VISIONIAS
INSPIRING INNOVATION
www.visionias.in

Sustainable Agriculture

PART 1

Understanding the concept and practices

Introduction

Food and fibre productivity in India has soared since the Green Revolution due to increased chemical use, new technologies, mechanization, specialization, and government policies that favoured maximizing production and reducing food prices. These changes have allowed farmers to produce more food and fibre at lower prices.

Although these developments have had many positive effects and reduced many risks in farming, they also came with significant costs including topsoil depletion, groundwater contamination, greenhouse gas emissions among others. Consequently, a growing movement for sustainable agriculture has emerged during the past few decades to question the necessity of these high costs and to offer innovative alternatives. Today the movement is garnering increasing support and acceptance within our food production systems.

So, in this edition of the Agriculture Series, we will unravel what sustainable agriculture means and what are the systems/practices associated with it? Further we will also understand why is it important to move towards sustainable agriculture? As a follow up to this document, we will examine the status of sustainable agriculture in case of India and the barriers that inhibit its complete adoption in the country.

What is Sustainable agriculture?

- While as a concept, sustainable agriculture is dynamic with wide variations in its definition and practice, it largely **encompasses production of plant and animal products, including food, in a way that utilizes farming techniques that protects the environment, public health, communities, and animal welfare.**
- The basic goals of sustainable agriculture are **environmental health, economic profitability, and social and economic equity.** Thus, sustainable agriculture, in the long term, seeks to-

- Satisfy human food and fiber needs.
- Enhance environmental quality and promote healthy biodiversity.
- Manage natural resources wisely.
- Make the most efficient use of non-renewable resources and on-farm resources
- Integrate natural biological cycles and controls.
- Sustain the economic viability of farm operations.
- Increase farm incomes.
- Enhance the quality of life for farmers and society as a whole and provide nutritious food.

Sustainable agriculture, agroecology, regenerative agriculture, organic farming, natural farming etc. are the most common terms used to describe various sustainable agriculture approaches.

What are the prominent systems and practices involved in Sustainable Agriculture?

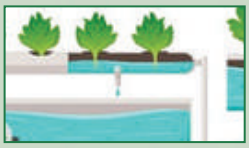
Some of the widely discussed sustainable agriculture practices have been mentioned below with their prime characteristics:

Sustainable agriculture systems	*Key Characteristics*
 **Organic Farming**	● **Prohibits use of synthetically produced agro-inputs** like fertilizers, herbicides or pesticides and Genetically modified seeds. ● **Maintaining organic matter levels and encouraging biological activity in soil.** ● Using **relatively insoluble nutrient sources** made available to the plant by the action of soil micro-organisms. ● **Effective recycling of organic materials including crop residues and livestock manures.** ● Weed, disease and pest control relying primarily on crop rotations, natural predators, diversity, etc. ● Conservation of wildlife and natural habitats.

 **Natural Farming (includes Subhash Palekar natural farming and community-managed natural farming)**	● Termed as '**do nothing farming**' and involves elimination of tillage and external inputs like chemical agro-inputs. ● Uses **low-cost, locally-sourced inputs** such as natural mixtures made using cow dung, cow urine, jaggery, etc. and indigenous Seed. ● Enhanced biomass recycling and integration of livestock with crops for biological and economic synergies. ● Stimulating soil's microbial activities using **Biostimulants** and practices like mulch, crop covers, and symbiotic intercropping. ● **Botanical extracts** for pest management. ● **Poly-cropping**, where trees are integrated with various arable and perennial crops
 **Permaculture**	● **Follows 3 ethical norms:** ➤ care for the earth; ➤ care for people; and ➤ set limits to consumption and reproduction, and redistributes surplus. ● **Consciously designed landscapes, which mimic the patterns and relationships found in nature.** ● Stores resources when at peak abundance for use at a later period of scarcity. ● **Produces no waste and values diversity.** ● Close integration of terrestrial and aquatic systems, animal husbandry, and annual and perennial field crop plants. ● **Involves practices** like water harvesting structures, agroforestry, organic farming, social sciences, and animal and plant breeding.
 **Biodynamic farming**	● **Farms generate their own fertility** through composting, integrating animals, cover cropping, and crop rotation. ● Favors **open-pollinated, heirloom**, and **non-GMO** seeds and heritage breeds of animals. ● Observes on the **relationship between plant/animal growth** and **cosmic rhythms** by advocating practices like the lunar and cultural calendar synchronisation. ● Uses **Biodynamic preparations** (for crops and/or compost) made from medicinal plants, cow dung, quartz, Horn manure and living animals on the farm. ● **Approaches Pests and Diseases Holistically** creating the conditions for optimal soil, plant, and animal health, providing balanced nutrition and supporting healthy immunity.
 **Conservation agriculture**	● **Ecosystem approach** to agricultural land management with diversification of cropping systems. ● **Minimum mechanical disturbance** to soil (maximum 25 per cent of the soil is disturbed) through no-tillage /reduced tillage, direct seed and/or fertilizer placement. ● **Permanent maintenance of soil mulch** by retaining crop residues or cover crops on the field (minimum 30 per cent retention).
 **Precision farming**	● **Uses information technology** to ensure that the crops and soil receive exactly what they need for optimum health and productivity. ● **Site-specific management and distribution of inputs** to maximise long-term benefits and prevent wastage. ● **Utilizes technological tools** including-

