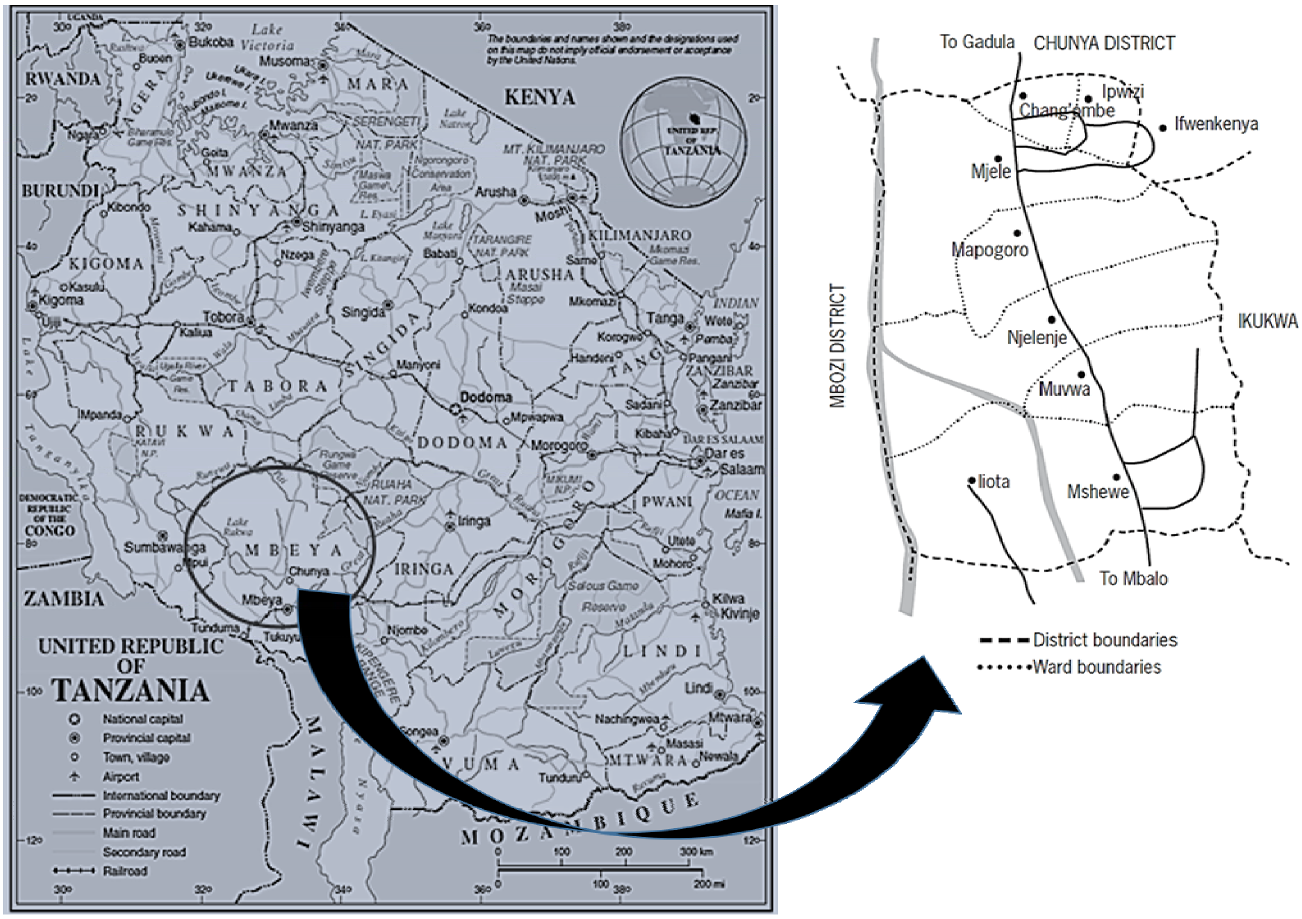

Figure 1. The location of the study sites. Source: United Nations and Mkomwa et al. (2007)

Table 1. Profiles of the four villages where the current CA training had been taking place.

