Sustainable Agriculture: Solution for the future of farming

Rohitashv Nagar[1]*, Deepak Nagar[2], Ravindra Meena[3], Brahmanand Bairwa[4]
[1,2,3,4]Department of Agronomy, School of Agricultural Sciences, Career Point University, Kota, Rajasthan (324005) Rohitashv Nagar* E-mail: rnagar1900@gmail.com*

Abstract Sustainable agriculture is the successful management of resources for agriculture to satisfy changing human needs, while maintaining or enhancing the standard of the environment and conserving natural resources. It was practised for nearly 6000 years of the preindustrial era, from 8000 to 2000 BC, without much disruption of nature. Sustainability is a perpetual issue in time scale with associated dynamism in resource base and outputs in terms of variety and quantity. Sacrificing agriculture sustainability will pose grave threat to the basic food security in agriculturally dependent countries. The ecological aspect of the negative effects is immeasurable. Agriculture is no longer location specific in terms of production as well as product outreach due to the technological advancements in production, transport, communication, supply chain and networking to cater to the demands of global citizens. The rate of changes expected and demanded from agriculture is acute and this precisely puts pressure on the long-term perspective of sustainability, that is directly related to the maintenance of support systems i.e., natural resource base. Assessment of sustainability should be done by including many indicators of physical, economical, demographic, ecological that have interrelationships in short term, and modifier effects in long term of various magnitude. The dynamics of resource changes in their per se availability, quality and utilization changes with time and newer scenarios emerge that should be valued in its entirety of inter-relationships.

Key words: Sustainability, Sustainable agriculture, Natural resources,

I Introduction:

Sustainable agriculture was practised for nearly 6000 years of the preindustrial era, from 8000 to 2000 BC, without much disruption of nature. [1-5]. Sustainable agriculture is defined as a system that, “over the future , enhances environmental quality and therefore the resource base on which agriculture depends; provides for basic human food and fibre needs; is economically viable; and enhances the standard of life for farmers and society as a whole”[1, 6, 7]. In addition, sustainable agriculture is defined as a commitment to satisfy human food and fibre needs and to reinforce the standard of life for farmers and society as an entire, now and into the future. Consequently, there is that no brief, universally acceptable definition of sustainable agriculture has yet emerged. This is because sustainable agriculture is viewed more often as a management philosophy instead of a way of operation [8], and intrinsically acceptance or rejection of any definition is linked to one's value system [9]. Sustainable agriculture should be taken as an eco-system approach, where soil-water-plants-environment-living beings sleep in harmony with a well-balanced equilibrium of food chains and their related energy balances. The goal is to deal with environmental problems with natural resources management to sustain significant increases in farm productivity through the efficient use of land and other resources, supply better economic returns to individuals, and contribute to the standard of life and economic development. It is essential that innovative technologies are wont to ensure sustainable agriculture and productivity using, modern irrigation systems, improved varieties, improved soil quality and conserving the environment using resource conservation technologies [2]. Although these changes have had many positive effects and reduced many risks in farming, there have also been significant costs.

Sustainable Agriculture: Sustainable agriculture is that the successful management of resources for agriculture to satisfy changing human needs, while maintaining or enhancing the standard of the environment and conserving natural resources CGIAR/TAC, 1988. The definition by G.K. Douglas (1984) formulated little earlier captures the essence of sustainable agriculture in its totality. “Sustainability must be considered long-term food sufficiency which needs that agricultural systems be more ecologically based and don't destroy their natural base.

