10. Proponents of sustainable agriculture cite evidence that sustainable yields can be equivalent if not surpass and be less variable than those attained using conventional methods.

11.1.4. Characteristics of Sustainable Agriculture:

1. Maintains adequate productivity levels.
2. Productivity is relatively stable.
3. Conserves and/or improves natural resources base.
4. Ecofriendly.
5. Diversified (it favors biological diversity).
6. Most economical (input use efficiency is high).
7. Improves quality of life because of better food and nutritional securities.
8. Prefers biological technology to chemical technology.
9. Favors sustainable development of human society.
10. Enhances use of on-farm renewable resources and diminishes use of off-farm inputs.

11.2 Principles of Sustainable Agriculture:

1. Input optimization

The on farm resources tend to increase due to the adoption of sustainable production practices. Few examples of alternated resources are family labor, intensive grazing systems, recycled form of nutrients, legume nitrogen, crop rotation, use of solar energy, and advanced management of pests, soils and woodlands.

2. Diversification

To develop healthy soils and reduced purchased inputs, sustainable agriculture emphasizes varied cropping and livestock systems. Diversification can lead to more constant farm income by lowering economic danger from climate, pests and fluctuating markets.

3. Conservation of natural capital

It is standard accounting practice to devalue capital assets. Nevertheless, in sustainable agriculture, economic value is formed by maintaining the productivity of land and water resources, while improving human health and the environments.

4. Capturing value added

The marketing of crops products grown is by far is the weakest link in the farmer's role in the field to table food system.

5. Community

The elements of sustainable agriculture are vital to all communities. If we are to support sustainable agriculture, we must distinguish the rural/urban interconnection, the differences and marvelous opportunities..

Conditions/Aims

1. Sustainable agriculture system has to prevent degradation of natural resources.
2. It must be environmentally friendly i.e., shield and improve air, water and soil quality and health.
3. It has to be economically feasible both in short and long term perspective for enhancing the productivity.
4. It has to maintain the human needs of today and tomorrow with quality food.
5. It has to replenish nutrients.
6. It has also to control weeds, insects and diseases through biological and cultural methods.
7. Society acceptability.

11.3 Elements of Sustainable Agriculture:

1. Biodiversity:

The 5-10 million species are estimated to exist in the world that constitutes terrestrial as well as marine biodiversity. Erosion of biodiversity is proceeding at an unprecedented rate of 2.5 species per hour driving 1.0 million species into extinction by the end year of 2050. Biodiversity is well-recognized at different genetic levels. It needs to be studied and conserved at each level. Agro-biodiversity, which is part of natural biodiversity, must not be seen in isolation and conservational approaches should be extended to all floral and faunal wealth.

2. Promising varieties:

Role of promising varieties in sustaining crop productivity stems from the ability to perform better even under constrained environments. Promising varieties, over the long period of time have proven their worth through the following features:

a) Enhance to food security through stabilization of crop productivity.

b) Input use efficiency is better.

c) Ecofriendly, because of resistance to prevalent to biotic and abiotic stresses.

d) Improved grain quality ensures nutritional security.

e) Increase employment opportunities because of sustained productivity and increased profitability.

f) Location specific breeding as resulted in development of different ecotypes and thus, has enhanced varietal diversity in agricultural crops.

3. Integrated Nutrient Management:

Increased fertilizer consumption during the last three decades has led to the decline the ratio of grain: nutrient. In fact, fertilizer use is largely imbalanced with excessive application of nitrogen. It has deteriorated soil health. Therefore, no way is left out except resorting of integrated nutrient management system which makes combined use of chemical fertilizers, organic manures and biofertilizers. The system ensures balanced nutrition for plant growth with much adverse effects on an environment. Following points are required to keep INM economical and more effective.

i. NPK recommendations must be backed by proper soil tests.

ii. Balanced fertilization through organic manures, chemical fertilizers, biofertilizers and micro-nutrient applications. This will maintain physical, chemical and biological potential of soils.

iii. Constant soil fertility watch by study of nutrient response of crops and nutrient removal by crops.

iv. Developing INM technology for different crop sequences in different crop situation.

v. Besides FYM, other sources of organic manures such as crop residues, green manuring and composting should be evaluated and recommended.

vi. Inclusion of a legume in crop rotation and inoculation with efficient strains of Rhizobium needs to be promoted.

