



Enhancing Soil Fertility and Crop Productivity through Crop Residue Management: A Review

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ABSTRACT

Competing uses of crop residues and suggesting their management is one of the conservation agricultural practices which have a very efficient strategy to increase the soil fertility and crop productivity. Among the available organic sources of plant nutrients, crop residue is one of the most important sources for supplying nutrients to the crop and for improving soil health besides increasing the organic matter of the soil. Crop residue enhances the physical and chemical characteristics of soils and, in general, serves as a steady source of food for the fauna, flora and many creatures that inhabit the soil. The slope of the farmland determines how much crop residue is left on the farm. As a result, farmlands with steep slopes require a lot of crop leftovers, whereas farmlands with moderate slopes require fewer crop residues. The maintenance and productivity of the farmland, which results in fertile farmland and improved crop output, may be achieved if the principal obstacles pertaining to uses of agricultural leftovers were resolved.

Key words: Chemical and physical soil properties, Crop productivity, Crop residue, Depleted soil nutrients.

Modern agriculture faces soil fertility depletion and low crop productivity problems in different countries. Use of unbalanced, insufficient and pro-macronutrient fertilizers, as well as insufficient or no use of organic manures and crop wastes, as well as reduced use of high-quality biofertilizers, all contribute to a decline in soil fertility (Babu *et al.*, 2014). Crop residues are parts of the plants left in the field after crops have been harvested and thrashed. These materials have at times been regarded as waste materials that require disposal, but it has become increasingly realized that they are important natural resources and not wastes (Tesfaye Alemu *et al.*, 2006; Kumar and Goh, 2000).

According to Lemtiri *et al.* (2016), crop residues are not only the above-ground part not harvested for crop production, but also the below-ground parts known as root systems, which are consistently incorporated into the soil. To manage the residues in a productive and profitable manner, conservation agriculture (CA) offers a good promise. Crop residue can minimize the rain drop impact and splash erosion problems on the cultivated field (Lemtiri *et al.*, 2016). Soil cover is one of the most critical factors in ensuring the success of CA. In conventional agricultural systems, residues are usually fed to animals and the animals manure was not returned into the soil (Gete *et al.*, 2010). The nutrient cycle is so opened and this leads to depletion of soil nutrients. In many places communal grazing rights are observed and protecting the residues on the fields from free roaming animals.

With the adoption of conservation agriculture-based technologies crop residues can be used for improving soil health, increasing crop productivity, reducing pollution and enhancing sustainability and resilience of agricultural crop production. The resource conserving technologies (RCTs) involving no or minimum tillage, direct seeding, bed planting

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and crop diversification with innovations in residues management are the possible alternatives to the conventional energy and input-intensive agriculture. In the past, role of crop residues has been viewed and evaluated largely in terms of nutrients balance, maintaining biodiversity, greenhouse gases (GHGs) mitigation, improved input-use efficiency, sustaining agriculture and human health (IARI, 2012).

Low levels of soil organic matter, appearance of multiple nutrient deficiencies due to over mining from soils and poor management of crop residues (CRs), leading to lower yield of crops were observed in general in developing countries and in particular in Ethiopia (Singh and Sidhu, 2014). Crop residues are good sources of plant nutrients, primary source of organic matter (as C constitutes about 40% of the total dry biomass) added to the soil and important components for the stability of agricultural ecosystems. Recycling of crop residues has to be one of the ways of improving soil nutrient content and maintaining soil productivity (Ogbodo, 2011). Almost all crop residues were removed from the cultivated land and nothing is returned to the cultivated land so that depletion of soil nutrients and lower crop yield productivity are the major problems created especially in developing countries.

Therefore, the main objective of this paper is to review the impacts of crop residue management for enhancing soil fertility and crop productivity.

The materials for the compilation of this paper, different literatures on enhancing soil fertility and crop productivity through crop residue management was reviewed from books, journals and proceedings from internet sources. The methods of this paper would be organizing the obtained resources from the internet and then it was written by taking the ideas of the resources what the literatures really said about the impacts crop residues management on enhancing soil fertility and crop productivity perspectives.

Management options for crop residues

Crop residue management (CRM) can be defined as a technology whereby at the time of crop emergence at least 30% of the soil surface is covered by organic residue of the previous crop (Erenstein, 2002). Some countries have developed strategies for successful management of crop residues to avoid on-farm burning. Crop residue usage for crop production perspectives depends on the availability of crop residues in the areas (Valbuena *et al.*, 2015).

