

Agronomic interventions for enhancing diverse agroecosystems services

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Agriculture and ecosystem services are interconnected in different ways. Payments for ecological services (PES) and novel methods of agricultural management, including regenerative agriculture, organic farming, conservation agriculture and the management of biological diversity provide opportunities for augmenting ecosystem services in agroecosystems while sustaining or increasing the farm productivity. Beneficial actions will depend on strong supporting policies and legal frameworks, besides developing the knowledge and leadership capacity in farming communities to evaluate the prospective payback. The maintenance of ecosystem services and the long-term productivity and stability of agriculture ecosystems requires a paradigm shift in agriculture that looks to progress from single solutions to production problems towards a collective approach that supports several ways to improved use of soil, water and biotic resources to boost the ecosystem services.

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AGRO ecosystem services (AES) signify the common interface between agro-ecological functioning and seasonal production economics of any particular agro-ecosystem that divulges viable nature-human interactions maintaining environmental quality. The AES concept aims for ‘the benefits people obtain from ecosystems’ to ‘the contributions that ecosystems make to human wellbeing’ including ecological economics i.e., the monetary value involved for all goods and services coproduced by ecological processes for the farming communities towards their ensured daily livelihood, food and nutritional security under diverse agro-climatic conditions and facilitate cultural conservation. Ecosystem processes and functions signify the biophysical relationships that exist among the building block units of ecosystem, irrespective of their role in human wellbeing. In courtesy, ecosystem services are the subset of ecosystem processes and functioning

for the direct and indirect benefit people derive from multi-functioning ecosystems.

Agronomic interventions for AES

Agronomic interventions in agricultural ecosystems provide food, forage, bioenergy and pharmaceuticals which are essential for human and animals. These interventions in agro ecosystem produce a variety of ecosystem services, such as regulation of soil and water conservation, carbon sequestration, support for biodiversity, increase the pollination, natural pest control, increasing crop productivity, provide healthy food, maintenance of soil health, improve environmental quality, reduce the land degradation, nutrient cycling and hydrological services.

Regulation of soil and water conservation

Soil and water are indispensable for the existence and survival of all

terrestrial life. Soil supports plant life by providing a medium for their growth and development. It is a non-renewable natural resource and susceptible to rapid degradation through various forms of erosion processes. Worldwide, around 52% of total productive land has been degraded by various kinds of degradation processes and almost 80% of the terrestrial land is affected by water erosion. Further, annually ~10 million hectares (mha) of cropland becomes unproductive at the global level due to soil erosion with an average rate of 30 t/ha/year soil erosion. It has been estimated that water erosion results in a global flux of sediments of 28 Pg/year.

Use of soil and water conservation measures including biological measures (vegetative strips, protective wind shelters, natural drainage way protected by a permanent grassed water-way, reforestation), agronomic measures (contour farming, choice of

crops, crop rotation, cover crops, intercropping, strip cropping, mulching, conservation tillage, organic farming, land configuration techniques, agroforestry measures) and mechanical measures (terracing, bunding, trenching, check dams, *etc.*) is imperative to reduce runoff, soil erosion and to improve soil quality, water quality, moisture conservation, and overall crop productivity in a sustainable way. Agronomic measures are applicable in the landscape of <2% slope which reduce the impact of raindrops through the covering of soil surface and increasing infiltration rate and water absorption capacity of the soil which results in reduced runoff and soil loss through erosion. The combined use of agronomic, biological and mechanical measures will help in improving and sustaining agricultural productivity.

Carbon sequestration

Soil carbon (C) sequestration implies the removal of atmospheric CO₂ by plants and storage of the fixed C through incorporation into soil organic matter. Carbon exists in a variety of forms, mainly as plant biomass, soil organic matter, and gas carbon dioxide (CO₂) in atmosphere and dissolved in sea water. Worldwide, about 1417 Pg of soil carbon is stored in first meter soil depth, while 456 Pg soil carbon is stored in above below ground vegetation and dead organic matter.