4. Tissue Culture and Biotechnology:

Tissue culture and biotechnology are contributing towards sustainable crop production via generating organisms capable of rendering services to human society in a better way. Their application in amelioration of agriculture summed up as under:

i. **Wide Hybridization:** It refers to the crossing or gene transfer between two species, genera, families or sometime even two kingdoms.

ii. Anther-culture for hastening varietal development programs in crop plants.

iii. DNA finger printing for varietal or species characterization.

iv. Transgenic plants for herbicide tolerance, insect resistance, disease resistance, male sterility and high protein quality.

v. Micro-organisms genetically transformed to produce medicinal chemicals, degrading pesticides and various industrial effluents.

5. Multipurpose Trees (Agro-forestry and Horticulture):

Keeping in view elevating demands for tree products, preference should be given to plantation of multipurpose trees (MPTs) in different agro-silviculture, silvi-pastoral or agro-horticultural systems.

6. Integrated Pest Management:

By the 20th century multiple suppression techniques such as sanitation, crop combinations, crop sequence, resistant varieties and chemicals were deployed to control pest populations. Miracle effects of DDT and to, four-d marked the indiscriminate use of chemicals in agriculture. Subsequently, it was realized that many of the chemicals were not biologically degradable. Barlett (1965) coined the term ‘integrated pest control’ and defined it as the blending of biological control agents with chemical control measures.

IPM integrates all the available pest control method to provide a farmer most effective, economical and sustainable technology where pesticides are a last resort and priority is on eco-friendly control measures.

Benefits:

i. Lower production cost because of reduced application of chemical pesticides.

ii. Safer environment to live.

iii. Brings in ecological sustainability by conserving natural enemies.

iv. Enormous government savings from pesticides import and subsidies.

v. Farmers are relieved off of pesticide poisoning and other related hazards.

vi. Frequency of pest resistant and resurgence is reduced.

vii. Reduced pesticide residues in the crop produce and food products.

7. Legume based cropping systems:

Reduction in productivity is due to cereal crop rotation (shallow root system), imbalanced crop-soil nutrients, more diseases and pest attack and more unit of water per unit of productivity. It is now acknowledged fact that continuous persistence of a crop rotation in a field causes 'soil sickness', mining of certain nutrients while accumulation of other and unification in farmers diet (responsible for enhancing malnutrition). Pulses are poor man's proteins and provide tangible solution to the prevalent malnutrition in the world. In addition, cultivation of pulses endowed with several advantages such as:

i. Growing legumes in rotation with cereal improves nitrogen mineralization potential in soil.

ii. Green manuring with legumes gives an advantage of 40-90% on nitrogen per hectare.

iii. Make the crop sequence sustainable by favoring soil, plant and environment health.

iv. Some legumes have character of high phosphorous efficiency/ by phosphate solublilization i.e., *Phaseolus vulgaris*.

v. Enhance crop productivity per unit area by increasing cropping intensity such as rice-wheat replacement by Rice-Wheat-Mung/Urd (summer).

vi. Improve soil structure, soil microbial activity, water holding capacity, buffering capacity and release of growth promoting substances.

vii. Act as soil binding crops.

viii. Legumes are drought resistant.

ix. Legumes prove diverse service to human society such as timber, fodder, oilseed, medicine, pulses and ornamentals.

x. Richer harvest of proteins per unit area.

8. Secondary and micro-nutrient applications:

Revolution in agricultural production occurred because of steady supply of micro-nutrients such as N, P and K to crops. Now the productivity levels are stagnant rather declining in some high productive zones. The reason has been deficiency of secondary and micro-nutrients namely Ca, Mg, S, Fe, Mn, Zn, Co, Mo and Cu in soils.