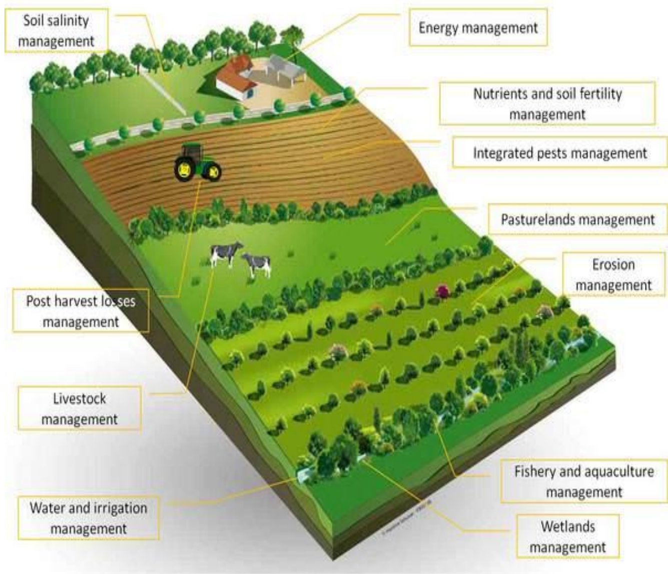

Fig. 1. Sustainable Agriculture

Effect on productivity and ecological viability:

Productivity: Vertical improvement in crop yield is inevitable under the ever-declining per capita arable land. This is compounded by the competing demands for land and water from profitable ventures of industry and urbanization through special economic zones, further complexed due to practicing agriculture in sub optimal agro ecological conditions.

II Literature Review

The needs are compelling and resources are limiting. The twin challenges of decreasing per capita arable land and limits to intensification through the current practice of increasing external inputs have necessitated a search for newer, alternative paradigms for increasing both production and productivity with acceptable levels of adverse ecological and socio-economic impacts. This is the current concern in terms of the productivity component of sustainable agriculture. Owing to the combined efforts at individual farmer, regional, and national levels, global food production has thus far been sufficient to feed everyone if the food were distributed consistent with needs (Pinstrup, 2002), thus bringing in the equity issue of sustainability. This has been achieved mainly through productivity increases since the 1950s, through the intensification of agriculture by the land saving technologies of high yielding varieties/breeds of crops and animals fertilizers, pest control chemicals, irrigation and time-and labour-saving machinery. Unbridled use of these external inputs in the last six decades has given rise to an unprecedented scale of environmental pollution; degradation of agricultural lands through erosion, salinization, waterlogging, and so on; and economic challenges because of the increasing cost of purchased inputs. It is very clear now that there are ecological, environmental, economic, and even social limits to intensification in many of these over-exploited areas, where lower rate of growth, lowering of factor productivity, and even yield declines are surfacing. In addition, the high cost of production and low 10 profitability are threatening the sustainability of the levels of productivity of these intensive cultivation systems (Cassman et al., 1997; Ladha et al., 2003; Pingali et al., 1995). Economic Viability: with growing needs of human development and comfort, the practice of agriculture has grown from "subsistence" to profit, from "local to global" in domain, directly affected, and adjusted by the dynamics of market demand, modified by socio-economic-political compulsions.

III METHODOLOGY

Ecological Viability: The modern methods of agriculture production of plants and animals with reliance on monocultures, improved plant types with high productivity potential that demand higher qualities of nutrients and water, powerful pesticides that aims to eradicate the pests (weeds, insects and weeds), modified production environment through poly houses for overcoming weather dependency of agriculture, mechanization etc., undoubtedly increased the yields and profits but caused lasting negative impact on soil and environment and biota. Increased greenhouse gas emissions, loss of diversity of crops, fauna and flora, development of pesticide resistance and resurgence, nutritional imbalance in produce due to specialty produce, displacement of cattle population, modified micro-climate affecting larger macro-climate in the region, associated infrastructure development of warehouse, cold storages, roads, transport, etc. is seriously impacting the regional/local ecological balance. Conservation and enhancement of the quality of the natural resources of land, water, air, and biodiversity to sustain biological productivity and ecosystem services is basic to sustainable agriculture.Maintaining the ecological viability of agricultural production systems is more complex than the sustainability of natural ecosystems, because an agro-ecosystem is a system of human intervention with mandatory goals. Conserving the production resource base and maintaining environmental safety and quality are the basic criteria for the ecological sustainability of agricultural production. Short-term biological productivity alone is not an indicator for ecological health or the integrity of the system. Ecological processes, to use a metaphor of the 'agriculture factory' (Vandermeer, 1992), need to be overhauled and serviced to remain fit for use through proper management techniques involving efficient use of inputs. Apart from guarding the resource base, this will also reduce environmental pollution and degradation and keep them within the absorptive capacity of the environment. Attributes such as soil quality, fertility balance, and other indicators of sustainability are manifestations of healthy ecological processes and of natural resources that have not had their physical, chemical or biological integrity compromised. 11 Agricultural systems operating on agro-ecological principles with reduced use of external inputs and non-renewable resources are more ecologically sound than those that depend predominantly on external inputs, which have the potential to wreck resources, the environment, livestock, wild life, soil microorganisms, useful insects like pollinators and predators. Increasing biologically favourable inputs such as crop residues, manures, green manures, legumes, crop rotations, biological pest control, and minimum tillage facilitates better use of ecosystem services and enhances ecological soundness. A wide variety of farming practices developed at different times in different regions, such as organic farming, alternate farming, ecological farming, and biodynamics, represent a greater degree of ecological prudence and soundness in terms of resource conservation and environmental safety than modern systems. The human element in agriculture makes it somewhat subjective and value oriented. Agricultural systems have the imperative to sustain biological productivity as their primary goal. In addition, they have to fulfil other aspects of human welfare such as sustaining life-support services, adequate profitability, and social responsibility toward rural farming communities.

