

Regenerative Agriculture and its Prospects in Nepal: A Review

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- The authors declare that there is no conflict of interest.

ABSTRACT

Modern agriculture is heavily dependent on soil. Soil's carrying capacity is being decreased these days due to erosion, depletion of soil nutrients and climate change. Regenerative agriculture is a way of farming both plants and animals that enriches and restores topsoil, and in turn, improves the water cycle. Nepal is also facing the ill effects of the conventional agriculture system. Therefore, an attempt has been made in this review article to highlight some of the alternative production systems suitable for Nepal. The findings of this review paper were about regenerative agriculture technology reduced the cost of production through minimum tillage, less use of agriculture inputs, less labor, consumption of less irrigation, maintaining soil moisture, water holding capacity and nutrient value through crop residue, crop rotation, soil cover, reduced soil erosion and run off top layer soil and increases the soil fertility through soil carbon sequestration that mitigates the climate change effects. The major constraints of regenerative agriculture are the lack of appropriate information and technologies in hand. For policymakers, farmers and food processing and marketing companies, regenerative agriculture has been an alternative production system with lower impacts on the environment. Therefore, to promote the identified and developed regenerative agricultural practices, participatory research in the farmer's field with large-scale demonstration across the agro-ecological domains of the country.

Keywords: Holistic agriculture, regenerative agriculture, soil cover, tillage.

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INTRODUCTION

Nepalese agriculture production system's productivity is not in pace with the nations' need. It might be due to limited inputs and resources like fertilizer, seed and irrigation, management of land for higher productivity and profits, crop and food diversification, linked with marked information, intended production system for import exchange and export upgrade, and value chain development and linked to the regional and global value chain (DOA Final report 2018). Therefore, there is an urgent need to go for an alternative but holistic agricultural production system in Nepal.

Regenerative farming is an alternative decision-making framework that offers a set of principles and practices to grow food in accord with nature and rectify the land from degradation. This farming includes farming and ranching with a thoughtful of the land's natural resource availability, building and prioritizing soil health, reducing and ultimately eliminating the use of harmful chemicals, integrating animals onto agricultural land, and cultivation strong relationships with communities (NRDC 2022). Regenerative agriculture is a long term practices as sustainable conservation agriculture farming system that improves food and nutritional value, improves soil fertility and sequestration of carbon from the atmosphere that improves the livelihoods of the farmers. Crop or plant absorbed carbon through the atmosphere which re-establishing the organic carbon into the soil that stimulates the soil health and its fertility.

Principle and Practices of Regenerative Agriculture

1. Conservation Agriculture (CA)

Of the many practices, Conservation Agriculture (CA) is one that improves and enhances the agriculture production by increasing its profit and ensures the food security which reduces the use of additional inputs and resources balance the ecosystem. The keystone of conservation agriculture is minimum tillage sideways with other soil conservation practices. There are three elements for conservation agriculture practices i.e. crop residue, minimum tillage or no disturbance of soil and crop rotation (Karki and Shrestha 2014). Conservation Agriculture practices of no tillage, residue retention and crop rotation can mitigates climate change effects maintain higher soil quality and its fertility, enhanced crop productivity and secure food, increased economic return and maintain ecosystem around. According to FAO, Conservation Agriculture (CA) is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. CA is characterized by three linked principles named as no tillage, soil cover and biodiversity (Kassam et al 2015).

Resource conservation technology based as rice-wheat system as conservation agriculture practices was first adopted by IRRI and CIMMYT under CSISA project in 2009 with less irrigation water, labour, input costs and efforts to enhance the agriculture production and productivity in central Terai region of Nepal. In the Eastern Terai of Nepal, Conservation Agriculture was experimented and promoted under Sustainable and Resilient Farming Systems Intensification' (SRFSI) project (2014–2020), CIMMYT to increase crop productivity and resilience.(Saharawat et al 2022).