Inadequate macro and micro nutrients application result in one or more of the following problems:

i. Deterioration of soil health in terms of physical, chemical and biological properties.

ii. Low nutrient use efficiency.

iii. More pollution due to increased leaching, volatilization and run-off of nutrients.

iv. Adverse effects on soil flora and fauna.

v. Crop produce of low quality.

vi. Reduce crop yield.

vii. More proneness to disease and pest due to reduce plant vigor.

9. Water harvesting technology:

FAO estimates that 60% more food will be required in next 30 years by world's population. In future water harvesting technology for the various agro-ecosystems will be the key factor

in sustaining the crop productivity in different regions of the world. Following points must receive due consideration in implementation of water harvesting technologies:

i. Recycling and re-use of waste water.

ii. Development of micro watershed for proper rain water harvesting.

iii. Soil moisture conservation technology through agronomic, breeding and soil management techniques.

11.4 Organic Agriculture

11.4.1 Concept

According to definition of USDA organic farming is a production system, which shuns or prohibits the use of synthetic inorganic fertilizers, pesticides, growth regulators and livestock feed additives. This system mainly depends upon crop rotations, crop residues, animal manures, green manures, off-farm organic wastes, mechanical cultivation, mineral bearing rocks and features of biological pest control to sustain soil productivity, to supply plant nutrients and to control insects, pathogens and weeds.

According to the definition of FAO, organic farming is successful management of resources for agriculture to assure changing humans needs while preserving or improving the quality of environment and consuming natural resources. It emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions need locally adopted systems. This is accomplished by using, where possible, agronomic, biological, and mechanical methods as opposite to using synthetic materials, to complete any specific function within the system. In organic farming major emphasis is given on recycling of recyclable organic wastes (crop residues, animal waste and municipal and sewage wastes). These are valuable sources of plant nutrients and humus. When industrial waste are recycled as manure for crop production and are subjected to squalor and assimilative capacity of soil pollution of streams/rivers receiving these wastes is reduced to a large extent as compared to their direct discarding in water bodies. The manurial value and quality of these wastes could be improved by composting and enriching these organic sources along with inexpensive material such as rock phosphate. Crop residues have wide C:N ratio and when applied directly nutrients may get immobilized leading to initial adverse effect on crop growth. Hence, sufficient protection is necessary to use residues after proper composting with proficient microbial inoculants. Inoculation of these wastes produces enough simple sugar for growth and multiplication of beneficial micro flora like free living nitrogen fixers and phosphate solubilizers in the soil which ultimately increases crop yield.

11.4.2. Aims / Objectives of Organic Farming

International Federation of Organic Agriculture Movement (IFDAM) expressed the objectives as follows:

i. To work, as much as possible, within a closed system with regard to organic matter and nutrient elements,

ii. To preserve and increase long term fertility and productivity of soils,

iii. To stop degradation and re-establish natural equilibrium

iv. To avoid all form of pollutions that may result from agricultural techniques,

v. To minimize the use of fossil energy in agriculture,

vi. To work with natural system rather than seeking to dominate them,

vii. To use as far as possible, renewable sources in locally organized agricultural systems,

viii. To push and improve the biological cycles with farming system involving microorganisms, soil flora and fauna, plants and animals,

ix. To give all livestock, conditions of life that allow them to execute all aspects of their innate (natural) behavior,

x. To continue the genetic diversity of agricultural system and its surroundings, including the protection of plants and wildlife habitats,

xi. To produce food of high nutritional quality in adequate quantity,

11.4.3. Principles of Organic Farming

Organic farming system is based on the active interaction between the soil, plant, animal, humans, ecosystem and the environment. The system is directed towards enhancing natural life cycles rather than suppressing nature. The basic principles of organic farming are Health, Ecology, Fairness and Care. International federation of organic agricultural movements (IFOAM) was formed in 1972 in France. IFOAM summarizes the principles and practices in the standards in the manual as follows:

1. To manufacture food of high nutritive quality in adequate quantity.

2. To work with natural system and cycles rather than looking for to dominate them.

3. To push and improve biological cycles inside the farming systems, involving micro-organisms, soil flora and fauna, plants and animals.