The root cause of degradation of agricultural land is its low soil-carbon content that disrupts many important soil-mediated ecosystem functions. Conservation agriculture, with the following three core inter-linked principles, is a viable option for sustainable agriculture and is an effective solution to check land degradation (IARI, 2012):

- Minimizing mechanical soil disturbance and seeding directly into untilled soil to improve soil organic matter content and soil health.
- Enhancing organic matter cover on soil using cover crops and/or crop residues. This protects the soil surface, conserves water and nutrients, promotes soil biological activity and contributes to integrated pest management;
- Diversification of crops in associations, sequences and rotations to enhance system resilience.

Permanent crop cover with recycling of crop residues is a pre-requisite and integral part of conservation agriculture. However, sowing of a crop in the presence of residues of preceding crop is a problem. But new variants of zero-till seed-cum-fertilizer drill/planters, Turbo Seeder and rotary-disc drill have been developed for direct drilling of seeds even in the presence of surface residues. These machines are very useful for managing crop residues for conserving moisture and nutrients as well as controlling weeds in addition to moderating soil temperature (IARI, 2012).

Benefits of crop residues on soil properties

Crop residue is one of the most important conservation tillage factors for improving physical and chemical soil properties (Meena *et al.*, 2015). Combined application of crop residues and chemical fertilizers can balance the soil properties and increases the crop yields (Linquist *et al.*, 2007). Residue helps reduce surface run-off and soil loss, conserving soil moisture and improving soil microorganism populations, soil organic matter content and soil hydraulic/

physical properties (Olaoye, 2002). The effectiveness of residue is linked to the soil topography and slope that affect the sustainability of the residue on the soil surface. Relatively flat fields can be protected against water erosion with 12 to 20% residue cover. Fields with steeper or longer slopes require at least 50 to 60% residue cover.

According to IARI, (2012), beneficial effects of residues depend on distribution, quality and quantity of residues. If residues are standing, they might not adequately intercept vertically falling raindrops compared to flat residues. Quality of residues, which is defined on the basis of the carbon to nitrogen (C: N) ratio determine turnover rates and precursors for SOM build up. Depending on the chemical composition particularly C: N of crop residues and organic matter, decomposition is rapid if it is dominated by sugars, starches and proteins; slow when dominated by cellulose, fats, waxes and resins or very slow when dominated by lignin.

Impact of crop residues on soil fertility and crop yields

Crop residues play an important role in the cycling of nutrients (Singh *et al.*, 2019; Singh and Sidhu, 2014). It has a residual effect to improve the soil fertility and crop productivity as compared to inorganic sources (Dhar *et al.*, 2014). Crop residue had significantly higher levels of pH, total N, available P and exchangeable K, Ca and Mg than crop residue treatments were not applied (Mbah and Nneji, 2011; Ogbodo, 2011; Singh *et al.*, 2008; Mandal *et al.*, 2004). This was as a result of the release of the organic forms of those elements in the residue. Incorporation of crop residues into soil or retention on the surface has several positive influences on physical, chemical and biological properties of soils. These practices increase hydraulic conductivity and reduce bulk density of soil by modifying soil structure and aggregate stability (Lemtiri *et al.*, 2016). Mulching with plant residues raises the minimum soil temperature in rain-season due to reduction in upward heat flux from soil and decreases soil temperature during dry-season due to shading effect.

The crop residues act as a reservoir for plant nutrients, prevent leaching of nutrients, increase cation exchange capacity (CEC), provide congenial environment for biological N₂ fixation, increase microbial biomass and enhance activities of enzymes such as dehydrogenase and alkaline phosphatase. Increased microbial biomass can enhance nutrient availability in soil as well as act as sink and source of plant nutrients. Crop residues provide a constant food source for soil fauna, flora and a habitat for many organisms (Tilak, 2004). The crop residues play an important role in amelioration of soil acidity through the release of hydroxyls especially during the decomposition of residues with higher C: N and soil alkalinity through application of residues from lower C: N crops, including legumes, oilseeds and pulses. The role of crop residues on carbon sequestration in soils would be an added advantage in relation to climate change and GHGs (greenhouse gases) mitigation besides to soil fertility and crop yield productivity (IARI, 2012).

