REGENERATIVE AGRICULTURE FOR RESTORING SOIL HEALTH AND MITIGATING CLIMATE CHANGE

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Food grain production of India is estimated to be 330.5 million tonnes in 2022-23 which is 15 million tonnes more than that of the preceding year as per the third advance estimate of 'production of major crops' released by the Ministry of Agriculture & Farmers Welfare. Despite the success in crop production that has ensured food security in the country, food inflation and its volatility is still challenging the food production sector. The growing population, increase in average per capita income, and effects of globalisation will definitely raise the demand for a greater variety of good quality food products in India. But, global developments such as declining availability of resources (e.g., land, water, nutrient), and climate changing effects may challenge our future food production targets while ensuring sustainable use of natural resources. Furthermore, issues such as land degradation, soil erosion, and loss of organic matter are deeply intertwined with decline in environmental quality and threaten livelihoods of millions of people around the world (Bouma *et al.* 2017). In this context, the Sustainable Development Goals (SDGs) provide clear guiding principles and targets to encourage sustainable food production under the global theme of eradicating poverty.

SDG 2 (Zero Hunger) is the most straightforward link that connects soils, food production, and healthy living. Therefore, there is a need to focus on cost-effective agriculture technologies that are capable of protecting environment along with conserving natural resources. Regenerative agriculture (RA) is one of the solutions to resolve most of these issues discussed. RA is a form of farming that aims to rehabilitate and restore the quality of soil used for agricultural purposes. In addition to restoring the soil quality, RA can also help to restore the water cycle and is an effective tool for carbon sequestration and a major milestone for climate change as it improve the resilience and vitality of soil that forms the food everyone consumes.

There is no separate entity or practice that can define the nature and meaning of RA, but it encompasses a variety of sustainable agricultural practices that are used in various combinations to ensure maximum

efficiency in the soil restoration process. For example, crop residue recycling (as much as possible) along with regular addition of compost or biochar improves soil fertility. With time, adoption of regenerative agriculture practices reduces requirement of agricultural chemicals without much reduction in crop yield compare to 'before transformation period'. The major technology used in regenerative agriculture is the cultivation of crops and vegetation that would effectively capture carbon from the atmosphere whilst contributing effectively as a carbon sequestrating tool. In short, a combination of agricultural practices those have less negative or even net positive effects on the environment and/or society. In addition to restoring the fertility of the soil, it also helps to rehabilitate and restore impulsive lands which are not currently used for farming practices.