IV RESULT

Social Acceptability: Social justice and equity, the fourth component of sustainability, is even more complex. It is more a phenomenon external to the farm and natural resources but of human values, that affects the farming practices and level of adoption of technologies acceptable to the social norms in the farming community. It is also linked to the macroeconomic policies of the governments and countries to encourage or restrict adoption of particular technology or resource through curbs and promotions. It also encompasses a plethora of definable as well as vague parameters such as poverty, cultural factors, education, social capital, justice and equity, value systems, food security at the household, regional and national levels, livelihood opportunities, and government policies.

Table 1. Properties of natural ecosystems compared with modern and sustainable agroecosystems.

Property	**Natural ecosystem**	**Modern agroecosystem**	**Sustainable agroecosystem**
Productivity	Medium	High	Medium (possibly high)
Species	High	Low	Medium

diversity			
Functional diversity	High	Low	Medium–high
Output stability	Medium	Low–medium	High
Biomass accumulation	High	Low	Medium–high
Nutrient recycling	Closed	Open	Semi-closed
Trophic relationships	Complex	Simple	Intermediate
Natural population regulation	High	Low	Medium–high
Resilience	High	Low	Medium
Dependence on external inputs	Low	High	Medium
Human displacement of ecological processes	Low	High	Low–medium
Sustainability	High	Low	High

Gliessman (2005).

Indicators of Sustainability: Measuring sustainability is most challenging and complex and there can be no universal measure possible as per the wide expectations seen from varied definitions and varied dimensions. 18 RIEDC (1997) indicated a general broad measurable component under each hierarchical level of components of sustainability. Hoang (2013) had analysed productive performance of crop production systems in an integrated analytical framework considering economic, institutional, physical, social and technological factors and indicated that in a dynamic analysis to make efficiency framework to be forward looking, climate change innovations in crop science to be incorporated.

Table 2. Sustainability indicators (Adopted from RIEDC, 1997)

Hierarchical level	**Sustainability indicators (Economic, social and environmental)**
Cropping system/ Farming system	Non-negative trends in: 1. Farm productivity 2. Net farm income 3. Total factor productivity 4. Nutrient balance 5. Soil quality 6. Residues in soil, plant, products 7. Farm water use efficiency 8. Farmer skills and education

	9. Debt service ratio 10. Health 11. Time spent on other social cultural activities
Agro-ecosystem (Watershed, Agroecozone, etc.	Non-negative trends in: 1. Regional production 2. Regional income 3. Regional total factor productivity 4. Regional nutrient balance 5. Income distribution 6. Species diversity 7. Soil loss 8. Surface water quality 9. Ground water quality 10. Regional social and economic development indicators
Global, National, Regional Systems	Indefinitely meet the demands at acceptable social, economic and environmental costs.