4. To conserve and enhance the fertility the soil.

5. To use, as for as possible, renewable resources in locally controlled agricultural systems.

6. To work as much as possible within a closed system with respect to organic matter and nutrient elements.

7. To give all livestock, conditions of life that allows them to perform all features of their innate behavior.

8. To keep away from all forms of pollution that may result from agricultural techniques.

9. To uphold the genetic diversity of the agricultural system and its surroundings, including the protection of plants and wildlife habitats.

10. To allow agricultural producers an acceptable return and satisfaction from their work including a safe working environment.

11. To consider the wider social and ecological impact of the farming system.

Certain basic principles of organic farming (Sharma, 2002) are mentioned below:

1. **Crop and soil management:** Organic farming support crop rotation and use of organic manures including green manuring for increasing soil organic matter and humus leading to improvement in soil water retention, ion exchange, soil conservation and animal life in the soil.

2. **Nutrient Management:** All the organic matter produced on the farm should be returned to the soil to maintain adequate humus content on a long term basis.

3. **Plant Protection:** Organic farmers relay on diverse population of soil organisms, insects, birds and other organisms to remain the problem in check. When the pest population gets out of balance, farmers will apply a variety of strategies such as the use of insect predators, mating disruption, traps and barriers.

4. **Soil and Water Conservation:** Only running water can erode the soil. The velocity of running water can be minimized through contour cultivation trenching, contour bonding, terracing, gully plugging, grassing the water waves etc. depending on slope and other farming practices. Watershed management programs play key role in organic farming.

5. **Sustainable utilization of biodiversity:** Genetic diversity is the basis of future improvement to meet the diversified and ever chasing needs of the mankind. Agro biodiversity includes genetic diversity of plants, livestock, fisheries, microbes, insects, fungi and viruses. Agricultural growth has battered biodiversity in agro ecosystems including plant genetic resources, jeopardizing productivity and food security leading to broader social costs. Hence, scientific management of these invaluable resources has assumed greater importance overtime.

6. **Post-Harvest processing and storage:**

1. Preservatives are not permitted.

2. Synthetic colors or additives are discouraged.

3. Storage or packing of products should be in bio-degradable structures.

11.4.4. Need for Organic Farming

Organic farming is the path that directs us to live in agreement with nature. Organic farming is viable alternative to conventional agriculture and is the key to sound development and a sustainable environment. It minimizes environmental pollution and the use of non-conventional resources. It preserves soil fertility and soil erosion by the implementation of suitable conservation principles. Several reasons like limited land holdings, poor economic conditions of farmers, rise in input cost etc. have been characterized for the need of organic farming. In a broad sense, three major reasons are: ever increasing population demanding increased food grain production, depletion of natural resource base, and environmental pollution stresses the need for ecofriendly technologies i.e., organic farming. Table 11.1 illustrates the differences between conventional and organic agriculture.

11.4.5. Standards for Organic Crop Production

1. Conversion period

The time between the start of organic management and certification of crops is known as conversion period. The whole farm, including livestock should be converted according to the standards over a period of time as per specifications. Diversity in crop production and animal husbandry must be set in such a way that all the elements of farming interplay. The standards requirement shall be met during the conversion period. Start of conversion period may be calculated from the date of application. To ensure a clear separation between organic and conventional production, the certification shall inspect the production system.

1. Choice of crops and varieties

All kind of materials should be certified organic, climate friendly and resistant to insects and diseases. Chemically untreated conventional seed and plant material may be used when certified organic seed and plant material is not available. The use of genetically modified seeds, pollens, transgenic plants is prohibited.