	➤ **System for collecting spatial information** (remote sensing, ground-based analytical methods) and ➤ **System of spatial control of operations** (GPS, drones, sensors etc.)
 **Agroforestry**	● Woody perennials (trees, shrubs, bamboos, palms) are integrated on purpose on the same land as crops and/or animals. ● **Includes systems like-** ➤ **Agrisilvicultural systems:** combination of crops and trees, such as alley cropping. ➤ **Silvopastoral systems:** combine forestry and grazing of domesticated animals on pastures, rangelands or on-farm. ➤ **Agrosylvopastoral systems:** integrate all - trees, animals and crops.
 **System of Rice Intensification (SRI)**	● Climate-smart agroecological approach for increasing rice and other crops' productivity. ● Reduced and controlled water application. ● Reduced plant density. ● Improved soil conditions through enhancing soil organic matter. ● Early, quick, and healthy plant establishment.
 **Integrated pest management (IPM)**	● **Prevention and Suppression** using methods like crop rotation, conservation tillage, hygiene measures etc. ● **Monitoring** through observations, use of scientifically sound warning, forecasting and early diagnosis systems etc. ● **Threshold-based intervention:** Threshold is the defined pest density, or population level, which when exceeded cause economically unacceptable damage or loss. ● **Priority to Non-chemical methods** like use of live natural enemies, soil-solarization etc. ● Minimal Pesticide use as a last resort with Anti-resistant strategies like combination of different pesticides that has different mode of action, applied in different time.
 **Integrated farming system (IFS)**	● **Judicious mix and positive interaction between two or more components -** such as horticulture crops, livestock, aquaculture, poultry/ducks, apiculture, and mushroom cultivation. ● Uses the cardinal principles of minimum competition and maximum complementarity with advanced agronomic management tools.
 **Sustainable Sugarcane Initiative (SSI)**	● **Raising nursery in portrays** using single budded chips. ● **Transplanting young seedlings** (25-35 days old). ● Maintaining **wider spacing** (5x2 feet) in the main field. ● Providing **sufficient moisture** through efficient water management technologies viz.,drip fertigation. ● Encouraging **organic method** of nutrient and plant protection measures. ● Practicing **intercropping** with effective utilization of land.

Vertical Farming Techniques:



Hydroponics,

Aeroponics

Aquaponics

- **Hydroponics**
  - **Sapling usually placed on a substrate** (like rock wool, volcanic ash, peat moss, coco coir or clay pebbles), which is dosed with nutrient-rich water periodically.
  - Many a times, plants are simply planted **along a channel that has flowing water.**
- **Aeroponics**
  - **Plants are grown in a controlled air environment** and are not placed on a substrate or in water.
  - The exposed roots are periodically sprayed with nutrient solutions for the plants to grow.
- **Aquaponics**
  - **Combines conventional aquaculture** (raising aquatic animals such as snails, fish, crayfish or prawns in tanks) with hydroponic crops.
  - Water containing the waste material from the aquaculture fish is used to grow hydroponic plants and is then re-circulated in the system to be reused by fish.

Transformative adaptation in agriculture

- It is intended to change the fundamental attributes of agricultural systems in response to actual or expected climate and its effects.