Farming and Natural Resources Management:

The basic natural resources of soil and water are the prime resources under the purview of management during a given ecological region with applicable potentials and limitations to realize productivity of crops and animals. When the assembly of food and fibre degrades the natural resources base, the power of future generations to supply and flourish decreases. The decline of ancient civilization in Mesopotamia, the Mediterranean region, Pre-Columbian south west U.S. and Central 22 America is believed to possess been strongly influenced by natural resources degradation from no sustainable farming and forestry practices.

Daly (1990) provided the overall guidelines for conserving natural resources and ecological sustainability as:

1. The speed of harvest, consumption, and use of renewable resources should not exceed their rate of regeneration.

2. The speed of waste generation should not exceed the assimilative capacity of the environment.

3. The depletion of non-renewable resources should be compensated for by the event of the same amount of a renewable substitute. These are the three commandments underpinning the sustainable management of all kinds of natural resources.

Soil: Soil is that the foremost natural resources for agriculture. It is a critically important component of the biosphere from which all living organisms, including citizenry, derive shelter, food, growth and every one other activities. Soil acts as an integrator of the environment, namely, the lithosphere (land), hydrosphere (water), atmosphere (air), and biosphere (living organisms) and plays the foremost important role in sustaining biosphere.

Karlen et al. (1997) classified the essential functions of soil more explicitly and completely as follows:

1. Sustaining biological activity, diversity, and productivity

2. Regulating and partitioning water and solute flow

3. Filtering, buffering, degrading, immobilizing and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposition.

4. Storing and cycling nutrients and other elements within the earth's biosphere.

5. Providing support for socio-economic structures and protection for archaeological treasures related to human habitation. Soil is additionally a serious source, sink for global gases, and plays a crucial role within the regulation of radioactively active gases (greenhouse gases) within the atmosphere. Soils constitute the most important terrestrial pool of carbon, estimated at approximately 1550 Pg, which is central to the worldwide carbon cycle. The world's soils also contain approximately 95 Tg nitrogen (Lal et al., 1995). Both of those pools contribute actively to atmospheric greenhouse gases through decomposition and oxidation because of deforestation and faulty land management practices. Within the past decade, 1.6 billion tonnes of carbon is estimated to possess been emitted annually as a results of land clearance, compared to six .4 billion tonnes released into the atmosphere by the combustion of fossil fuels. Erosion caused by water and wind is one among the important reasons for soil degradation. Water erosion is that the most widespread sort of erosion, affecting 56% of worldwide acreage. Deforestation, removal of vegetative cover through overgrazing, and mismanagement of agricultural land are the most causes of water erosion. Wind erosion occurs widely in arid and semi-arid regions and in coarse textured soils without vegetative cover and affects 26% of the worldwide area. The worldwide Agro-ecological 23 Zones (GAEZ) programme of the FAO (1978-1991) has estimated that some 16% of worldwide acreage in danger of erosion. Erosion continues to be a significant threat to our continued ability to supply adequate food. Numerous practices are developed to stay soil in situ, which include reducing or eliminating tillage, managing irrigation to scale back runoff, and keeping the soil covered with plants or mulch. Adoption of no tillage may benefit conservation in soils especially under initial high fertility conditions (Fabrizzi et al., 2005) with none adverse impact on productivity.