Characteristics	Mshewe	Muvwa	Njelenje	Mapogoro
Size (ha)	1427.8	2205.1	4373.9	1657.4
Water resource	Spring and stream.	Stream.	A distant small stream.	Distant small spring and stream.
	Several public faucets in village center.	Few public faucets in village center.	Three wells in village center.	Very distant wells.
	Accessible easily the whole year.	Accessible easily the whole year.	Water availability was a major constraint.	Water was not easily accessible.
Soil properties	Moderately acidic (pH 5-6). Total nitrogen content: 0.06% to 0.21%. Total organic carbon: 0.5% to 2%. Total Cation Exchange Capacity (CEC). 6-15 cmol kg^{-1}. Gradient of physical soil properties: - Darker and softer silt loam and silt clay top soil around the Mbeya range forest. - Pale, drier, harder loamy clay, sandy loam, clay top soil with yellowish/brownish subsoil around the Songwe valley. Njelenje and Mapogoro were rock-shelter with the debris of volcanic eruptions (Delvaux et al. 2013).			
Food crops	Maize, beans, banana, paddy rice, sweet potato, cassava, potato, groundnuts.	Maize, beans, banana, sweet potato, cassava, groundnuts.	Maize, beans, sweet potato, cassava, potato, groundnuts.	Maize, beans, banana, sweet potato, cassava.
Cash crops	Vegetables, sugarcane, sunflower, and few coffee.	Vegetables, sugarcane, sunflower, and few coffee.	Vegetables, sunflower, and few coffee.	Vegetables and sunflower.
Animals	Poultry, pig, goat, and cattle were major animals in all villages.			
Grazing land	Family land, communal grazing land nearby the foothills of Mbeya range forest and Songwe valley, and other farmlands. Fencing the farms or homestead was not custom; animals roamed and grazed freely.			

Farmers practiced monoculture, intercropping, and rotation which were passed down generations. The major intercropping combined maize and beans. Recently, sunflower was also included. Crop rotation alternated maize and beans. Farmers practiced rotation with beans to maintain soil fertility. Farmers were aware of the poor soil condition therefore ploughing was important to make the soil friable. Furthermore, farmers recognized the importance of inorganic fertilizers to boost production thus inorganic fertilizer shall always be purchased despite of the high price (Table 2).

Animal husbandry was free-range and the animals were local bred. Since farmers were not familiar with composting, they collected the dry farm yard manure then scattered it in the homestead. The use of farm yard manure was limited due to its low availability.

Crop diversification training and actual adoption

At the moment of the study, farmers learned legumes intercropping and rotation from the group demonstration plot. The new legumes introduced were lablab (*Dolichos lablab*) and pigeon pea (*Cajanus cajan*). In the past, mucuna (*Mucuna pruriens*) was also promoted. Farmers had been showing different attitudes toward these various legumes (Table 3).

Based on farmers' experiences-based evaluation, key factors determining the successful diversification strategy were observed. Napier and Camboni (1993) and Traore et al. (1998) found that awareness on soil problems could positively be related to farmers' conservation attitude. In the context of Mshewe, despite of farmer's awareness of the low soil fertility and their understanding of legumes functions for soil improvement, they had not yet ultimately approved the new legumes.

Table 2. The local monetary values of important farm management components.

Variable	Tariff/price		
Farm operation			
Land rent	TZS	74100	per ha/2 years
Labor for ploughing	TZS	74100-98800	per ha
Labor for weeding	TZS	49400-74100	per ha
Inputs			
Hybrid maize seeds	TZS	4000	per kg
Fertilizer	TZS	50000 - 55000	per bag of 50 kg
Subsidized fertilizer	TZS	27000	per bag of 50 kg
Outputs			
Maize	TZS	4000 - 7000	per tin
Beans	TZS	15000 - 25000	per tin
Sunflower	TZS	5000 - 6000	per tin
Mature chicken	TZS	7000-10000	Each
Mature goat	TZS	40000-50000	Each
Mature pig	TZS	60000-70000	Each
Mature livestock	TZS	300000-400000	Each

Note: 1 tin = 20 kg. TZS 2285 = € 1 (http: //www.boatanzania.com, 17 February 2014).

Table 3. Local farmers' implementation of legumes diversification.

Action	Number of households	Land size (ha)	Period of integration	Evaluations
Trialing "Legumes intercropping in small plots"	21	0.1-1.2	1-3 seasons	- Lablab improved soil moist - No maize yield improvement - No direct benefits of lablab - Pigeon pea was edible - Legumes must be edible or marketable - Small ruminants grazed on pigeon pea and lablab - Beans performed better for soil productivity
Adopting "Integrating legumes continuously in larger area"	2	1.8	> 3 seasons	- New legumes improved soil moist - Mucuna and lablab suppressed weeds - Maize yield improved after 2-3 years - Mucuna was feedstuff - Lablab and pigeon pea were foods - Animals liked pigeon pea and lablab - Seeds were not available in the market
Ignoring	10	-	-	- More efforts but no direct benefits
Abandoning "Abandoning legumes after experimentation"	10	0.1-0.2	1-3 seasons	- Mucuna and lablab retained soil moist - No benefits of mucuna and lablab - Mucuna and lablab attracted snakes - Pigeon pea seeds were unavailable after consumption - Pests attacked lablab

