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A REVIEW

Innovations and technology : An economic analysis of their contribution in managing natural resources for sustainable development

PARVANI SHARMA, RAKESH NANDA, POONAM PARIHAR AND S.P. SINGH

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ABSTRACT

The rapid growth has helped Indian agriculture mark its presence at global level. India stands among top three in terms of production of various agricultural commodities like paddy, wheat, pulses, groundnut, rapeseeds, fruits, vegetables, sugarcane, tea, jute, cotton, tobacco leaves, etc (GOI, 2008-09). But with the change in phases, the improvements in agricultural technologies and practice means has resulted in more consumption of food per head available than 40 years ago.In addition to this increasing crop yields in many parts of the world, advances in agricultural technologies have also contributed to a safer food supply, and in some cases, improved environmental quality. Over the next 30 years, agriculture will have to sustain an additional 2 billion people from an increasingly fragile resource base. Ever-growing demands and increasing pressures on land and water resources mean that agriculture has to become even more productive, efficient and environmentally sound and to foster this will require the application of new technologies , scientific knowledge improved resource management and continued public and private research investment in emerging technologies. With the beginning of the new century, the world has to faced enormous challenges to meet the food, feed and fibre needs of a growing population with rising incomes. It has been estimated that by 2025 the global population will be approximately 7.9 billion, up from 6 billion currently. Global cereal and meat demands will increase by 46% and 56%, respectively.To put an end to and to conserve the natural resource "sustainability" is commonly seen as a property of an ecosystem. But sustainability can be seen from other perspectives, which are more relevant for extension. Environmental issues emerge from the human use of natural resources. Sustainability can, therefore, be defined in terms of human reasons, activities, and agreements. Sustainability emerges out of shared human experiences, objectives, knowledge, decisions, technology, and organization. Agriculture becomes sustainable only when people have reason to make it so. Other than the introduction of sustainability innovation is also playing an important role and it should also be incorporate in natural regenerative processes, such as nitrogen fixation, nutrient recycling, maintenance of soil structure and fertility, and protection of natural enemies of insect pests, weeds and diseases, into agricultural practices. These approaches can make better use of the indigenous knowledge of farmers and, where it can be appropriately , combine with new science-based technologies for optimum results.

KEY WORDS : Sustainable development, Technology, Innovation, Food security, Productivity

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MEMBERS OF THE RESEARCH FORUM

Correspondence to:
PARVANI SHARMA, Division of Agricultural Extension Education, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology, JAMMU (J&K) INDIA
Email: pravanis9@gmail.com

Authors' affiliations:
RAKESH NANDA AND POONAM PARIHAR, , Division of Extension Education, Sher-e-Kashmir University of Agricultural Sciences and Technology, JAMMU (J&K) INDIA

S.P. SINGH, Division of Economics and Statistics, Sher-e- Kashmir University of Agricultural Sciences and Technology, JAMMU (J&K) INDIA

India's Independence was won in the backdrop of the great Bengal famine of 1942-43. No wonder, our first Prime Minister, Jawaharlal Nehru said early in 1948, 'everything else can wait but not agriculture'. Thanks to the packages of technology, services and public policies introduced since the beginning of the first Five Year Plan in 1950, the country has transformed itself from a begging bowl image to one which occupies the first or second position in terms of production and area in several major crops. Agriculture is an important sector of Indian economy as it contributes about 17% to the total GDP and provides employment to over 60% of the population. Indian agriculture has registered impressive growth over last few decades. The food grain production has increased from 51 million tonnes (MT) in 1950-51 to 250 MT during 2011-12 highest ever since independence . The rapid growth has helped Indian agriculture mark its presence at global level. India stands among top three in terms of production of various agricultural commodities like paddy, wheat, pulses, groundnut, rapeseeds, fruits, vegetables, sugarcane, tea, jute, cotton, tobacco leaves, etc (GOI, 2008-09). But with the change in phases the improvements in agricultural technologies and practice means has resulted in more consumption of food per head available than 40 years ago.In addition to this increasing crop yields in many parts of the world, advances in agricultural technologies have also contributed to a safer food supply, and in some cases, improved environmental quality. Over the next 30 years, agriculture will have to sustain an additional 2 billion people from an increasingly fragile resource base. Ever-growing demands and increasing pressures on land and water resources mean that agriculture has to become even more productive, efficient and environmentally sound and to foster this will require the application of new technologies, scientific knowledge, improved resource management and continued public and private research investment in emerging technologies.