Attributes of Transformative Adaption in Agriculture

RELOCATION

Example: Coffee shifted upslope to cooler locations

FUNDAMENTAL SHIFTS

Example: Farmers shifting from rice to aquaculture

NEW TECHNOLOGY/METHODOLOGY

Example: Introduction of storm-resistant greenhouses allow for production of broader range of vegetables

**Sustainable Practices such as Crop Rotation, Mulching etc. involved in the agricultural systems discussed above, have been discussed in detail in the appendix.*

In Conversation!

Organic, Natural and Zero Budget Natural farming: How are they different?

Vinay: Hey Vini! Did you hear about Anita, she is planning to leave her corporate job and undertake natural farming on her ancestral land in the village.

Vini: Wow! That sounds great. You know my uncle is an organic farmer. This makes me wonder, are organic and natural farming the same thing?

Vinay: Well from what I have heard from Anita, they do have some common practices like both systems discourage farmers from using any chemical fertilizers and pesticides and encourage them to use local breeds of seeds. But there are some differences as well.

Vini: Okay. Can you tell me more about the differences?

Vinay: Sure! One of the major differences is that while in organic farming, organic fertilizers and manures like compost, vermicompost, etc. are added to farmlands from external sources, no external fertilizers are used whatsoever in natural farming.

Vini: So how do farmers ensure that their soil is fertile enough to raise a crop in natural farming?

Vinay: Well! In natural farming, rather than addition of external inputs, decomposition of organic matter by microbes and earthworms is encouraged right on the soil surface itself, which gradually adds nutrition in the soil, over the period.

Vini: Okay! So natural farming approach imitates the way of nature to achieve soil fertility without the need of human inputs.

Vinay: Yes exactly! This is why there is no plowing, no soil tilling, and no weeding in natural farming, precisely as it would be in natural ecosystems. But such practices are often undertaken in organic farms.

Vini: Okay. Now I understand. But recently I have also been hearing a lot about Zero budget natural farming (ZBNF). Do you know how is it different from both organic and natural farming?

Vinay: Sorry I don't have much knowledge about that Vini. Let's ask Mukherjee Ma'am next time we see her.

Vini: Good idea!

LATER IN THE DAY

Mukherjee Ma'am: Hello Students! What brings you two here today?

Vinay: Hello Ma'am! We'd like to learn about ZBNF.

Vini: And we are both curious about how it is different from organic and natural farming?

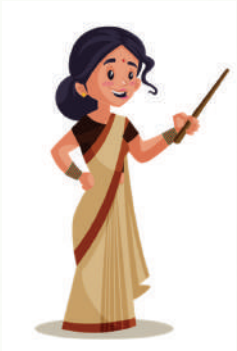
Mukherjee Ma'am: Well, let me start by telling you about the origin of natural farming. This farming approach was established by Masanobu Fukuoka, a Japanese farmer and philosopher who introduced it in his 1975 book The One-Straw Revolution. Consequently, in India, a version of this approach known as ZBNF was popularised by Maharashtrian agriculturist and Padma Shri recipient Subhash Palekar in the mid-1990s.

Vini: So ZBNF essentially follows the principles of natural farming?

Mukherjee Ma'am: Yes. But as you know natural farming tries to eliminate use of external inputs, ZBNF uses this principle to try and achieve an additional goal of reducing the cost of production to zero, making farming into a "zero budget" exercise. For this, Mr Palekar has devised some elements specifically for Indian farmers.

Vinay: Ma'am, what are these elements?

Mukherjee Ma'am: There are four core elements-



1. Bijamrita, which are formulations prepared using cow dung and cow urine from native co species to treat the seeds to protect them from diseases;
2. Jiwamrita, which is fermented microbial culture obtained from cow dung, urine, jaggery, pulse flour and uncontaminated soil that acts as a catalytic agent to promote the activity of microorganism and earthworms in the soil;
3. Acchadana, which means mulching; and
4. Waaphasa, which means promoting good aeration of soil.

Vini: Thank you so much for the information, Ma'am.

Vinay: Yes. Thank you! We learnt a lot today.

Mukherjee Ma'am: Happy to help you students. Have a good day!

The applicability of these practices, systems and the **associated principles** are not limited to the cropping sector but directly or indirectly **connected to the livestock sector, fisheries sector among others.**

Why is it important to move towards sustainable agriculture?

