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Crop Residue Management in Conservation Agriculture Systems in Zimbabwe Smallholder Farming Sector: Importance, Management Challenges and Possible Solutions

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Abstract

Conservation agriculture (CA) is promoted as a cropping system that has potential to alleviate poor crop yields in smallholder farming while protecting the environment. It involves maintenance of permanent soil cover, diverse crop rotations and/or interactions; and minimum soil disturbance. CA is associated with crop residue management challenges due to low crop biomass yields and crop-livestock interactions in Zimbabwean smallholder farming sector. There is competition on crop residue uses causing challenges in retaining adequate crop residues for full benefits of using residues to be realised. Among the crop residues management options fencing fields reduces the chances of crop residues grazing by free roaming cattle during the dry season. Construction of rakes to pile up crop residues where cattle cannot access has been practiced in some communal areas. Farmers have practised the system of taking the crop residue harvest to homesteads into protected areas to reduce risk of grazing. Farmers may use fences around fields to reduce access into fields. However, all these management options require an investment from the farmers who are resource constrained. Farmers may use non-crop residues such as thatch grass and reduce competition for crop residue use where farmers feed them to livestock during the dry season.

Keywords: Crop residue management, conservation agriculture, smallholder, permanent soil surface cover, management challenges

Introduction

Smallholder crop yields have remained low in Southern Africa and their increase has been very slow and this has been attributed to the detrimental effects of traditional ways of farming (Mazvimavi *et al.*, 2010). Traditional (conventional) farming involves the inversion of the soil using the mouldboard plough and this has led to enormous soil losses from arable lands hence, leading to low crop yields (FAO, 2002). There is a need to identify cropping systems that ensure the conservation of the soil and at the same time improving crop yields and conservation agriculture (CA) has been a suggested option to conserve the soil while at the same time improving crop yields. CA as defined by FAO (2002), is a cropping system that is based on three principles which are minimum soil disturbance, maintenance of a permanent soil cover by the use of crop residues and cover crops; and diverse plant associations (which include crop rotations). Minimum soil disturbance is achieved by disturbing only the area where seed and fertilizer are placed using the simple hand hoe or more sophisticated tractor drawn implements such

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as the Happy seeder© and hence maintaining soil structure, reducing water and wind erosion (Montgomery, 2007). Animal drawn direct seeders and Magoye chisel-tine opener (Magoye ripper) are also possible options that can be used in CA systems that ensure less soil disturbances. Permanent soil cover is attained by the retention of crop residues onto the soil surface.

The crop residues may be of the previous crop or may be imported into the field to achieve 30% or more ground cover (Berger *et al.*, 2012). A diversification of plants is achieved by practising crop rotations or intercrops with other plants. Crop rotations can break disease and pest cycles and hence, reducing management costs and may add in nitrogen if the associate crop is a legume hence, reducing production costs at the same time improving yields (Thierfelder *et al.*, 2012). The full benefits of CA are realised when the cropping system is adopted as a full package than adopting only one of the principles (Twomlow *et al.*, 2008). However, the adoption of CA as a full package in the smallholder farming sector of Zimbabwe is apparently slow as well as its growth to a larger scale (Chiputwa *et al.*, 2011; Mavunganidze *et al.*, 2013). Farmers are, in different circumstances and/or for different reasons, unable to adopt all three principles and this paper addresses the issue of crop residue management by smallholder farmers to achieve permanent soil cover, its importance, challenges that limit smallholder farmers in implementing this principle and the possible solutions to their challenges.