Many industrialized and developing countries have achieved impressive rates of agricultural growth in the recent past. For example, Asia transformed its agriculture by doubling rice and wheat production during the period from 1970 to 1995 by expanding planting areas and using Green Revolution (GR) technologies. Over the same period, real per capita rural incomes has almost doubled which has resulted in declination of poverty.However, these gains did not come without some negative consequences and the indirect effect is on the natural resources , as they are an important material basis for a stable national economy and social development. While keeping this thing in an account the country is facing serious concerns of reduction in arable land due to urbanization, annual loss of nearly 5,334million tonnes of soil due to erosion, and depleting water resources, but we have forgotten that soil and water plays a vital role in optimizing agriculture production. Not only this the economics disparities has also increased within the country and excessive use of the applied inputs like fertilizers,crop protection products and irrigation has resulted in environment damage. With the beginning of the new century,the world has to face enormous challenges to meet the food, feed and fibre needs of a growing population with rising incomes. It has been estimated that by 2025 the global population will be approximately 7.9 billion, up from 6 billion currently. Global cereal and meat demands will increase by 46% and 56%, respectively.

Along with science, local technologies (Gandhi, 1982) and people's knowledge systems such as ethno forestry have an important role to play for biodiversity conservation and sustainability. Tribal's bag (Cox, 2000) and ancient texts (Tunon and Bruhn, 1994) may still be the best way to screen for new herbal medicines that may be useful in the treatment of diseases in the era of global climate change. Village communities and other small-scale societies residing continuously over a territory create, transmit and apply comprehensive knowledge about the resources contained in the territory. In villages where women take active part in natural resource management including agriculture and forestry they develop repositories of local knowledge that is continuously applied, tested and improved over time (Harding, 1998).The 1992 Convention on Biological Diversity requires that every contracting party should respect, preserve and maintain knowledge, innovations and practices of traditional and local communities and promote the wider application with the approval and involvement of the holder of such knowledge, innovations and practices and encourage the equitable sharing of the benefits. To conserve the natural resources intellectual property rights are now being extended to beyond the conventional domain of mechanical and chemical innovations to include biological resources. National Biological Diversity Act of India in response to our commitment to the Convention on Biological Diversity and it must, therefore, devise operational mechanisms to share benefits of commercial applications of traditional knowledge on biodiversity with local communities. Also useful shall be to ensure a harmonized basket of rules made under the Patent Act, Protected Plant Varieties Act, and the Biological Diversity Act.

Agricultural growth and environment :

It has been estimated that since prospects for further expansion of agricultural land and irrigated areas are limited, increased food demand must be met primarily through higher productivity on existing cultivable land, moreover increased production needs to be achieved in ways that are safe for the environment, farmers and consumers. Access to science-based agricultural innovations and technologies are critical for achieving this.Inter-relationship and inter-dependence among water, land, vegetation and animal resources determine the nature and kind of livelihood support systems particularly in rural areas. But the depletion of these resource-base and increasing in biomass-demand of the expanding human and livestock population are attracting the attention of all concerned. It is, therefore, pertinent to evolve strategies for sustainable natural resource management systems. It is also imperative to observe the changes taking place in the land-use pattern in general and in the agricultural sector in particular, which will have implications for local bio-diversity and the ecosystem, and food and nutritional security of the local people.It is increasingly clear that climate change as the dominant global scale environmental concern will have a profound influence on the agro-ecological conditions under which farmers and rural populations need to develop their livelihood strategies, manage their natural resources and achieve food security and other ends (Leeuwis and Hall, 2010). In most contexts, climate change can be regarded as part of a complex' problem situation in several senses: (a) there is often considerable uncertainty about specific climatic and ecological dynamics at play; (b) climatic and ecological change have (initially unknown) consequences for several interrelated societal realms (e.g. agriculture, forestry, fisheries, health, energy, economy, migration, etc.), and (c) it is likely that there are different and competing human interests and values at stake (e.g. between rich and poor, farmers and pastoralists, food' and fuel', economy and ecology, etc.). It admits this complexity that appropriate human responses will have to be developed.

However, while certain agricultural practices in the past have had negative environmental and sustainability consequences, it is also in agriculture that we find solutions to the question of sustainability.