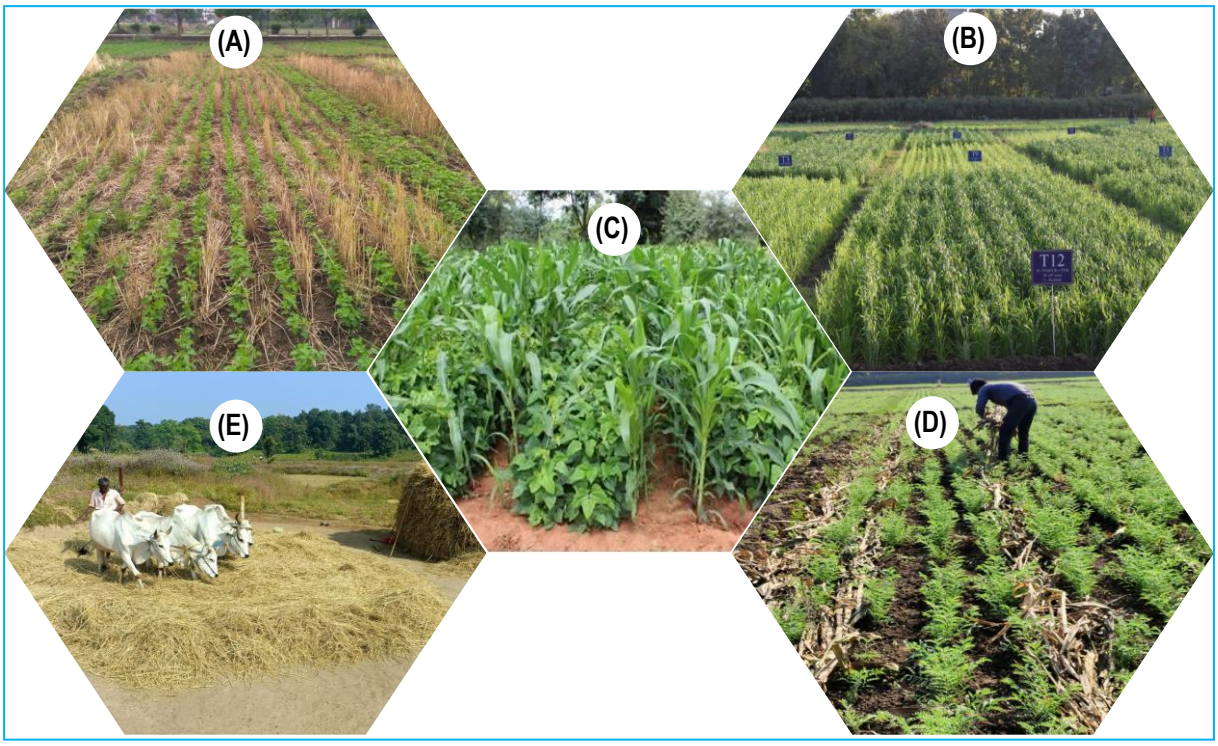

Figure 1. Pillars of regenerative agriculture (a) Minimum soil disturbance (b) Crop rotation (c) Maximize crop diversity (d) Keep the soil covered (e) Integration of livestock with cropping system

MAJOR TECHNIQUES IN REGENERATIVE AGRICULTURE

Minimum Soil Disturbance-Conservation Tillage: Disruption of soil due to ploughing and tillage may lead to erosion that can negatively affect texture and quality of the soil. In conservation tillage, where the soil surface used for farming is covered with about 30% of crop residues, soil building process get renewed with time along with soil fertility restoration. Besides, this tillage widely reduces soil erosion caused by water. Minimum soil disturbance also augment biodiversity of the agro-ecosystem by providing shelter to small animals such as rabbits, quail, and mice. Meena et al (2016) observed soil fertility and texture improvement with time due to the adoption of conservation tillage

Keep the Soil Covered: A permanent soil cover is essential to protect soils against the deleterious effects of exposure to rain and sun as well as to provide a regular supply of food micro and macro-organisms in the soil and to alter the soil physical environment to support the growth and development of soil organisms. Crop residue is the key component of soil cover that protects top soil from erosion and plays an important role in building soil organic matter, nutrient recycling and improving soil quality (Chauhan et al. 2012). Crop residue is an important source of carbon and also has significant effect on physical, chemical and biological properties of soil (Kumar and Goh 2000).

Crop Rotation with Maximum Crop Diversity: Crop rotation ensures specific nutrients are not stripped off from soil and prevent build-up of specific materials or elements in the soil over prolonged periods. Rotating crops using legumes minimizes build-up of population of pest and diseases causing agents through life cycle disruption, promote biological nitrogen fixation, control off-site pollution and enhance biodiversity. Growing diverse crops helps to bring farmers to soil rebuilding process; and good textured, rich, varied, and nutrient-dense soils provide them the best yield in return. Also, crop diversity and crop rotation allows not all nutrients but only specific set of nutrients to get absorbed by specific crops and this process ensures soil get enough time to get rejuvenated incorporating nutrients it lost in each crop season.