1.1 Minimum Tillage or Minimize Soil Disturbance

Minimum tillage or zero tillage is a principle of regenerative agriculture that helps to reduce the soil disturbance through direct seeding method and increase the soil microorganism activity that improves the soil structure, reduce soil degradation and conserve the more content of carbon in

the soil. The negative impact on soil microorganism activity which is related to both plant and soil, soil nutrient cycle and ecological resilience due to mechanical, physical, and chemical like synthetic fertilizer, herbicide, pesticide, and fungicide. One tea spoon of healthy soil has more active organisms than building house structure (Sahu and Das 2020).

Generally, soil erosion or degradation is a major problem that occurs in mid hills during monsoon season. The conventional tillage practices significantly resulted loss of topsoil during monsoon season in vertical steep and fragile cultivable land. The field experiment was conducted in factorial randomized complete block design on acidic sandy loam soil (Lithic Dystochrept) during the summer season of 2001 and 2002 at Kathmandu University (1500 masl) to assess the effects of tillage and cropping patterns on soil and nutrient losses, crop yield and soil fertility. The treatments were consisted of two main treatments (conventional and reduced till) and two sub-treatments (sole maize and maize + soybean). Soil organic carbon (OC), total nitrogen (N), plant available phosphorus (P) and exchangeable potassium (K) were determined for the original soil and eroded sediment using standard methods. Thus, minimum tillage resulted significantly reduced the annual soil and nutrient losses than conventional tillage. (Atreya et al 2006). Therefore, overall minimum tillage improves the health and fertility of soil.

Conservation agriculture technology increases the status of soil fertility. Soil fertility is interrelated with soil organic carbon, minimum tillage, crop residue, cover crops, mulching, and compost or manuring, livestock manure etc. Globally, soil degradation and erosion is major issues occurs due to geographical and social diversity, intense cultivation, more number of population, lack of governmental plan, strategy and policy (Rijal 2020). The loses of fertile land about 24 billion tons and dry land degradation reduces National domestic product (NDP) in developing countries by up to eight percent in world every year (UN 2019). Due to fragile geology, the loss of top layer soil on slopping terraces is about 87 Metric tons hectare year⁻¹ in Nepal (Rijal 2020). Row or tall-growing crops such as sorghum, maize, pearl millet, etc. are soil erosion allowing crops whereas close growing cover crops soybean, lentil, cowpea, green gram, black gram, groundnut, etc. are reducing soil erosion. Seed rate should be high while sowing for increasing the crop canopy density (Kumawat et al 2020). Conservation agriculture impacts physical properties of soil such as bulk density and porosity as well as chemical and biological properties (Naab et al 2017and Verhulst et al 2010). Reduced or minimum tillage reduced the total annual soil losses and soil nutrient losses as compare to conventional tillage (Figure 1).

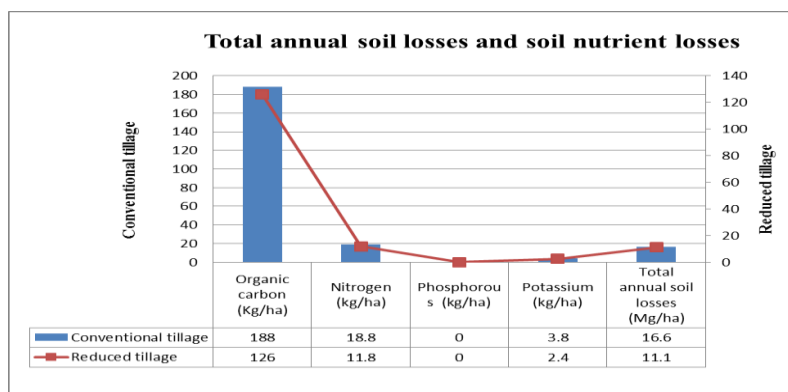


Figure 1. Applications of reduced tillage in hills of central Nepal (Source: Atreya et al 2005)

