- Apply composts and manures to increase soil organic matter stocks.
- Improve pasture/rangelands through grazing, vegetation and fire management both to reduce degradation and increase soil organic matter.
- Cultivate perennial grasses (60-80% of biomass below ground) rather than annuals (20% below ground).
- Restore and protect agricultural wetlands.
- Convert marginal agricultural land to woodlands to increase standing biomass of carbon.

Reduce direct and indirect energy use to avoid greenhouse gas emissions (CO_2, CH_4 and N_2O)

- Conserve fuel and reduce machinery use to avoid fossil-fuel consumption.
- Use conservation or zero-tillage to reduce CO_2 emissions from soils.
- Adopt grass-based grazing systems to reduce methane emissions from ruminant livestock.
- Use composting to reduce manure methane emissions.
- Substitute biofuel for fossil fuel consumption.
- Reduce the use of inorganic N fertilisers (as manufacture is highly energy intensive), and adopt targeted and slow release fertilisers.
- Use integrated pest management to reduce pesticide use (avoid indirect energy consumption).

Increase biomass-based renewable energy production to avoid carbon emissions

- Cultivate annual crops for biofuel production, such as ethanol from maize and sugar cane.
- Cultivate annual and perennial crops, such as grasses and coppiced trees, for combustion and electricity generation, with crops replanted each cycle for continued energy production.
- Use biogas digesters to produce methane, so substituting for fossil fuel sources.
- Use improved cooking stoves to increase efficiency of biomass fuels.

Source: Pretty et al., 2002

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Agro-ecology: alternative production system

Agro-ecology is a discipline that uses ecological theory to design, manage and evaluate agricultural systems that are productive but also conserve natural resources. Agro-ecological farming also refers to interactions of all important biophysical, technical and socio-economic components of farming systems and regards these systems as the fundamental units in which mineral cycles, energy transformations, biological processes and socio-economic relationships are considered in an interdisciplinary way. Agro-ecology is closely related to the concept of sustainable agriculture. Agro-ecology is a climate smart agriculture that seeks to increase productivity in an environmentally and socially sustainable way, strengthen farmers' resilience to climate change and reduce agriculture's contribution to climate change by reducing greenhouse gas (GHG) emissions and increasing carbon storage on farmland.

Agro-ecological farming is a whole-systems approach to food, feed and fibre production that balances environmental soundness, social equity and economic viability among all sectors of the public, including international and intergenerational peoples. Inherent in this definition is the idea that sustainability must be extended not only globally but indefinitely in time and to all living organisms including humans.

Agro-ecological farming is based on the following:

- The application of ecology to the design and management of sustainable agro-ecosystems.
- A whole-systems approach to agriculture and food systems development based on traditional knowledge, alternative agriculture, and local food system experiences.
- Linking ecology, culture, economics and society to sustain agricultural production, healthy environments and viable food and farming communities.

As a climate smart agriculture, agro-ecology includes proven practical techniques such as mulching, intercropping, zero-tillage; agro-forestry, improved grazing and improved water management. By increasing the organic content of soil, its water-holding capacity increases, making yield more resilient to climate change and increasing the stock of carbon on farmland.

Principles of agro-ecology

In the search to reinstate more ecological rationale into agricultural production, scientists and developers have disregarded a key point in the development of a more self-sufficient and sustaining agriculture: a deep understanding of the nature of agro-ecosystems and the

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principles by which they function. Given this limitation, agro-ecology has emerged as the discipline that provides the basic ecological principles for how to study, design and manage agro-ecosystems that are both productive and natural resource conserving and that are culturally sensitive, socially just and economically viable.

The core principles of agro-ecology include recycling nutrients and energy on the farm, rather than introducing external inputs; integrating crops and livestock; diversifying species and genetic resources in agro-ecosystems over time and space; and focusing on interactions and productivity across the agricultural system, rather than focusing on individual species. It is highly knowledge-intensive, based on techniques that are not delivered top-down but developed on the basis of farmers' knowledge and experimentation. It goes beyond a one-dimensional view of agro-ecosystems—their genetics, agronomy, edaphology, and so on—to embrace an understanding of ecological and social levels of co-evolution, structure and function. Instead of focusing on one particular component of the agro-ecosystems, agro-ecology emphasises the interrelatedness of all agro-ecosystem components and the complex dynamics of ecological processes.