Water: Freshwater is the most critical and limiting natural resource for sustainable agriculture. Water is that the principal resource that has helped agriculture and society to prosper, and it has been a serious limiting factor when mismanaged. Agriculture uses as much as 60 to 80% of freshwater supplies globally. The number of people living in water-stressed countries will increase six fold in the next 20 years, and this will prove a big challenge to global and regional food security (IFPRI, 1997a; 1997b). Huge investments in water storage and transfer systems have been established in many parts of the world, which allowed crop production to expand to very arid regions. In drought years, limited surface water supplies have prompted overdraft of groundwater and consequent intrusion of salt water or permanent collapse of aquifers in many regions leading to degradation of potential lands and a serious threat to food security and the environment. Erratic patterns of precipitation, drought, and floods because of global warming exacerbate the existing constraints. Curtailing the share of water that goes to agriculture and ensuring its conservation and sustainable use are essential for future food security, economic and human development and social harmony. Projection indicate that the productivity of water in agriculture needs to be doubled within the next decade and a half to spare enough water for civic, and industrial use and to make agricultural water use sustainable. Areas of improving water management include improving water conservation and storage measures (in situ) and safe run off collections, growing drought-tolerant crop species and adopting efficient irrigation methods/systems (Raman, 2006). The challenge programme for water and food launched by the CGIAR envisages integrated action combining science and technology, management, and environmental factors, and provides hope for ushering in a "Blue water Revolution". Energy: Energy has been identified as the second most critical factor next only to water, for sustainable development. The economic progress is coterminous with energy consumption (Brown, 2001). Global agricultural systems are flawed because of energy profligacy or energy poverty. Energy over-use leaves dirty ecological footprints, whereas, energy poverty creates serious impediments to food security, livelihoods, and human development. Energy-poor systems require energy infusion, preferably of the renewable kind, such as solar, wind and biomass energy. Modern agriculture is heavily dependent on non-renewable energy sources; especially petroleum that cannot be sustained indefinitely as clear projections of the finiteness of the resource is established. Sustainable agricultural systems should reduce reliance on non-renewable energy sources, explore, and exploit many opportunities of on-farm renewable sources of energy generation and use that can also mitigate climate change, as biomass is a carbon-neutral resource. Renewable energy sources like solar, wind and bioenergy are particularly useful in rural areas because of their local availability, adaptability to dispersed small-and medium scale energy requirements, reliability, and 24 environmental safety. It has been estimated that these could provide up to 57% of economic energy needs in Africa, 33% in Latin America and 22% within the Asia Pacific region (Hicks, 1997).

Summary: Sustainability is a perpetual issue in time scale with associated dynamism in resource base and outputs in terms of variety and quantity. Sacrificing agriculture sustainability will pose grave threat to the basic food security in agriculturally dependent countries. The ecological aspect of the negative effects is immeasurable. Agriculture is no longer location specific in terms of production as well as product outreach due to the technological advancements in production, transport, communication, supply chain and networking to cater to the demands of global citizens.The value system attached to the primary products of agriculture with the associated limitations has transformed it altogether to an era of value added products and specialty services. The rate of changes expected and demanded from agriculture is acute and this precisely puts pressure on the long-term perspective of sustainability, that is directly related to the maintenance of support systems i.e., natural resource base. Measurement of sustainability throug h key indicators and their integration from multitude of aspects can best be depicted using AMOEBA diagram as per the processes of MESMIS. The reality of climate change, shrinking natural resources both in quantity and quality, the glaring catastrophic projections of the shortages of 5Fs (Food, Fodder, Fiber and Fuel and Foresttimber) to meet the burgeoning population and industrial raw material calls for urgent action for sustainability of agriculture.

V CONCLUSION

The realization of the shrinking carrying capacity of our planet to support humanity perpetually is essential to avoid over exploitation with the resultant protection of the natural resources and simpler and essential demographic changes. Yet, the resilience of natural systems with proper understanding, care and support from the humans can slow the clock of destruction.Assessment of sustainability should be done by including many indicators of physical, economical, demographic, ecological that have interrelationships in short term, and modifier effects in long term of various magnitude. The dynamics of resource changes in their per se availability, quality and utilization changes with time and newer scenarios emerge that should be valued in its entirety of inter-relationships.

VI References:

[1] T. Crews, C. Mohler, and A. Power, "Energetics and Ecosystem Integrity: The Defining Principles of Sustainable Agriculture " American Journal Alternative Agriculture, vol. 6, p. 146, 1991.

[2] M. Dover and L. Talbot, "To Feed the Earth: Agro-Ecology for Sustainable Development," 1987.

[3] USDA, "Report and Recommendations on Organic Farming," U.S. Gov. Printing Office, Washington, DC1980.

[4] D. R. Keeney, "Toward a Sustainable Agriculture: Need for Clarification of Concepts and Terminology," American Journal Alternative Agriculture vol. 4, p. 101, 1989.

[5] R. Lowrance, P. F. Hendrix, and E. P. Odum, "A Hierarchical Approach to Sustainable Agriculture," American Journal Alternative Agriculture, vol. 1, p. 169, 1986.