1.2 Crop Diversity and Rotation

Crop rotation is the rotation of crop practice of cultivation different types of crops in sequence at low cost of cultivation on the same field to acquire maximum profit by conserving and maintaining the soil fertility. Diversification of crop and rotation of crop are the principle of regenerative agriculture that helps to reduce the losses of top layer soil which can be achieved through both crop residues and cover crops. The crop rotation and diversification guards the soil from wind and water erosion, lower the temperature of the soil, and feed the microorganisms to the soil and compose soil organic matter that controls naturally disease and pest problems (Sahu and Das 2020). Crop or plant diversity helps to reduce the use of insecticides and pesticides by controlling pathogens, insect and weed infestation during crop production. Crop rotation promotes water infiltration and improves soil structure by expanding the length of rooting zones. A diverse crop rotation is not diet for microorganisms of soil but it is also nutrients for different layers of soil. Crop rotation function as biological drives also required for deepest layer of soil nutrients that helps to cultivate commercial crop. Crop rotation helps to uptake plant nutrients through diverse soil flora and fauna (Karki and Gyawaly 2021). Mixed cropping of legumes and maize do not help to conserve soil and nutrient loss in hills of central Nepal. Therefore, minimum tillage practices is a possibility for minimizing soil disturbance and nutrient losses without losing economic yields in central hills of Nepal (Atreya et al 2006). Crop rotation through leguminous crop act as the nitrogen fixation and cover crop having high and dense canopy helps to reduce soil erosion, re-establish and sustaining soil fertility, and conserves soil and water, suppresses weed growth, control diseases and insect pests infestation, show effective of input use, and system productivity while reducing the soil erosion (Kumawat et al 2020).

Crop diversity (cover crop, leguminous and non-leguminous crop) plays an essential role in regenerative agriculture to ensure food, nutritional and livelihood security for agriculture production. Leguminous crop is act as nitrogen fixation. The challenges regarding losses of biodiversity in India due to use of huge amount of agro-chemicals, chemical fertilizers, fragmentation, soil degradation, excessive conventional tillage, inappropriate crop rotation, water scarcity, post-harvest losses, natural disasters and climate change impacts (Jacob et al 2019). Cover crop as green manure crops called as nutrient management tools which plays vital role in soil conservation. It improves physical and chemical properties of soil followed by other legumes beans, Sun hemp, dhaincha, green gram. Cowpea followed by other legumes such as velvet beans, sun hemp and black gram are the best cover crops. Cover crops also help to reduce the global warming effects. Cover crop as leguminous and non-leguminous crop helps to decrease the soil erosion by one hundredth time than of bare soil and also increased C:N ratio in atmosphere (Rijal 2020).

1.3 Soil Cover and Water Retention (Mulch and Crop Residue)

Mulching and crop residue keep to soil moisture and conserve it called soil cover. Mulching helps to reduce weed infestation, control insect and diseases problem, reduce top layer soil degradation and erosion, maintain percentage pore space, increase in infiltration rate, overall crop growth and development and increase the crop production (Rijal 2020). Mulching is any organic or non-organic material which protects the soil from erosion and run off, reduces evaporation, increase infiltration, control soil temperature, recover soil structure and fertility, reduce weed infestation problem and conserve soil moisture which prevents the formation of hard crust layer of soil during heavy rainfall condition. Mulching with organic matter increases the water holding capacity, macro and micro fauna biodiversity activity, and soil fertility but

inorganic mulching is costly and labor intensive which don't improve soil health but have a longer life span than organic mulching. (Kumawat et al 2020). Though adoption of conservation agriculture saved water by 15-50% and increased in nutrient use efficiency of the crop by 15-25% (Karki and Shrestha 2014).