Some major issues for concern currently are:

– Nitrate and pesticide residue pollution arising from agriculture.
– Loss of biodiversity due to pollution, agronomic practices such as mono-cropping, destruction of natural habitats, over-exploitation of natural stocks of fish and forests.
– Soil nutrients, organic matter and natural resource degradation, including salinification associated with irrigation.
– Agriculture's carbon foot-print — fossil fuel use in production of chemical inputs, in farming practice, in food processing and related agro-industries. Transport of agricultural produce to distant markets.
– Agriculture's water use foot-print — excessive water use in intensive agricultural production and competition with others uses, particularly drinking water as well as effects on water quality through pollution.
– Agriculture's contribution to climate change, both in terms of it contribution of greenhouse gases CO_2 but also methane; and its role in climate change mitigation strategies (biofuel production, but also a range of bio-production systems with benign or beneficial environmental consequences, carbon sequestration).

To put an end to this and to conserve the natural resource "sustainability" is commonly seen as a property of an ecosystem. But sustainability can be seen from other perspectives, which are more relevant for extension. Environmental issues emerge from the human use of natural resources. sustainability can, therefore, be defined in terms of human reasons, activities, and agreements. The definition of sustainability then becomes part of the problem because people need to agree on how they define sustainability and what priority they will give it (Pretty, 1994). In this approach, sustainability is not a scientific, "hard" property which can be measured according to some objective scale, or a set of practices to be fixed in time and space. Rather, Sustainability is a quality that emerges when people individually or collectively apply their intelligence to maintain the long-term productivity of the natural resources on which they depend (Sriskandarajah *et al.,* 1989). In other words, sustainability emerges out of shared human experiences, objectives, knowledge, decisions, technology, and organization. Agriculture becomes sustainable only when people have reason to make it so. They can learn and negotiate their way towards sustainability. In any discussions of sustainability, it is important to clarify what is being sustained, for how long, for whose benefit and at whose cost, over what area, and measured by what criteria. Answering these questions is difficult, because it means assessing and trading off values and beliefs. Campbell (1994) has put it this way: "Attempts to define sustainability miss the point that, like beauty, sustain ability is in the eye of the beholder.... It is inevitable that assessments of relative sustainability are socially constructed, which is why there are so many definitions."

Other than to bring sustainability in agriculture certain innovative solutions should also be incorporate in natural regenerative processes, such as nitrogen fixation, nutrient recycling, maintenance of soil structure and fertility, and protection of natural enemies of insect pests, weeds and diseases, into agricultural practices. These approaches can make better use of the indigenous knowledge of farmers and, where it can be appropriately , combine with new science-based technologies for optimum results.Apart from innovations certain technologies have also been developed for water harvesting recycling and economic usage. Integrated watershed management models for different agro-ecological regions and agronomic practices have been developed to conserve soil and water. Scientific approaches have been developed to stabilize sand-dunes by introducing tree species like *Acacia tortilis* (from Israel) which establish successfully in sand-dune affected areas. Agroforestry provides an ideal approach for the optimum utilization of natural resources like water, soil and sunlight. Agroforestry has been in practice for a long time in India. Growing of tea, coffee, ginger, turmeric and cardamom in the shade trees and intercropping with trees like coconut are common in the tropical regions. Through research efforts indigenous and exotic species of plants have been identified for agri-horti-silvi-pastoral, silvipastoral, agri-silvi-pastoral and agri-horticulture in different agroecological regions. Agri-silvi combination of *Acacia nilotica* and wheat or chickpea has been found suitable for improving the productivity of marginal and dry areas. Various multipurpose tree species of *Acacia, Albizia, Azadirachta, Butea, Casuarina, Dalbergia, Hardwickia* and *Tecomella* have been recommended for agroforesstry in different agro-climatic regions of the country and for achieving sustainable productivity from wastelands With the greater scope in industrialization and urbanization, mankind's great demand for natural resources and their large scale exploitation and consumption has resulted in the weakening, deterioration and exhaustion of these resources. One difficult task faced by all countries is to guarantee the lasting utilization of natural resources at the lowest possible environmental cost while still assuring economic and social development .The plant science industry shares the international community's recognition that major improvements in agricultural performance are fundamental to achieving the overall goals of sustainable development, as put forth in Agenda 21, signed by 100 heads of state and governments in Rio de Janeiro in 1992, and reaffirmed during the 2002 World Summit on Sustainable Development held in Johannesburg . We are committed to being "part of the solution," and will continue to provide innovative solutions that protect the environment, enhance economic viability of farms and rural livelihoods, and improve the quality of life for farmers and their communities.

