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Review Article

Conservation Agriculture: The dynamics of Ecology and Ecological Services

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Abstract

The green revolution in India has basically been the resultant of seed-fertilizer-water application with massive participation of famers, scientists and executor at different level to usher a quantum jump of food grain production, from 55 MT(1955) to 120 MT(1970). But the dividend of green revolution has been outnumbered by fall out in ecological balances due to injudicious use of agrochemicals associated with farm mechanization led soil erosion and compaction. The skewed focus on selected high yielding gene in rice and wheat has been responsible for loss of crop biodiversity. In our operating agro-ecosystem, the provider of food-fuel-fodder, water is contaminated, soil is eroded, organic carbon is depleted and biodiversity is marginalized. So, we need to have Conservation Agriculture through minimizing soil disturbances, retention of crop residues and sustainable intensification in classical crop rotation. All these being done with a goal to protect and preserve our precious natural resources, stabilizing and augmenting food production and livelihood for millions, and, of course making our agro-ecosystem more resilient to generate dedicated ecological services to mankind and other life forms to save our civilization. The text of conservation agriculture is more contextual when the brunt of climate change is becoming more deleterious and complex. The issues of farmers' participation stand so critical simply because without their participation, no conservation agriculture is possible.

Keywords: Conservation agriculture; Climate change; Ecological services, Ecological resilience, Retention of crop residue.

Introduction

Poverty, pollution and erosion are the three deleterious issues to civilisations and agriculture, perhaps, the worst affected, sector of ecological and economic concerns. Every year, around 15–18 tonnes of top soils are eroded off to add to the impoverishment of soil regime. On the other side, the energy prodigal nature of agriculture along with over exploitation of ground water have added to the misery of our key production ecology.

Conservation agriculture is mainly a concept for resource-saving agricultural crop production to achieve acceptable profits along with high and sustainable production levels subsequently conserving the environment" (FAO 2007). So, it has evolved as an alternative approach to conventional agricultural systems in which tillage is practised to varying levels to control weeds, pests, nutrient incorporation and to check soil compaction problems where conservation agriculture helps to maintain, to the extent possible, a year-round soil cover by residue retention from previous crops or incorporation from another field/crop and/or a cover crop to improve the soil quality and minimal soil disturbance by no or reduced tillage practices and through crop diversification and/or crop rotations to restrict the pest problems (Dillaha et al.).

Globally, as an estimate, 1.53 billion hectares of cropland (Thenkabail et al., 2009) in 2009, are covered under conventional tillage. Global cropland under conservation agriculture in 2009 was approximately 106 million hectares (Derpsch et al., 2009) where in conservation tillage seeds are planted into untilled soil by opening either a narrow slot, trench or band only of sufficient width and depth to obtain proper seed coverage.

Conservation agriculture is being adopted rapidly in both developed and developed countries, mainly larger land holders are eager to adopt with the exception of Brazil, where conservation agriculture has been adapted by many small farmers. In general, perceived benefits of conservation agriculture includes more profitable and sustainable agricultural production, reduced fuel and machinery costs, reduced pesticide costs, improved opportunities for double and triple cropping, higher yields, improved soil quality, restored soil biodiversity, reduced erosion and depletion, improved soil water management, soil carbon sequestration (improved soil quality and carbon sequestration for benefit in terms of climate change), and water quality management due to possible reductions in leaching losses of agrochemicals, sediment, and organic matter from cropland.

And also there are many potential ecosystem services associated with the practice of conservation agriculture. Ecosystem services are mainly, benefits to humans from the ecosystems. Ecosystem services were classified into the following categories of services by the Millennium Ecosystem Assessment (2005). Ecosystem services to which conservation agriculture may have significant contributions are,

Provisioning services: These are ecosystem products or functions that support different life systems in and around.

- food (including seafood and game), crops, wild foods, and spices
- water
- pharmaceuticals, biochemicals, and industrial products
- energy (hydropower, biomass fuels)

Regulating services: These are ecosystem functions that make the system deterrent of impurities, pollutants and regulate inhibitors to ecosystem resilience.

- carbon sequestration and climate regulation
- soil moisture storage
- regulation of stream flows and groundwater levels
- waste decomposition and detoxification
- purification of water and air
- crop pollination
- pest and disease control
- erosion control

Support services: The services that make the ecology more conducive to system productivity and resilience.