Importance of crop residues in smallholder farming systems

Crop residues are retained to the soil to achieve permanent soil cover which in-turn gives benefits to the farmer. Thierfelder and Wall (2008) described the retention of crop residues as the key drive in the positive realisation of the benefits of CA. Crop residues on the soil surface reduce direct raindrop impact on the soil hence reducing soil erosion (Anderson, 2009; Thierfelder *et al.*, 2013; Thierfelder and Wall, 2009). The presence of crop residues and considerable nitrogen applications has been shown to improve soil properties (physical, chemical and biological) (Ailincâi *et al.*, 2012). A build up in soil micro- and macro- fauna and an increase in biological activity of the soil have been reported when a permanent soil cover with crop residues is maintained and this improves soil properties such as porosity hence infiltration (Thierfelder and Wall, 2008). An increase in the microorganism population in the soil, facilitated by the presence of crop residues, ensures an increase in microbial decomposition of plant material hence an increased rate of build-up of organic matter, which leads to improved soil structure hence higher crop yields (Rengel and Singh, 2010). Crop residues prevent the hardening of the soil hence facilitate easier emergence of crops and also improves the cation exchange capacity of the soil hence easier availability of important micro elements to the crops (Batiano and Mokwunye, 1991). Nitrogen is an important element for crop growth and development and it is very essential in attaining high crop yields in smallholder agriculture and if legume residues such as of *Mucuna pruriens* (L.) are used as cover, their decomposition releases nitrogen into the system and hence greater yields (Erenstein, 2003). The amount of nitrogen released from the residues over time, however, depends on the quality of the residue (Schomberg *et al.*, 1994). Nitrogen may be supplemented to cropping systems in the form of urea, which can be hydrolysed to form an unstable compound carbamic acid. Carbamic acid can decompose rapidly to form ammonia and carbon dioxide (Teasdale *et al.*, 1985; Benini *et al.*, 1999). Ammonia is unavailable to plants and escapes into the atmosphere unless it reacts with water to form ammonium that is available to plants and hence the presence of crop residues ensures moisture conservation increasing the chances of ammonium formation. (Schwab and Murdock, 2005).

Ammonia volatilization affects the economic efficiency of cropping systems and is affected by several environmental conditions such as temperature, pH and soil moisture of which higher temperatures and drier conditions promote increased ammonia volatilization (Olson-Rutz *et al.*, 2011). The presence of crop residues conserves moisture and prevents direct heating of the soil surface by the sun, which reduces nitrogen volatilisation (Schwab and Murdock, 2005) which is an advantage to smallholder farmers who cannot input high levels of synthetic fertilizers. Crop residues can be a source of cattle feed during the dry season when most of the grazing pastures are exhausted (Jayasuriya and Owen, 1989).

Crop residue management, challenges faced by smallholder farmers and possible solutions to their challenges

Some smallholder farmers practicing CA understand the need for maintaining a permanent soil cover, but they produce inadequate crop biomass to meet the demand for the residue for different uses (Savadogo, 2000). Crop residues are used for different purposes other than soil surface cover in the field and these include feeding their livestock during the dry seasons and as a source of fire in countries such as Ethiopia (Tsigie *et al.*, 2011). Utilisation of crop residues can be through the brown route or the green route at farm level. In the brown route, farmers opt to feed their crop residues such as maize stalks to livestock (which are an important component of the smallholder farming system set up) during the dry season and then collect manure from the livestock and use it as a source of organic matter in their fields (Mafongoya, personal communication). This is a common method in Zimbabwean smallholder farming sector. If farmers opt to go the brown route, they compromise the use of residues for ground cover. However, farmers will still have an option of using other non-crop residues such as thatch grass (*Hyparrhenia filipendula*) (picture 1) and feed crop residue to livestock and then use their manure in the fields.

Picture 1: shows thatch grass used by farmers as supplementary soil surface cover in maize systems in Zimuto village of Masvingo in Zimbabwe

However, CA cropping system seems to favour the green route where crop residues are retained in the field as post-mortem green manure cover crops or as crop residue harvested at the end of the season (Saini, 2009). Due to the high demand for crop residues, there is need for sustainable crop residues management practices that ensures maintenance of a permanent soil cover in the CA plots. Among the management strategies for crop residues is fencing the farmers plots either with barbed wire or biological (live) fences that ensures that free roaming livestock do not get access to the crop residues in the fields (picture 1).