Sustainable agriculture practices and systems (SAPSs) provide alternatives to ongoing conventional agricultural practices and seek to minimize or eliminate their negative ramifications on environment, natural resources, and communities.
Following benefits highlight the significance of SAPs:

- **Securing farmers' income:** SAPSs sustains economic viability of agriculture and augments farmer's income by-
  - **Lowering cost of production** through minimizing use of all external inputs and promoting resource use efficiency.
  - **Diversifying source of income.**
  - **Empowering farmers to set prices for their products** with sustainably produced food fetching premium prices.
  - **Reducing chances of crop failure and losses and making agriculture more resilient** by crop diversification and integrating climate change adaptation/mitigation within agricultural practices.

In Practice

- ZBNF aims at making the cost of growing and harvesting plants zero.
- Under IFS, farmers have multiple income sources such as through milk production, fisheries, production of on farm organic manure etc.

- **Increasing soil fertility:** SAPSs focus on restoring natural capacity of soils to replenish macro and micronutrients, limit disturbance of soil surface, improve the soil physical properties such as granulation, good tilth, good aeration, easy root penetration, water holding capacity etc. and prevent erosion which **enhances agricultural productivity in the long run.**

In Practice

- Organic farming enhances soil organic content through practices such as mulching, cover crops, use of organic manure, vermicompost, etc.

- **Ensuring nutritional and food security:** By making the entire agricultural sector sustainable and diversifying crop production to include nutritious food varieties, SAPSs significantly enhances the overall food and nutrition security in the long run.
  - Further, SAPSs decentralizes food production by prioritizing small family or community owned farms, thus **strengthening domestic food production, reducing reliance on global supply chains and stabilizing the food supply.**

In Practice

- ZBNF encourages use of local seeds which are suited to agro-climatic conditions.
- Permaculture promotes cultivation of leguminous plants in intercropping or as cover crops, which are a crucial source of proteins and other minerals.

- **Enhancing resource use efficiency:** SAPSs encourage minimal and precise application of inputs and provide alternatives to conventional agricultural practices which rely on extensive use of chemical fertilizers, pesticides, fungicides, insecticides etc., and artificial irrigation.
  - Resource efficiency is key to tackle issues like groundwater depletion, greenhouse gas emissions, eutrophication, air and water pollution etc.

In Practice

- Under Precision Farming, nitrogen-use efficiency has been reported to increase by 368%.
- Under IPM, chemical pesticides use had reduced by 50-100% for rice and 30- 50% for cotton.
- SRI is known to consume 50-60% less water than traditional methods.

- **Production of healthy and clean food:** Excessive pesticide use has been associated with adverse health impacts for farmworkers, consumers, pollinators and other biodiversity. For instance, in humans it has been linked to cancer, Alzheimer's Disease, and even birth defects. By promoting mechanical and natural ways for managing pest, SAPSs prevent toxic chemicals from entering food chain and reduce human and animal health hazards.
  - Further natural practices are said to enhance taste and nutritional value of food produced.

> **In Practice**
> - IPM advocates for use of chemical pesticides as a last resort and even tolerance of pests unless economically unviable.

In Conversation!

Are organic and naturally grown products tastier and more nutritious?

Vinay: Hey Vini! Did you go to the new restaurant I suggested you?

Vini: Hi Vinay! Yes, I did. The food there was delicious and so flavourful, just like you told me.

Vinay: You know one of the reasons the food tasted so good was because they source all their fruits and vegetables from organic and natural farms.

Vini: But why does it matter how the food is produced? Don't all fruits and vegetables taste the same?

Vinay: Well Vini! It has been found that organic food products have higher antioxidant levels which affect food's organoleptic qualities–taste, aroma, and mouthfeel–and how the human senses detect a food's unique flavor.

Vini: Interesting! But what is the reason behind it?

Vinay: Since organic farming prohibits chemical pesticides that are widely used in conventional farming, organic plants produce more phenols and polyphenols that defend against pests, in turn nurturing higher concentrations of antioxidant compounds.

Vini: Okay. Do natural practices have an impact on nutritional quality of food as well?

Vinay: Yes. Conventionally farmed soil also tends to have high levels of nitrogen from synthetic fertilizers. This Nitrogen is used by plant as quick and easy energy source to create high levels of sugars and starches in place of other minerals. Also, biodynamically grown foods have been found to contain higher levels of vitamins, minerals, and amino acids.