- nutrient dispersal and cycling
- seed dispersal
- primary production

Cultural services: This is related to functioning that supports aesthetics, entertainment, values and cultural ethos ofcommunity people and stakeholders.

- cultural, intellectual and spiritual inspiration
- recreational experiences (including ecotourism)
- scientific discovery

The erosion of ecology in natural resources

At present, food and agricultural systems have greater success in supplying large volumes of food to global markets. However, high-external input, resource-intensive agricultural systems have caused massive deforestation, water scarcities, biodiversity loss, soil depletion and high levels of greenhouse gas emissions. Despite significant progress in recent times, hunger and extreme poverty persist as critical global challenges. Even where poverty has been reduced, pervasive inequalities remain, hindering poverty eradication.

Restoration of ecology and ecological services through Conservation Agriculture

The core principles of agro-ecology (Archer S. 2008), and have the immediate objectives of:

1. building soil structure, improving soil

health, recycling nutrients and ensuring local sourcing,

2. conserving and using water efficiently,
3. sustaining and improving functional diversity (both on a spatial and a temporal scale).

Hence, conservation agriculture could help in the restoration and re-engineering of ecology including the agro-ecology to a great extent. Conservation agriculture may help in re-building agro-ecology by maintaining carbon sequestration, maintenance of soil health, by checking soil erosion and ground water depletion, energy balance, mitigating climate change related problems etc through maintaining ecosystem services.

Carbon Sequestration and Climate Regulation

One of the most positive aspects of conservation agriculture is its contribution to increase soil carbon compared with tillage-based conventional agriculture systems. Lal (2004) in his studies of the benefits of increasing soil carbon on its potential for carbon sequestration for climate regulation found that the carbon sink capacity of the world's agricultural and degraded soils is 50 percent to 66 percent of the global historic carbon loss of 42 to 78 gigatons of carbon and that improved land management practices on the world's agricultural and degraded soils could sequester 50 percent to 66 percent of the historic soil carbon loss. This is equivalent to 0.4 to 1.2 Gt C/year, or 5 percent to 15 percent of global carbon emissions. Lal also stated that the rate of increase in the Soil Organic Carbon (SOC) stock, through recommended management practices, follows a sigmoid curve, attains the maximum 5 to 20 years after adoption of recommended management practices, and continues until SOC attains a final equilibrium. Hillel and Rosenzweig (2009) also studied that the conversion to no-till farming increased soil organic carbon by rates varying from 0.1 to 0.7 Mg/ha-yr and, like Lal, indicated that such positive increments cannot be expected to continue indefinitely as well managed carbon depleted soils will tend to approach their natural equilibrium (or C saturation) state within a few decades. Lal (2004) reported similar rates of soil organic carbon sequestration in agricultural and restored ecosystems depending on soil texture, profile characteristics, and climate, which ranged from 0 to 0.15 Mg/ha-year in dry and warm regions, and 0.1 to 1.0 Mg/ha-yr in humid and cool climates.

Soil Moisture Storage

In semi-arid and arid regions, variable pattern of rainfall and scarcity are significant constraints to agricultural productivity and here, conservation agriculture would be expected to increase infiltration, soil moisture storage and utilization, and also water use efficiency. Unfortunately, in many low rainfall regions with significant dry seasons, it is difficult to maintain an effective soil organic matter cover because of competing uses as livestock feed or sometimes as fuel. In these cases, conservation agriculture may not work because of removal of the organic cover, even with no-till, results in bare soil and the formation of a soil crust, which will decrease the potency for water infiltration. This was stated by Rockström et al. (2009) in case of conservation farming strategies for arid and semi-arid agriculture in East and Southern Africa. It was seen that yields were higher with conservation agriculture than conventional tillage during drier rainy seasons but there was not much difference in yields during wetter rainy seasons suggesting that conservation farming in savannah agro-ecosystems may foremost function as a water harvesting system, which will enhance the ability of crops to check dry spells.

Water Productivity

The key principles for improving agricultural water productivity are to infiltrate as much precipitation or irrigation as possible while simultaneously reducing all soil water outflows, i.e. drainage, seepage, percolation, and soil evaporation loss. And conservation agriculture helps by enhancing infiltration, reducing soil evaporation, and increasing soil water holding capacity. It has seen for conservation agriculture in arid and semi-arid East and Southern Africa, crop yields improved 20 percent to 120 percent, and water productivity increased by 10 percent to 40 percent (Rockström et al., 2007).