In context of Nepal, conservation agriculture based technologies is in primary stage. The very few farmers are well known about it whereas many farmers still prefer conventional practices. The major challenges of crop cultivation in Nepal are scarcity of labor; high cost of cultivation, no mechanization, lack of skilled man power for operating machines that may reduce the potential crop productivity. In terai and plain area, precision land leveling, no-till systems, furrow irrigated raised bed planting systems, easy accessibility of agriculture machines or equipment, crop residue management practice and crop diversification are easily accessed to promote the appropriate conservation agriculture technology as compare to hilly and sloppy terraces areas. In hilly area, there are very limited source like crop residue used for livestock feed, lack of means of transportation that causes problem for loading and unloading the heavy agriculture machines and equipment, poor affordability of the farmers for machines and rain-fed agriculture that is very difficult to adopt the conservation agriculture based technologies by farmers (Karki and Shrestha 2014). The main factors for conservation agriculture adoption by farmers are lack of knowledge about conservation agriculture, insufficient farm machineries and tools, small land holdings, poor infrastructures, and lack of policy regarding conservation agriculture (Karki and Gyawaly 2021).

1.4 Cover Crop, Soil Nutrient and Water Retention Capacity

The cover crop having high canopy density depends on crop geometry and development of canopy for reducing the runoff of surface layer of soil nutrient and retaining water holding capacity. Mulching with organic matter increases the water holding capacity and water infiltration rate which helps to conserve soil moisture. Legume crops have good biomass provided better cover to protect soil than the row crops. The advantages of cover crops are protection of soil from the erosive impact of raindrops, runoff, and wind, act as an obstacle in water flow, reduce flow velocity, and in that way reduce loss and runoff of soil, residue combination and deep root system increase soil organic matter, improve nutrients content to the component crop and succeeding crops through biological nitrogen fixation, improve water quality and water holding capacity of the soil, improve soil properties, suppress weed growth, and increase crop productivity (Kumawat et al 2020). Anthropogenic and adverse natural activities are the major factors for the deterioration of natural resources and available limited resources on the earth. Fundamental natural resources are soil and water for the agricultural production and sustainability as well as for the protection of the natural ecosystem. The total land area has been degraded about 68.4% by the water erosion process in India. Intensive conventional agricultural practices accelerate the soil erosion process (Kumawat et al 2020). Crop residue covers soil surface about 30% through conservation tillage to reduce the soil degradation and erosion (Bergtold and Sailus 2020). The amount of water erosion reduced by 1 to 2 orders of magnitude and wind erosion with increase in crop strength in conservation tillage than conventional tillage systems. Crop rotation and minimum tillage system reduced wind and water erosion. Sowing date and time, recommended fertilizer dose, optimum plant population, proper irrigation reduces the losses caused by runoff and erosion for obtaining optimum crop growth. Physical appearances associated with soil structure, soil aggregation and aggregate stability that influenced by soil organic matter (Rijal 2020). Conservation agriculture is mechanized crop production systems includes reduced tillage, minimum tillage, no-till, direct

drill, mulch tillage, stubble-mulch farming, trash farming, strip tillage in large scale to reduce the impact of raindrops and retain the soil moisture with the maintenance of soil organic carbon. Conservation tillage improves the infiltration rate and reduces runoff and evaporation losses, soil health, organic matter, soil structure, productivity, soil fertility, and nutrient cycling and reduces soil compaction. (Kumawat et al 2020).

2. Integrated Livestock, Compost or Manure Application

Generally, animals are grazing in field compressing the unwanted plants into the soil by their hooves and composed of source of organic nutrients for the new plants growth that's helps to build up organic matter into the soil and provides draft power and manure to agriculture, income, nutritional and other byproducts (Sherchan and Karki 2006). The excrement of animals is good source of nutrients for water retention capacity and seed germination (Sahu and Das 2020). About 60% of livestock's feeds come from low quality crop residues and 40% from the forest. Farmers are used both plant nutrients and poultry manures where poultry industry act as attractive entrepreneur. (Sherchan and Karki 2006).