[6] C. B. Flora, "Building Sustainable Agriculture: A New Application of Farming Systems Research and Extension," Journal of Sustainable Agriculture, vol. 2, pp. 37-50, 1992.

[7] E. V. Kambewa, Contracting For Sustainability: An Analysis of the Lake Victoria-EU. Nile Perch Chain: WageningenPers, 2007.

[8] R. J. MacRae, J. Henning, and S. B. Hill, "Strategies to Overcome Barriers to the Development of Sustainable Agriculture in Canada: The Role of

Agribusiness," Journal Agricultural Environmental Ethics vol. 6, p. 21, 1993.

[9] E. A. Clark and S. F. Weise, A Forage-Based Vision of Sustainable Agriculture: Madison, WI, 1993.

[10] Pinstrup, A.P. 2002. Towards a sustainable food system: What will it take? Keynote presentation for the Annual John Pesek Colloquium in Sustainable Agriculture, March 26-27, Iowa State University.

[11] Cassman, K.G., Olk, D.C. and Dobermann, A. 1997. Scientific evidence of yield and productivity decline in irrigated rice systems of tropical Asia. International Rice Commission Newsletter, 46: 7-16.

[12] Ladha, J.K., Pathak, H., Tirol-Padre, A., Dawe, D., & Gupta, R.K. 2003. Productivity trends in intensive rice–wheat cropping systems in Asia. p 45-76. In Sustainability of the rice-wheat cropping system: issues, constraints, and remedial options. (eds) JK Ladha, JE Hill, JM Duxbury, RK Gupta and RJ Buresh, ASA Special Publication 65, ASA-CSSA-SSSA, Madison, WI, USA.

[13] Pingali, P., Hossein, M. and Gerpacio, RV. 1995. Asian Rice Bowls: The Returning Crisis. Walling ford, UK: CAB International.

[14] Vandermeer, J.M. 1992. Thoughts on Agriculture and the Environment in a Post-Modern World. Symposium on Enhancing the Future of the Land Grant System. Irving CA: National Academy of Sciences Board on Agriculture.

[15] Gliessman, S.R. 2005. Agroecology and agroecosystems. In The earthscan reader in sustainable agriculture (ed. J. Pretty). London, UK: Earthscan.

[16] Haong, Viet-Ngu, 2013. Analysis of productive performance of crop production systems: An integrated analytical framework. Agricultural Systems. 116: 16-24.

[17] Karlen, D.L., Mausbach, M.J., Doran, J.W., Cline, R.G., Harris, R.F. and Schuman, G.E. 1997. Soil quality: A concept definition and framework for evaluation. Soil Society of America Journal, 61: 4-10.

[18] Lal, R., Kimble, J.M., Levine, E. and Whitman, C. 1995. World soils and greenhouse effect: An overview. In: Soils and Global Change, R. Lal, J.M. Kimble, E. Levine, and B.A. Stewart (Eds). Boca Ratan, FL: Lewis Publishers, pp.1-7.

[19] Fabrizzi, K.P., Garcia, F.O., Costa, J.L. and Picore, L.I. 2005. Soil water dynamics, physical properties and corn and wheat responses to minimum and no tillage systems in the southern Pampas of Argentina. Soil and Tillage Research, 81: 57-69.

[20] FAO. 1978-1991. Agro-Ecological Zone Project. Rome: Food and Agriculture Organisation.

[21] IFPRI. 1997a. Water Resources in the Twenty-First Century: Challenges and Implications for Action. Washington DC: International Food Policy Research Institute.

[22] IFPRI. 1997b. The World Food Situation: Recent Developments, Emerging Issues and Long Term Prospects. Vision 2020 Food Policy Report. Washington DC: International Food Policy Research Institute.

[23] Raman, S. 2006. Agricultural Sustainability: Principles, Processes and Prospects. Food Products Press, New York, USA, pp.474.

[24] Brown, LR. 2001. Eco-Economy: Building on Economy for the Earth. Washington DC, and New York: World Watch Institute and W.W. Norton.

[25] Hicks, A. 1997. Power and food security. Paper presented at the Solar World Congress, August 24-30, International Solar Energy Society (ISES), Tejon, Republic of Korea.