Soil Erosion

Conservation agriculture and other forms of conservation tillage highly reduce soil erosion which has been documented in most of the studies regarding conservation agriculture. A study conducted in Mississippi (Dabney et al., 2004), it has found that, on a silt loam soil comparing no-till and chisel/disc till under corn cultivation, no-till decreased soil erosion significantly while the land was in no-till for 5 to 10 years and for the first year after no-till ended, but a year no-till was abandoned and tillage was reinstituted, the protective effects of the previous no-till were no longer significant.

Energy balance

Complex mechanical and technological operations in agriculture have a significant influence on energy consumption and environmental pollution. Plant production system involves much energy in soil tillage, sowing, spraying, fertilization, watering, harvesting, transportation, and storing. Especially energy consuming are soil tillage operations such as ploughing, deep soil loosening, and also the application of rotary tillage equipment (Koga et al., 2009 andStajnko et al., 2009). In many cases, conventional tillage, i.e. ploughing, consumes 29-59% of total diesel required as fuel for the complete technology (Koga et al., 2009, Stajnko et al., 2009 and Barut et al., 2011). Fuel consumption for soil tillage field operations depends greatly on different technical, technological, meteorological and other conditions (Sirhan et al., 2002 and Mileusni et al., 2010). Mileusnic et al., (2010) found that fuel consumption in conventional tillage and no-tillage systems is highly influenced by tractor engine power, the working width of soil tillage equipment, the number of working parts, the distance separating the parts, the equipment weight and other parameters also. To reduce cost of soil tillage and increase in the environmental friendliness, reduced tillage or no-tillage systems are highly needed. The main goals of these tillage systems are the sustainable environment and soil, for protection of the soil from erosion, for decrease in leaching of the fertile soil layer, or to reduce work time and fuel consumption, and decrease the cost of agricultural production (Sarauskis et al., 2014, Lithourgidis et al., 2009 and Morris et al., 2010). And the energy balance assessment of different technologies states that reduced soil tillage technologies are often more advantageous than the traditional ones in terms of savings in diesel, i.e. fuel consumption (Mileusni et al., 2010) and work time (Sanchez-Giron et al., 2007) as well as in terms of environmental sustainability and the reduction of the gaseous emissions causing the greenhouse effect (Stajnko et al., 2009, Sarauskis et al. 2014 and Morris et al., 2010). The well-balanced management of energy input intensity is one of the most important tasks for modern agriculture, as energy is an important factor for the socio-economic development of any country, ensuring energy safety, economic competitiveness and environmental protection (Ang et al., 2010 and Eskandari et al., 2015).

Bio-diversity conservation

The intensification of agriculture and the traditional techniques based on extensive tillage have negative impact on soils, causing degradation in the physical and chemical parameters and causing loss of biodiversity. Conservation agriculture and the related management practices have demonstrated in the last decades to be an efficient tool to combine food productivity with environmental protection around the world. So, the reduction or no-tillage, the permanent soil cover, and the crop rotation or diversification practices have discernible positive effects on soils, including the improvement of physical and chemical properties, the decrease of water run-off and wind erosion, and an increase of water retention. The use of cover crop and the organic residues on the surface enhance the stability of soils and regulate temperatures. Therefore, the biodiversity increases (Conti 2015).

Conclusion

To ensure food security, maintaining factor productivity at a sustainable level and an egalitarian growth, the resilience of ecology is a must. Conservation Agriculture (CA) is organically dovetailed to the resilience of ecology and ecological services there in. So, minimal disturbances to soil, incorporation of crop residues to soil and reengineering the cropping sequence with a view to more eco friendly response to production interventions as much as earning livelihood for millions are the basic approaches being followed in Conservation Agriculture. If ecological services are arrested of natural functioning and behaviour, no agricultural production and management is possible. With erosion of soil at its present rate, contamination of both ground and surface water and destruction of biodiversity at its steep decadence, our agriculture is confronting with serious threats, which is being reflected in stagnant growth and deteriorating quality in all terms and connotations.

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