2. Fertilization policy

Biodegradable material of microbial, plant or animal origin produced on organic farm should be the basis of fertilization program. Sufficient quantity of such material should be used to improve or at least to maintain the soil fertility. Manures containing human excreta are not allowed for use if the produce is for human consumption. Mineral fertilizers are permitted in supplementary role to carbon based materials. Such fertilizers can be applied in their natural composition and should not be provide more soluble by chemical treatment.

1. Soil and water conservation

Soil and water conservation should be handled in a sustainable manner. Related measures should be taken up to stop erosion, salinization of soil, inappropriate use of water and pollution of ground and surface water. Clearing the land by flaming, if required should be minimum. Clearing of primary forests is prohibited. Excessive utilization and reduction of water resources is not allowed.

1. Plant protection

Organic farming system must be carried out in a way which ensures that losses from insects, diseases and weeds are reduced. Emphasize should be on the use of balanced fertilizer program, adaptable crops and varieties and resistant cultivars. Weeds, insects and diseases should be managed by preventive, cultural techniques. Natural enemies of pests and diseases should be protected and encouraged through proper habitat management. Products used for plant protection, prepared at farm, local plants, animals and microbes are allowed. Thermal weed management and physical methods of insects

Table 11.1.: Difference between conventional/modern and organic agriculture

Sr. No.	Particulars	Conventional agri.	Organic agric.
1	Type of farming	Only crops	Agro-forestry, animal husbandry
2.	Plant nutrients	Chemical fertilizers only	F.Y.M., G.M., compost, rotation, bio-fertilizers
3.	Pest control	Pesticides	Cultural method, crop rotation, biological method
4.	Ecology	Fragile	Stable
5.	Inputs	High productivity and low diversity chemicals are used	High diversity, renewable and biodegradable inputs are used
6.	Use of resources	The rate of extraction exceeds the rate of regeneration, deforestation, overgrazing, pollution of water bodies take place.	The rate of extraction from forests, underground water resources and other renewable resources do not exceed the rate of regeneration
7.	Quality of food	Food material contain toxic residues	Food materials are safe

and diseases are allowed. Use of synthetic agrochemicals, synthetic growth regulators and genetically engineered organisms or products is banned.

11.4.6. Future Prospects of Organic Agriculture in Pakistan

In Pakistan, during 2001, 2009 ha area was certified organic area which is about 0.08% of total agriculture.

11.4.7. Organic Farming Systems:

Some of the organic farming systems, in brief, include the following:

1. **Biological Farming:** The Reams system is based on the LaMotte-Morgan soil test and the use of rock phosphate, calcium carbonate and compost to achieve nutrient ratios of 7:1 calcium to magnesium, 2:1 phosphorus and potassium and so on. It permits the use of selected chemicals fertilizers (avoiding disruptive materials such as anhydrous ammonia and potassium chloride) and agrees to use low input approaches to use of insecticides and pesticides.

2. **Nature Farming:** It counter parts organic farming putting special emphasis on soil health through composts rather than other organic sources, if possible. Use of microbial preparations is also gaining importance in nature farming in the near past.

3. **Permaculture:** It is apprehension with planning ecological human habitats and food production systems and follows specific guideline and principles in the design of these systems.

4. **Alternate agriculture:** Alternate agriculture recognizes that a piece of land on which crop plants are grown in an ecosystem, where balance should be maintained between interacting organisms.

5. **Ecological agriculture:** Ecological farming is more labor intensive and several of its components such as vermicomposting, vermin-ash and generation of botanical pesticides, rearing of beneficial insects etc. offer scope for unemployed and landless youth.

6. **Integrated Intensive Farming System (IIFS):** Intensification is through integrated farming involving animal husbandry, fishery and agroforestry.

7. **Low external input supply agriculture (LEISA):** It is a production system that utilizes synthetic fertilizers, pesticides and herbicides lower rates normally recommended. Yield is sustained through greater stress on cultural practices, IPM, INM and utilization of on-farm resources and management.

8. **Biodynamic agriculture:** It considers farm as a living system where one activity affects the other.