Even though fencing is an effective crop residues protection measure, most farmers are cash constrained to purchase wire fences or construct wooden fences. In the effort to protect crop residues, some farmers adopt the use of rakes constructed from wood which are more than one meter from the ground where cattle cannot reach the crop residues which they later spread the crop residues at the onset of the season. This has been a successful method commonly practised by communal farmers in Zimuto communal area (picture 2) who are practicing CA through facilitations by research institutes such as CIMMYT. This method is also applicable to fields that are far from the homesteads. Some farmers take their crop residues from the fields to their households where they closely monitor them and put them in protected places (picture 2) to reduce the risk of getting them grazed by cattle before the onset of the season. However, these methods of removing the residue and keeping it away from the field surfaces take away the essence of permanence in surface cover hence, allowing residual nitrogen to be lost from the cropping system through volatilization. Also, if it happens to rain during the off-season, rain drop impact on soil surfaces is not cushioned since residues would have been removed from the soil surfaces hence, soil erosion may occur.

Picture 2: (top) showing a maize residue rake at one of Zimuto communal farmer's fields to keep maize residue from grazing by stray cattle during the dry season; and (bottom) crop residues taken to a protected place near a homestead in Nyarukunda village of Zimbabwe

Although the removal of residue may be effective, it is labour intensive and keeps the farmer busy throughout the year. Labour availability in smallholder farming sector is inadequate hence, this may compromise the success of maintaining an important principle of CA.

Staking of crop residue on rakes also tends to shorten the period which micro- and macro-organisms would act on and decompose the residue for organic matter build up thereby compromising soil structure improvement.

In order to avoid grazing of crop residues by stray cattle or for easier management of the residue, farmers may also concentrate more on fields closer to the homestead for high yields where they easily manage the crop residue. Use of organic repellents to protect residues has been demonstrated and this is another option in the protection of crop residue from cattle grazing (Mutsamba *et al.,* 2012). Organic repellents are substances that can be used to deter certain species of animals from protected items or objects (Osko *et al*., 1993). Using this method ensures that the more labour intensive transfer of residues is eliminated since this can be done in the fields. Strengthening of strict grazing policies within communities may also ensure the banning of free-roaming cattle even during the off-season period to prevent grazing of crop residue hence, maintaining permanent soil surface cover. Improving soil fertility to boost crop yields through the use of synthetic fertilizers, leguminous cover crops and/ or organic manures is another option to improve crop biomass production hence, more biomass to meet the demands of all its farm household uses. Relay cropping or intercropping the main crops with non-palatable associate crops such as *Tephrosia vogelii* (L.) gives farmers an option to both feed the main crop residue to cattle and retain associate crop residue for ground cover or the other way round.

Conclusions

Crop residues are a very important component at smallholder farming level practising CA and if their use is managed well, they give considerable returns to crop-livestock systems. Maintenance of a permanent soil surface cover gives better benefits than when the residue is removed during the off-season. Smallholder farmers find permanent soil cover difficult or almost impossible to maintain due to the competition for crop residue for different household uses. The full benefits of the uses of crop residues as soil surface cover are not fully realised because the residues are removed at some point during the dry season. Cropping systems that supplement biomass such as intercropping reduce pressure on the crop residues and hence making it almost possible for permanent soil cover to be attained. The use of a fence to keep cattle out of the fields could be a considerable option since this ensures that crop residue are not grazed or moved thereby maintaining a permanent soil surface cover throughout the entire year. If wire fences are expensive farmers may also use live fences where they plant fast growing, thorny bushes or vines (e.g. *Bougainvillea spp*) around their fields to keep livestock out of their fields (Wall, 2009). Organic repellents are another affordable option that can protect crop residue from livestock grazing during the dry season. Measures that protect crop residues from being removed from the fields need to be considered as part of the CA farming system package for the benefits of the system to be fully realised.

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