Agro-ecosystems are communities of plants and animals interacting with their physical and chemical environments that have been modified by people to produce food, fibre, fuel and other products for human consumption and processing. Agro-ecology is the holistic study of agro-ecosystems, including all environmental and human elements. It focuses on the form, dynamics and functions of their interrelationships and the processes in which they are involved. An area used for agricultural production, e.g. a field, is seen as a complex system in which ecological processes found under natural conditions also occur, e.g. nutrient cycling, predator/prey interactions, competition and symbiosis and succession changes. Implicit in agro-ecological research is the idea that, by understanding these ecological relationships and processes, agro-ecosystems can be manipulated to improve production and to produce more sustainably, with fewer negative environmental or social impact and fewer external inputs.

Agro-ecology techniques and designs function as an "ecological turntable" by activating and influencing key components and processes of the agro-ecosystem:

a. Enhance recycling of biomass and optimise nutrient availability and balance nutrient flow.
b. Secure favourable soil conditions for plant growth, particularly by managing organic matter and enhancing soil biotic activity.
c. Minimise losses owing to flows of solar radiation, air and water by way of microclimate management, water harvesting and soil management through increased soil cover.
d. Species and genetic diversification of the agro-ecosystems in time and space.
e Enhance beneficial biological interactions and synergisms among agro biodiversity components thereby resulting in the promotion of key ecological processes and services.

These principles can be applied by way of various techniques and strategies. Each of these will have different effects on productivity, stability and resiliency within the farm system, depending on the local opportunities, resource constraints and, in most cases, on the market.

Agro-ecology practices

A wide panoply of techniques based on the agro-ecological perspective has been developed and successfully tested in a range of regions. These approaches involve the maintenance or introduction of agricultural biodiversity (diversity of crops, livestock, agroforestry, fish, pollinators, insects, soil biota and other components that occur in and around production systems) to achieve the desired results in production and sustainability.

- Crop rotation: Temporal diversity incorporated into cropping systems, providing crop nutrients and breaking the life cycles of several insect pests, diseases and weed life cycles.
- Polycultures: Complex cropping systems in which two or more crop species are planted within sufficient spatial proximity to result in competition or complementation, thereby enhancing yields.
- Agroforestry systems: An agricultural system in which trees are grown together with annual crops and/or animals, resulting in enhanced complementary relations between components increasing multiple uses of the agro-ecosystems.
- Cover crops: The use of pure or mixed stands of legumes or other annual plant species under fruit trees for the purpose of improving soil fertility, enhancing biological control of pests and modifying the orchard microclimate.
- Animal integration in agro-ecosystem aids in achieving high biomass output and optimal recycling.

All of the above diversified forms of agro-ecosystems share in common the following features:

Maintain vegetative cover as an effective soil and water conserving measure, met through the use of no-till practices, mulch farming and use of cover crops and other appropriate methods.

Provide a regular supply of organic matter through the addition of organic matter (manure, compost, and promotion of soil biotic activity).

Enhance nutrient recycling mechanisms through the use of livestock systems based on legumes, etc.

Promote pest regulation through enhanced activity of biological control agents achieved by introducing and/or conserving natural enemies and antagonists.

Mechanisms for increasing carbon sinks and reducing CO2 and other greenhouse gas emissions in agricultural systems.

Increase carbon sinks in soil organic matter and above-ground biomass

- Replace inversion ploughing with conservation and zero-tillage systems.
- Adopt mixed rotations with cover crops and green manures to increase biomass additions to the soil.
- Adopt agroforestry in cropping systems to increase above-ground standing biomass.
- Minimise summer fallows and periods with no ground cover to maintain soil organic matter stocks.
- Use soil conservation measures to avoid soil erosion and loss of soil organic matter.