Farmers witnessed the effectiveness of the broad-leaves mucuna and lablab to maintain soil moist and suppress weeds but they preferred the edible pigeon pea. Most farmers abandoned mucuna few years ago as the market was dysfunctional. Farmers who were still trialing lablab and pigeon pea had already shown their intention to drop lablab as they could not acquire its pragmatic use. Farmers were evidently risk-averse to the new legumes since they did not experience the paybacks. Therefore, in majority they maintained maize and beans. This low adoption rate could be exacerbated by the current evaluation by some farmers who failed to see the superiority of the new legumes diversification over their prevalent maize-beans combination.

As Feder (1980) and Feder et al. (1985) proposed on the early adoption concept; farmers consider the risk and uncertainties of a new technology. Innovation is likely to be adopted when it has high relative advantage (Pannell et al. 2006); the degree to which an innovation is perceived as better than the practice it surpasses (Rogers, 2003). This advantage depends on adopter's personal goals, biophysical and socioeconomic context. Smallholders were relatively reserved on experimenting as they depreciated risks coming with the new technology. While waiting for the proof on the benefits of a new innovation, they continued with the current practices (Nkala et al. 2011).

This hostile attitude emerged due to major incompatibilities of newly introduced legumes with farmer's conditions. Incompatibility may oppose farmer's personal values and prevailing circumstances (Pannell et al. 2006). Incompatibilities emerged in form of the less immediate impacts of legumes on farmers' livelihood, the unsuitability of particular legumes with the communal husbandry issue, the absence of market to access required resources (particularly seeds and pesticides) and sell harvests, and the unsolved local agronomic issues of new legumes (mainly pests). Empirical challenges and constraints were continuously encountered by farmers as resulted by the less compatible diversification propositions thus farmers ceased.

Lastly, there seemed to be rather weak social network hampering individual farmers to upscale particular legumes. This can be seen from the peculiar phenomenon with lablab; while few farmers had knowledge on the use of this crop, many were not aware of such benefits. The majority remained inexperienced thus indifferent about its potential. In this unique case, there is a room of improvement nevertheless to strengthen the local network and facilitate knowledge share for better advocate of legumes diversification.

Departing from this situation, it is clear that there is a need to tackle the current challenges and constraints encountered by farmers in Mshewe. The comprehensive assessment of the local context and an approach that focuses on farmer's experiential learning process (Carruthers et al. 2012) then shall be emphasized. It is necessary to involve farmers in evaluating diversification scheme in accordance with their pragmatic localities. Farmers' experiences and evaluations are important resources in perpetually redesigning the most acceptable diversification practices that fit the local context. Only by continuously acknowledging farmer's participation then agroecosystem diversification design can be well established.

The adoption of newly introduced legumes as part of diversification proposition has been rather low in Mshewe. Very few farmers were confident to accept the new legumes while others remained questioning while trialing and waiting for the proven benefits. This has resulted from the less compatible design of legumes diversification to the local context thus many challenges and constraint showed up on field. Learning from farmers' experiences and evaluation in integrating newly introduced legumes into their local farming system than shall be one key strategy in designing and promoting any diversification technology. Active participation of farmers must be encouraged to perpetually evaluate and redesign the most feasible and locally-accepted diversification practices.

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REFERENCES

Bescansa P, Imaz MJ, Virto I, Enrique A, Hoogmoed WB. 2006. Soil water retention as affected by tillage and residue management in semi-arid Spain. Soil Till Res 87: 19-27.

Carruthers G, Vanclay F. 2012. The intrinsic Features of environmental management systems that facilitate adoption and encourage innovation in primary industries. J Environ Manag 110: 125-134.

Castellanos-Navarrete A, Rodriguez-Aragonés C, de Goede RGM, Kooistra MJ, Sayre KD, Brussaard L, Pulleman, MM. 2012. Earthworm activity and soil structural changes under conservation agriculture in Central Mexico. Soil Till Res 123: 61-70.

Delvaux D, Kervyn F, Vittori E, Kajarn R, Kilembe E. 1998. Late quaternary tectonic activity and lake level change in the Rukwa rift basin. J African Earth Sci 26: 397-421.

Feder G. 1980. Farm size, risk aversion, and the adoption of new technology under uncertainty. Oxford Econ Pap 32 (2): 263-282.

Feder G, Just R, Zilberman D. 1985. Adoption of agricultural innovations in developing countries: a survey. Econ Dev Cult Change 33(2): 255-298.

Flower K, Cordingley N, Ward P, Weeks C. 2012. Nitrogen, weed management and economics with cover crops in conservation agriculture in a Mediterranean climate. Field Crops Res 132: 63-75.