Vini: So, organic farming is not just good for the environment, it is good for our taste buds and health too.

- **Conserving biodiversity:** Globally, food production is linked to 70% of biodiversity loss on land. SASPs helps farmers build synergies with natural ecosystems and promotes symbiotic relationship with on and off farm biodiversity.

> **In Practice**
> - Agroforestry creates a green corridor enabling sensitive species to move between different habitats.

- **Empowering rural communities:** A key aspect of SASPs is to train rural communities to undertake farming practices in a profitable yet sustainable manner. Further it advocates for adoption of traditional agricultural practices and helps in creation of green jobs for rural youth.

> **In Practice**
> - Practices like mulching, hand weeding, preparation of organic manure etc. are labour-intensive and generate additional employment.

- **Transforming Food Systems for Adaptation, Mitigation, and Resilience to climate change:** Agriculture is both a major source of emissions and the sector most affected by climate change (see infographic). SAPSs are expected to overhaul production segment of food systems and help farmers to enhance resiliency of agricultural production, progressively adapt to adverse effects of climate change as well as contribute to mitigation efforts.

➤ **SASPs role in Adaptation:**

- Encourages traditional crop production techniques suited to agro-climatic conditions.
- Promotes use of local seed varieties which are tolerant to drought.
- Reduces water and energy needs for agricultural production.

In Practice

- Transformative adaptation techniques in agriculture can help farmers to modify farming methods in accordance to changing climate.
- Precision farming can help farmers make use of scarce water resources in case of predicted water shortages due to climate change.

➤ **SASPs role in Mitigation:**

- Minimizes use of nitrogenous fertilizers (source of NOx a **Greenhouse gas).**
- Increasing energy efficiency on farms and promotes energy generation from renewable energy sources.
- Reduces methane emissions by encouraging on farm management of animal waste, continuous soil cover and judicious water use.
- Enables creation of additional carbon sink.

In Practice

- SRI promotes aerobic soil conditions that reduce methane emissions.
- Agroforestry is widely known for its carbon-sequestering abilities.

How Agriculture sector is reponsible for climate change?

21 percent of total GHG emissions across the globe are from agriculture, forestry, and other land use. Major sources of emission incldue-

* Deforestation and peatland degradation.
* Methane emission from enteric fermentation from ruminant animals and from anaerobic fermentation in manure management processes.
* NOx emission from excessive fertilizer use
* Methane emission from flooded paddy fields.
* Carbon emissions from fertilizer and pesticide industries, on-farm energy applications etc.

How is climate change predicted to impact agriculture production?

* **Slowed growth of agricultural productivity** due to increasing temperatures, water scarcity and other negative impacts of GHG emissions on air, soil, and water quality.
* **Increased occurrence of pests, weeds and diseases.**
* **Decreased wild fish population** due to ocean warming.
* **Reduced effectiveness of pollinator agents,** or disruption in the coordination of pollinator activity and flower receptiveness.
* **Reduced labour capacity, animal health, and dairy and meat production** due to heat stress.
* **Changes in distribution, growing area suitability and timing of key biological events,** such as flowering, impacting food quality and harvest stability.
* **Adverse impacts associated with Climate-related extremes** like Droughts, floods, and marine heatwaves.

Further, widespread adoption of SAPSs can play a significant role in strengthening position of India in global value network, by decreasing dependence on imports for chemical agricultural inputs and enhancing export of highly valued naturally and organically grown food.

Conclusion

India's agricultural sector has a large carbon footprint, contributing around 18 per cent of GHGs emitted. Thus, sustainable agriculture is set to play a central role in achieving multiple, pressing sustainable development and climate goals. Since, in sustainable agriculture, resource utilization and product production are closely combined with the goal of ecological conservation and sustainable development of the whole society, it will also eternally help in pursuing the stability, balance, and circulation of a dynamic and developing system.