Adoption of different agronomic management practices can be helpful in the sequestration of carbon. Such practices include no-tillage or reduced tillage, nutrient management, cover crops, crop rotations, green manuring, application of animal manures, agroforestry, *etc.* Adoption of these different agronomic practices will not only reduce the CO₂ emission and different GHGs, but also improve the crops yields, maintaining suitable biotic habitat, decrease nutrients' losses, improve soil health and productivity and will also improve farmer's income.

Nutrient cycling

Nutrient cycles serve as the link between agricultural systems and the

broader environment. These cycles may be localized to an agricultural ditch, a stream, or a watershed. At the regional and global scales, nutrient cycles connect agricultural practices to climate change, pollution of water and air, and extraction of geologic reserves. The two nutrients that most limit biological production in natural and agricultural ecosystems are nitrogen and phosphorus, and they are also heavily applied in agro ecosystems. To maintain ecosystem services, soil nutrient pools can be intentionally managed to supply crops at the right time, while minimizing nutrient losses by reducing soluble inorganic nitrogen and phosphorus pools. Practices such as cover cropping or intercropping enhance plant and microbial assimilation of nitrogen and reduce standing pools of nitrate, the form of nitrogen that is most susceptible to loss. Other good agronomic management practices include diversifying nutrient sources, legume intensification for biological nitrogen fixation and phosphorus solubilizing properties, and intensive diversifying rotations.

Mitigation of greenhouse gases emissions

The three main greenhouse gases (GHGs) emitted by intensive agricultural practices are carbon dioxide, methane and nitrous oxide. Airborne GHGs are responsible for the effects of climate change. Carbon dioxide is emitted by farm equipment moving across the farm's fields during tilling, planting, the application of pesticides and fertilizers and harvest. The more passes across the farm field, the more carbon that is emitted. Methane is one of the gasses emitted from the digestive tracks of ruminant animals (cattle, sheep, goats, buffalo) in a process called enteric fermentation. Manure is another source of methane. Agronomic practices can effectively reduce or offset agricultural greenhouse gas emissions through a variety of processes. Effective manure management can significantly reduce emissions from animal waste. Replacing synthetic nitrogen fertilizers with biological nitrogen

fixation by legumes can reduce CO₂ emissions from agricultural production by half. Chronic surplus additions of inorganic N, which are currently common place, can be reduced under these scenarios, leading to reductions in NO_x and N₂O emissions. Agronomic practices can offset GHGs by increasing the carbon sequestration. In particular, soil conservation measures such as conservation tillage and no-till cultivation can conserve soil carbon, crop rotations and cover crops can reduce the degradation of subsurface carbon which results less emission of GHGs from agricultural field.

Maintain soil health

Soil health is the state of the soil being in sound physical, chemical, and biological condition, having the capability to sustain the growth and development of land plants. There is no direct method to judge the status of soil health. The best set of measurements that will allow us to judge the status of soil health is called the minimum data set. The measurements that make up the minimum data set are called soil quality indicators or soil health indicators. The purpose of soil health assessment is to allow a farmer to know in which direction the soil health is going for better or for worse. When we know the direction of change, we can implement specific management practices to mitigate degradation if the soil is in poor shape or continue the current practices if the soil is improving. Without knowing the directional changes in soil health, it is not possible to effectively plan and implement better management practices.

Maintaining biodiversity

Traditional agricultural systems generally have less adverse impact on biodiversity than high inputs and intensified agriculture. Indigenous farmers often maintain ecologically sensitive agricultural and natural resource management practices based on accumulated experiences of interacting with the environment, and without access to external inputs, capital or scientific knowledge. Small

holder systems that rely on natural regeneration of the vegetal cover are not viable under high pressure on the land. The model of 'modern' agriculture is characterized for its large scale approaches to production, expanded use of irrigation, mechanization of production processes and a strong reliance on inputs such as chemical fertilizers and pesticides and specialized animal feed. These characteristics have caused loss of biodiversity at diverse levels. Mechanization led to the increase of large monoculture crops and plantations.