Establishment and maintenance of soil health is inextricably linked to the achievement of effective and efficient nutrient management goal in conservation agriculture. The conservation agriculture builds a stratified layer of crop nutrients, especially P on or near the soil surface. While reduced tillage and soil organic C build-up contribute to stable soil structure. This undisturbed structure produces macro-pores and preferential flow channels that can direct nutrients, including P, downward into deeper parts of the soil profile. The choice of cropping systems can have a strong influence on the soil quality through processes such as nutrient depletion and/or enrichment through production of biomass/crop residues, need for external inputs and impact on environment (IARI, 2012). Crop residue incorporation is one of the ideal management practices for improving soil fertility and crop productivity (Singh *et al.*, 2019; Tilak, 2004).

Yield response with crop residues management varies with soil characteristics, climate, cropping patterns and level of management skills. Higher yields with crop residues application result from increased infiltration and improved soil properties, increased soil organic matter and earthworm activity and improved soil structure after a period of 4-7 years (IARI, 2012). The improvement of soil chemical properties of the residue treated plots provided adequate environment for superior crop growth and yields than on the plots without residue treatments (Getachew *et al.*, 2012; Guto *et al.*, 2011; Ogbodo, 2011).

The crops could also have benefited from the changes in soil physical properties that result from treating soil with organic residues, including reduced soil density, increase soil aggregation, increase porosity, lower soil temperature, reduce resistance to root penetration, increases water infiltration and moisture retention, increase soil aeration and reduce loss of water to run-off (Lemtiri *et al.*, 2016). Crop residues physically slows down the velocity of rainfall before it comes into contact with the soil surface, preventing soil splashing and erosive surface run-off (Karuku *et al.*, 2014). The optimum crop growth and the highest grain yield were achieved from the highest crop residues and N rates (Keshavarznejad *et al.*, 2015; Okonji *et al.*, 2011; Sadeghi and Bahrani, 2009).

Constraints of using crop residue management

Major constraints to successful crop residue management in CA systems are related to the small baseline crop productivity and other alternative economic uses of crop residues such as livestock feed (Mhlanga and Muoni, 2014), fuel, bedding in kraals (animal paddocks) during the rainy season and construction (fencing and thatching) for some farming households. A series of challenges exist in using crop residues in conservation agriculture systems. These include difficulties in sowing and application of fertilizer and pesticides and problems of pest infestation (Scott *et al.*, 2010). Further limiting factor in adoption of residues incorporation systems in conservation agriculture by farmers include

additional management skills, hesitation of lower crop yields and/or economic returns, negative attitudes or perceptions and institutional constraints. In addition, farmers have strong preferences for clean and good looking tilled fields vis-a-vis untilled shabby looking fields (IARI, 2012).

CONCLUSION

Lower organic matter content of the soil brings soil nutrient depletion and lowers crop productivity. Crop residues were used as livestock feed, fuel and industrial raw materials. Crop residues, either partly or entirely must be used for conservation agriculture for ensuring the country's food security, making agriculture sustainable and the soil resource base healthy. All stakeholders *viz.* farmers, supply and value chain service providers, researchers, extension agents, policymakers, civil servants and consumers need to be engaged in understanding and harnessing the full potential of these valuable resources for sustainability and resilience. It is believed that the research, policy and development programs as outlined in this review paper will serve a great deal in managing crop residues at local and regional scales in order to improve the soil fertility and crop productivity in the country.

RECOMMENDATIONS

Soil fertility depletion and lower yield of crops are the most recently event that brings food insecurity so that crucial management options of crop residues should be addressed in order to tap the productive capacity of the cropping land. Therefore, the following recommendations should be practiced to sustain the soil fertility and crop productivity under crop residue management situation:

- Quantifying the recommended amount of residues of different crops which can be incorporated/retained, depending on the cropping systems, soil characteristics and climate without creating operational problems for the next crop or chemical and biological imbalance.
- Analyzing the C: N ratio before you apply crop residues on crop lands.
- Analyzing the benefit: cost, socio-economic impact and technical feasibility of off- and on-farm uses of crop residues.
- Developing a crop residues management policy for cropping lands defining clearly various competing uses in the country; provide modern cooking methods.
- Classifying crop residues as amendments and their use in agriculture should attract subsidy like any other mineral fertilizer or amendment.

Conflict of interest

There is no any conflict of interest among authors.

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