Giller KE, Corbeels 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 Crops Res 124: 468-472.

Kassam A, Friedrich T, Shaxson F, Pretty J. 2009. The spread of conservation agriculture: justification, sustainability and uptake. Intl J Agric Sust 7 (4): 292-320.

Lahmar R, Bationo BA, Lamso ND, Guéroc Y, Tittonell P. 2012. Tailoring conservation agriculture technologies to West Africa semi-arid zones: building on traditional local practices for soil restoration. Field Crops Res 132: 158-167.

Lugandu S, Dulla H, Ngotio D, Mkomwa S. 2012. The extent of adoption of conservation agriculture with trees by smallholder farmers in Tanzania. African Conservation Tillage Network, Dar es Salaam, Swedish International Development Cooperation Agency, and World Agroforestry Centre.

Mazvimavi K, Twomlow S. 2009. Socioeconomic and institutional factors influencing adoption of conservation farming by vulnerable households in Zimbabwe. Agri Syst 101: 20-29.

Mkomwa S, Mussei A, Mwakimbwala R, Mulengera N, Kiranga E. 2007. Mbeya District. In: Shetto R, Owenya M. 2007. Conservation Agriculture as Practiced in Tanzania: Three Case Studies. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of the United Nations, Nairobi.

Moitzi G, Szalay T, Schüller M, Wagentristl H, Refenner K, Weingartmann H, Liebhard P, Boxberger J, Gronauer A. 2013. Effects of tillage systems and mechanization on work time, fuel and energy consumption for cereal cropping in Austria. Agric Eng Int: CIGR J 15(4): 94-101.

NSCA. 2007. National Sample Census of Agriculture 2002/2003; Regional Report Mbeya Region. Dar es Salaam: National Bureau of Statistics, Ministry of Agriculture and Food Security, Ministry of Water and Livestock Development, Ministry of Cooperatives and Marketing, Presidents Office, Regional Administration and Local Government The United Republic of Tanzania.

Napier T, Camboni S. 1993. Use of conventional and conservation practices among farmers in the Scioto river basin of Ohio. J Soil Water Conserv 48 (3): 231-237.

Nguema A, Norton G, Alwang J, Taylor D, Barrera V, Bertelsen M. 2013. Farm-level economic impacts of conservation agriculture in Ecuador. Exp Agric 49 (1): 134-147.

Ngwira AR, Thierfelder C, Lambert DM. 2013. Risk and maize-based cropping systems for smallholder Malawi farmers using conservation agriculture technologies. Exp Agric: 1-21. DOI: 10.1017/S0014479713000306.

Nkala P, Mango N, Corbeels M, Veldwisch G, Huising J. 2011. The conundrum of conservation agriculture and livelihoods in Southern Africa. African J Agric Res 6 (24): 5520-5528.

Pannell D, Marshall G, Barr N, Curtis A, Vanclay F, Wilkinson R. 2006. Understanding and promoting adoption of conservation practices by rural landholders. Australian J Exp Agric 46: 1407-1424.

Rogers E. 2003. Diffusion of Innovations. Free Press, New York.

Rusinamhodzi L, Corbeels M, Nyamangara J, Giller KE. 2012. Maize-grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in Central Mozambique. Field Crops Res 136: 12-22.

Scopel E, Findeling A, Guerra EC, Corbeels M. 2005. Impact of direct sowing mulch-based cropping systems on soil carbon, soil erosion and maize yield. Agron Sust Dev 25: 425-432.

Thierfelder C, Wall PC. 2012. Effects of conservation agriculture on soil quality and productivity in contrasting agro-ecological environments of Zimbabwe. Soil Use Manag 28: 209-220.

Thierfelder C, Cheesman S, Rusinamhodzi L. 2013b. Benefits and challenges of crop rotations in maize-based conservation agriculture (CA) cropping systems of Southern Africa. Intl J Agric Sust 11 (2): 108-124.

Tittonell P, Scopel E, Andrieu N, Posthumus H, Mapfumo P, Corbeels M, van Halsema GE, Lahmar R, Lugandu S, Rakotoarisoa J, Mtambanengwe F, Pound B, Chikowo R, Naudin K, Triomphe B, Mkomwa S. 2012. Agroecology-based aggradation-conservation agriculture (ABACO): Targeting innovations to combat soil degradation and food insecurity in semi-arid Africa. Field Crops Res 132: 168-174.

Traore N, Landry R, Amara N. 1998. On-farm adoption of conservation practices: the role of farm and farmer characteristics, perceptions, and health hazards. Land Econ 74: 114-127.