Compost or manure application helps to improve soil structure, texture, aeration, fertility, nutrients, water infiltration and water-holding capacity. Livestock manure application is the main source of soil nutrients and organic matter through which plant uptake nutrients from the soil. The resentment for crop producers during measurement of organic matter (SOM) levels and soil resilience due to applications of steady combination of forage based rotations and manure. The C:N ratio is the ratio of carbon and nitrogen for improving soil and plant health. Nitrogen is a food source of soil microbes which decomposed and automatically incorporated with soil called organic nitrogen uptake by plant. Ideal C:N ratio is 20:1 for crop production. When C:N ratios greater than 25 to 30:1 cause nitrogen deficiency in case of maize crop (Christine 2015). Organic farming is an environmentally friendly agricultural crop production system includes organic sources for plant nutrient supply through FYM, compost, vermicompost, green manure, soil surface cover with cover crops, soil organic carbon, residue mulching, crop rotation, etc. to maintain a healthy and diverse ecosystem for improving soil properties and ensuring a sustained crop production that avoid the use of synthetic fertilizers or pesticides. Large amount of organic manures application enhancing of water infiltration through improved bio-physico-chemical properties of soil, and reduces soil erodibility. Conservation farming reduced soil erosion by 30-140% than conventional farming. (Kumawat et al 2020).

3. Agroforestry

Agroforestry act as fertilizer for cultivation of agriculture crops incorporating of livestock, trees, herbs and shrubs and also protect the soil run off and erosion through planting trees, herbs and shrubs that enhance the agriculture production and improve the livelihood. Agroforestry is also provided fodder to livestock. It is as regenerative agriculture practices are parallel interrelated with each other which is significantly resulted in food security due to environmental, economic and social benefits. The practice of agroforestry is similar to regenerative agriculture that is composed of five goals as soil fertility and health, water quality, biodiversity, ecosystem health, and carbon sequestration. Agroforestry is plays a major role for improving soil fertility by providing nutrients to the soil, retention of rain water and improving infiltration, reducing soil run off and erosion, producing habitat and food for biodiversity (Elevitch et al 2018). Regenerative agroforestry stands for

1. Integration: Occurrence of trees, shrubs, and perennials integrated into a farming system.
2. Density: Plants per unit area in horizontal structure
3. Multistory: Divisions represented in the layered structure and root systems in vertical structure
4. Multiple species: Number of plant families, genera, species, and varieties over time with temporal succession.

CONCLUSION

Regenerative agriculture farming systems plays a significant role overall in agriculture production improves the soil health through carbon sequestration known as key for controlling global warming. It conserves the natural resources through minimum tillage controls the soil degradation and soil erosion and biodiversity through crop rotation. Therefore, wider adoption of regenerative agriculture, Government of Nepal should be concerned to regenerative agriculture based policies and strategies, related requirement of farm machinery and provide training for operating machine to operators, organize meeting time to time with related stakeholders, scientists, universities, extension workers, farmers change the concept from conventional to conservation agriculture, technically knowledge on how do it like no tillage system, crop residue, green manuring, crop rotation and diversity, integrated livestock manure, soil carbon sequestration, herbicides, fertilizer dose, irrigation. Therefore, regenerative agriculture is more superior to conventional agriculture and must adopt regenerative agriculture by farmers with less use of resource materials like fertilizer, water irrigation, less labor, herbicides, and insecticides which reduces the cost of production that increases the crop productivity in Nepal and improves the livelihood of farmers.

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AUTHORS' CONTRIBUTION

Soni Kumari Das, Tika Bahadur Karki, Pankaj Gyawaly, Reshama Neupane, Rajendra Bhattarai, Sangita Kaduwal and Bhimsen Chaulagain equally contributed to conceptualize the topic and prepare the manuscript.

CONFLICTS OF INTEREST

The authors have no any conflict of interest to disclose.

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