Improving the environmental quality

Farming imposes unenthusiastic externalities upon society. It is affected by different sources such as loss of biodiversity, land erosion, nutrient overflow, more water usage, chemical fertilizers and pesticides. Farming also contributes to soil degradation, and water contamination due to leaching of agricultural chemicals into water supplies. The intensive use of pesticides can disrupt and erode biodiversity in natural habitats near and far from agricultural areas as they accumulate in the food chain. The challenge is to find ways for agriculture to efficiently and profitably produce sufficient and safe food to meet growing world demand without harming the environment and degrading natural resources. It has been proposed that some best agronomic management practices can reduce the level of some negative externalities from (conventional) farming. For sustainable agriculture, the most important key is the conservation of natural resources. Crop residues (roots, chaff, stems, and leaves) are the key source of organic matter replacement. Green manure is one of the best methods to maintain the life of soil; other methods are animal manure and straw residue, selecting good rotation, and reducing tillage which reduces the negative impacts of intensive agricultural practices on soil quality. Legume incorporation causes a change in microbial population toward greater metabolic activity and increases organic matter which helps

in reducing the adverse impacts of chemical pesticides. Nutrient management is another profoundly important aspect of agronomic growing operations, and much attention is given to this aspect of crop production management.

Biological control

Biological control of insect-pest in agroecosystems is an important ecosystem service that is often supported by natural ecosystems. Non-crop habitats provide the habitat and diverse food resources required for arthropod predators and parasitoids, insectivorous birds and bats, and microbial pathogens that act as natural enemies to agricultural pests and provide biological control services in agroecosystems. These biological control services can reduce populations of pest insects and weeds in agriculture by the intervention of agronomic practices such as crop diversification, growing smothering crops, stale seed bed technique, summer deep ploughing, thereby reducing the need for pesticides.

Pollination

Pollination is another important ecosystem service to agriculture that is provided by natural habitats in agricultural landscapes. Approximately 65% of plant species require pollination by animals, and an analysis of data from 200 countries indicated that 75% of crop species of global significance for food production rely on animal pollination, primarily by insects. Of the most important animal-pollinated crops, over 40% depend on wild pollinators, often in addition to domesticated honeybees. Only 35-40% of the total volume of food crop production comes from animal-pollinated crops, however, since cereal crops typically do not depend on animal pollination. Pollination services are more readily quantified than many other services.

Stimulant crops (coffee, cacao, and tea), nuts, fruits and edible oil crops were predicted to be particularly vulnerable to the loss of pollination services. The economic impact of insect pollination on world food production in 2005 in the 162 FAO

member countries has been calculated at ₹ 153 billion, but vulnerability to loss of pollinators varies among geographical regions due, in part, to crop specialization.

Water quantity and quality

Agriculture accounts for over 70% of worldwide water use, therefore providing sufficient quantities of clean water is a crucial ecological function offered to agroecosystems. Perennial vegetation in natural ecosystems like forests may control the amount of water captured, infiltrated, retained, and flowed throughout the landscape. Water availability in agroecosystems depends not only on infiltration and flow, but also on soil moisture retention, another type of ecosystem service. While the supply of surface water and groundwater ('blue water') inputs to agriculture through irrigation are indispensable in some parts of the world, 80% of agricultural water use comes from rainfall stored in soil as moisture (green water). Water storage in soil is regulated by plant cover, soil organic matter and the soil biotic community (bacteria, fungi, earthworms, etc). On-farm management practices that target green water can significantly alter these predictions of water shortages. For example, modifying the tillage regime or mulching can reduce soil evaporation by 35-50%. Rainwater harvest and on farm storage in ponds, dykes or subsurface dams can allow farmers to redirect water to crops during periods of water stress, recovering up to 50% of water normally lost to the system.