Agroforestry with Perennial Crops: Agro-forestry is a collective name for land use system in which woody perennials (trees, shrubs etc.) are grown in association with herbaceous plants (crops, pastures) or livestock in spatial arrangement. Agro-forestry systems consists of 4 basic components i.e., Agri-silviculture system (crops + trees), Agri-horticulture system (crops + fruit trees), Silvipastoral system (trees + pasture or animals), and Agri-silvipastrol system (trees + crops + pasture or animals). Agroforestry systems are much more than annual cropping systems in enhancing productivity, soil fertility, nutrient cycling, carbon sequestration potential micro climate, and conserving soil. For example, sugarcane+ *poplar* combination gave the higher returns than any other crop in first three years (and then poplar intercropping with wheat-*kharif* fodder for successive years (Chauhan et al, 2009). Dhyani et al. (2009) reported that alley cropping with leguminous tree subabul (*Leucaena leucocephala*) was effective for controlling soil erosion on sloppy lands. Agro-forestry is a promising land use system to increase and conserve aboveground and soil C stocks to mitigate climate change. Also, trees crowns act as windbreaks and shelterbelts together with protecting soil from the impact of rain drops and creating a specific micro-climate in particular area.

Biochar: Biochar, a fine-grained black carbon material produced through pyrolysis of plant biomass can improve soil fertility by improving the moisture retention quality of soil and allowing soil to retain nutrients for long time period. Use of biochar in agricultural fields not only contributes to carbon positivity but also reduce the greenhouse effect by sequestering carbon in soils. Lehmann et al. (2006) reported that biochar sequesters approximately 50% of the carbon available within the biomass feedstock being pyrolyzed, depending upon the feedstock type. Remaining percentage of carbon is released during pyrolysis and this may be captured for energy production. Biochar can effectively valorize the soil nutrients and enzyme dynamics, by enhancing soil water-holding capacity, cation exchange capacity, surface sorption capacity and base saturation when added to the soil (Liang et al., 2006). As regenerative agriculture emphasis on self-reliance, farmers may be motivated to produce biochar at farm level using their crop residue rather than relying on off-farm inputs. However, quality check of biochar produced at farm level is required because, quality of biochar depends up on a number of factors such as type of feedstock, temperature at which it is either pyrolyzed, gasified, torrefied or burnt, duration of the reaction that make biochar and the pre-treatment techniques.

Integration of Livestock with Cropping System: Ecosystem services can be significantly influenced by the nature and spatial configuration of the cropping systems, grasslands, and animal components of the farming system. Integration of livestock with cropping system and grassland at the farm level are often considered to have key economic and social benefits. Crop–livestock integration has three aims 1) reducing the openness of nutrient cycles following the rationale of industrial ecology 2) organizing land use and farming practices to promote ecosystem services 3) increasing farm resilience to adverse climatic and economic events. Integration of livestock with cropping system promotes introduction of cover crops, legumes and short duration grass lands as a source of livestock feed and these changes offer recoupling of carbon, nitrogen and phosphorus cycles. This kind of alliances are ideal for the dryland regions where crop-livestock systems dominate as this would also help in taking maximum benefit of livestock excreta (dung and urine). In fact, integration of livestock with cropping systems and

grasslands is one of the key actions helped spreading concept of RA in many countries. On the whole, it helps in making the system as a carbon sink and neutralizing the higher GHG emission from the livestock.

CONCLUSION

RA is not a single technology but it is an innovative process about which various stakeholders of agriculture need to be educated because, this process involves regenerating of the top soil and increasing biodiversity and input-use efficiency. It is based on the idea that healthy soils are the cornerstones of RA, which enable a symbiotic association between soil microbes and plants. RA centres around ecosystem services that mitigate climate change, sustain agri-food systems and produce healthy foods using innovative practices of conservation agriculture, integrated farming systems, agroforestry, organic farming, etc. along with Best Agricultural Practices (BMPs). In nutshell, RA improves the health of agr-ecosystem through a holistic systems approach including the wellbeing of animals, farmers and the society. It builds agro-ecosystem resilience by mitigating the changing climate effects.

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