Appendix

 Mulching	● It is the practice of covering the soil surface with organic materials (plant residues, straw, hay, leaf and compost, peat, and animal manure), or synthetic materials (polyethylene, wax-coated papers, aluminium, steel foils, and asphalt spray emulsions). It conserves soil moisture, avoids runoff and increases soil productivity.
 Cover crops	● Cover crops are crops planted to cover the soil rather than to be harvested. ● They can be rotated with other crops or intercropped and also grown in between cultivation seasons to control soil erosion, add organic matter to the soil, supplying nitrogen, controlling weeds, and fighting insects/pests.
 Vermicomposting	● It is a biotechnological composting process that uses certain earthworms to enhance the process of biomass waste conversion to produce good quality compost. The resultant product is a stabilised, uniformly sized substance with a characteristic earthy appearance known as vermicast/vermicompost. ● Vermicomposting differs from composting as earthworms accelerate decomposition rates and is considered more superior in quality due to higher nutrient content.
 Crop rotation	● It is the practice of planting two or more crops sequentially on the same plot of land to improve soil health, optimise nutrients, and combat pest and weed pressure. ● Simple rotation may involve two or three crops, while a complex rotation may incorporate a dozen or more.
 Intercropping	● It is the growing of two or more crops simultaneously in the same field and can be of various types viz. mixed, row, strip, and relay intercropping.
 Agricultural or plant biostimulants	● They are biological or biologically derived fertilizer additives and similar products that are used in crop production to supplement and enhance existing agricultural practices and crop inputs. They might achieve this by: ➤ Helping to improve nutrient-use efficiency. ➤ Helping plants tolerate abiotic stresses like heat, cold, drought, and too much water. ➤ Helping to improve quality attributes like nutritional content, appearance, and shelf-life.

TOPIC AT-A-GLANCE

Sustainable agriculture
Production of plant and animal products, including food, in a way that utilizes farming techniques that protect the environment, public health, communities, and animal welfare.

Environmental health
- Enhance environmental quality and promote healthy biodiversity.
- Manage natural resources wisely.
- Integrate natural biological cycles and controls.

Economic profitability
- Make the most efficient use of non-renewable resources and on-farm resources.
- Sustain the economic viability of farm operations.

Social and economic equity
- Satisfy human food and fiber needs.
- Increase farm incomes.
- Enhance the quality of life for farmers and society as a whole and provide nutritious food.

Prominent systems and practices involved in Sustainable Agriculture

Organic Farming	Prohibits use of synthetically produced agro-inputs; instead uses organic inputs like organic manure, bio pesticides etc. produced using natural raw materials.
Natural Farming	Termed as 'do nothing farming' and involves elimination of tillage and external inputs. Stimulates soil's microbial activities using Biostimulants and other practices.
Permaculture	Consciously designed landscapes, which mimic the patterns and relationships found in nature. Produces no waste and values diversity.
Biodynamic farming	Farms generate their own fertility through practices like composting etc. Uses Biodynamic preparations.
Conservation agriculture	Ecosystem approach to agricultural land management with diversification of cropping systems and Minimum mechanical disturbance to soil.
Precision farming	Uses information technology to ensure that the crops and soil receive exactly what they need for optimum health and productivity.
Agroforestry	Woody perennials (trees, shrubs, bamboos, palms) are integrated on purpose on the same land as crops and/or animals.
Integrated pest management (IPM)	**Prevention and suppression** of pests done using methods like crop rotation, conservation tillage, hygiene measures etc. **Threshold-based intervention** of pest management.
Integrated farming system (IFS)	**Judicious mix and positive interaction between two or more components -** such as horticulture crops, livestock, aquaculture, poultry/ducks, apiculture, and mushroom cultivation.
Vertical Farming Techniques	Includes practice where crops are raised outside traditional soil based farms, like- Hydroponics, Aeroponics and aquaponics.
Transformative adaptation in agriculture	Intended to change the fundamental attributes of agricultural systems in response to actual or expected climate and its effects.
Crop specific practices	System of Rice Intensification (SRI) and Sustainable Sugarcane Initiative (SSI).

Importance of moving towards sustainable agriculture

- **Secures farmers' income** by diversifying source of income; empowering farmers to set prices for their products and reducing chances of crop failure and losses and making agriculture more resilient.
- **Increases soil fertility.**
- **Ensures nutritional and food security** by making the entire agricultural sector sustainable and diversifying crop production to include nutritious food varieties.
- **Enhances resource use efficiency** by encouraging minimal and precise application of inputs.
- **Produces healthy and clean food.**
- **Conserves biodiversity** by building synergies with natural ecosystems and promotes symbiotic relationship with on and off farm biodiversity.
- **Empowers rural communities.**
- **Helps farmers to enhance resiliency of agricultural production, progressively adapt to adverse effects of climate change as well as contribute to mitigation efforts.**