The relatively new approach of payments for environmental services has often focused on supporting watershed protection and water quality enhancements that target the provision of blue water. It has been suggested recently that farmers should receive payments for 'green water credits' from downstream water users for good management practices that enhance green water retention as well as blue water conservation.

Soil structure and fertility

Soil structure and fertility provide

essential ecosystem services to agroecosystems. Well-aerated soils with abundant organic matter are fundamental to nutrient acquisition by crops, as well as water retention. Soil pore structure, soil aggregation and decomposition of organic matter are influenced by the activities of bacteria, fungi and macrofauna, such as earthworms, termites and other invertebrates. Micro-organisms mediate nutrient availability through decomposition of detritus and plant residues and through nitrogen fixation. Conservation tillage and other soil conservation measures can maintain soil fertility by minimizing the loss of nutrients and keeping them available to crops. Cover crops facilitate on-farm retention of soil and nutrients between crop cycles, while hedgerow vegetation reduces erosion and runoff among fields. Incorporation of crop residues can maintain soil organic matter, which assists in water retention and nutrient provision to crops. Together these practices conserve a suite of ecosystem services to agriculture from the soil. In general, water management and erosion control can aid in maintaining soil organic carbon. Soil carbon sequestration thus provides additional ecosystem services to agriculture itself, by conserving soil structure and fertility, improving soil quality, increasing the use efficiency of agronomic inputs,

and improving water quality by filtration and denaturation of pollutants.

Provide nutritious and quality food

Globally, there are different systems and standards available for control measures in value addition through processing of food meant for human consumption. Although grade standards on size, shape, colour and local preferences are available for most of the fruits and vegetables marketed and consumed in India, their quality in terms of maturity standards, residues of pesticides and other contaminants, microbial loads, etc. have not been adequately addressed. Good Agricultural Practices are 'practices that address environmental, economic and social sustainability for on-farm processes, and result in safe and quality food and non-food agricultural products'. These four 'pillars' of GAP (economic viability, environmental sustainability, social acceptability and food safety and quality) are included in most private and public sector standards, but the scope which they actually cover varies widely.

SUMMARY

Agroecosystem services signify the common interface between agro-ecological functioning and seasonal production economics of any particular agro-ecosystem that

divulges viable nature-human interactions maintaining environmental quality. Agriculture and ecosystem services are interconnected in different ways. Agronomic interventions in agricultural ecosystems provide food, forage, bioenergy, etc. which are essential for human and animals. These interventions produce a variety of ecosystem services, such as regulation of soil and water conservation, carbon sequestration, support for biodiversity, increase the pollination, natural plant protection, increased productivity, provide healthy food, improved soil quality, improved environmental quality, nutrient cycling and hydrological services. Payments for ecological services (PES) provide opportunities for augmenting ecosystem services in agroecosystems. Beneficial actions will depend on strong supporting policies and legal frameworks, besides developing the knowledge and leadership capacity in farming communities to evaluate the prospective payback.

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Jai Kisan, Jai Vigyan

- A total of ₹ 788.33 crores have been sanctioned for opening six new agricultural colleges for eastern India under Central Agricultural University, Imphal, and a new Central Agricultural University in Meghalaya.
- For the establishment of two new agricultural research institutes in Asom and Jharkhand, a sum ₹ 100 crores is allocated.
- First academic session of the Rani Lakshmibai Central Agricultural University has been allocated for four new agricultural colleges in Datiya and Jhansi.
- An Memorandum of Understanding was signed for transforming the Rajendra Central Agricultural University, Pusa, Samstipur, Bihar. A proposal of ₹ 400 crores is submitted in EFC.
- Post-Graduate Institute of Horticulture is being established in Amritsar, Punjab.
- Foundation stone of the Indian Institute of Agricultural Biotechnology is laid at Ranchi for promoting agricultural biotechnology.