The coming up of green agenda in agriculture :

While post-World War II agriculture can be viewed as driven primarily by goals of increasing production, productivity, incomes and reducing labour costs and inputs, concerns over the negative environmental impacts of conventional farming systems began to find a voice in the 1960s and 1970s (Welch and Graham, 1999). With growing evidence of the negative effects of the Asian Green Revolution (a package of intensive agricultural practices that used high-yielding varieties to boost food production in Asia) in the 1980s — due to heightened worries about pesticide poisoning and fertiliser pollution (Conway and Pretty, 1991) and the increasing popularity of studies of agro-ecosystems analysis (Conway, 1985) and agro-ecological approaches (Altieri, 1996) – ideas around sustainable agriculture began to gain ground, ultimately finding voice in policy in the nineties. Soon, the production-at-all-and any-costs approach began to give way to concerns about environmental costs and risks and a greater consideration of the benefits of alternative approaches to agricultural production and development.

Other than the 'green agenda' in agriculture the lens of four modes through which innovation can also best contribute and these are as follows (i) New science and generic technologies with green potential (ii) farming system innovations (iii) national integrated green regimes. It also offers up a fourth potential cross-cutting mode to examine whether market or policy-driven mechanisms are best suited to driving innovation in pursuit of a green agenda, and under what circumstances.Precision farming, or precision agriculture, is a technique that uses technology to collect and analyze data for the assessment of variations in soil or climate conditions, in order to guide the application of the right agricultural practices, in the right place, in the right way, at the right time. It relies greatly on new technologies, including the Global Positioning System, sensors, satellite or aerial images, and information management tools, to collect information on such variables as optimum sowing density, fertilizers and other input needs. This information is then used to apply flexible practices to a crop. This has the potential to increase agriculture productivity and raise farm incomes (through more efficient/ low input use), while at the same time decreasing costs for producing and accessing goods and services. Such tools also offer a cost-effective way to improve access and coverage of public services.

Technological innovation can improve the environmental performance of farming systems through innovations in engineering, information technology and biotechnology. Newer technologies can reduce the load of known toxins in agricultural production, substitute safer alternatives, protect ground or surface waters, conserve natural habitats, reduce nutrient loads in soils, lower gaseous nitrogen loss and reduce the amount of non-renewable energy used in the cropping cycle. These innovations imply changing current farm practices and using different technologies to enhance resource productivity and eco-efficiency.

Biotechnology is currently being used to develop new varieties of food, feed and fibre crops that have commercially valuable genetic traits, such as: herbicide tolerance, pest resistance, agronomic traits that improve yields and provide resistance to stresses, product quality traits that improve flavour and colour and technical traits such as chemical markers essential for breeding. Although genetically modified (GM) varieties of over a dozen plants species have received regulatory approval in different parts of the world, the large majority of GM plantings are for cotton, maize, rapeseed and soybean.Genetic modification is also currently being used in forestry to develop tree varieties that can reduce paper production costs and for the propagation of trees.The international agricultural research centres of the Consultative Group on International Agricultural Research (CGIAR) have been using these breeding approaches routinely for some time to develop drought-tolerant, pest resistant varieties. The same techniques, however, could be used to address environmentally-damaging traits; for example, responsiveness to chemical fertilizers. These techniques are, therefore, not intrinsically sustainable.

Conservation technologies and sustainable agriculture:

Traditional farming practices normally involve intensive soil tillage. This practice was normally associated with increased soil fertility due to mineralization of nutrients. However, farmers realized that in the longer run, excessive tillage actually reduces soil organic matter content and exposes soil to wind and water erosion, which in time leads to lower productivity. To compensate for the loss of natural regenerative processes, intensive agriculture has increasingly relied on fertilizer applications and other chemical inputs to increase productivity. According to the famous American author William Faulkner described the plough as “the villain of the world’s agricultural drama.” Although the negative effects of tillage operations have been recognised for sometime, it was only after the discovery of suitable selective, non-selective, contact and residual herbicides that effective solutions to combat these problems became possible. This stimulated worldwide investigations by the private sector (the plant science industry and manufacturers of farm implements), public research institutions and enterprising farmers to develop innovative crop establishment techniques that either fully eliminated or minimized the need for tillage operations. Under techniques developed to suit various crops and environments – no-till, zero- till, minimum- till, ridge- till, mulch-till – seed is sown directly into the previous crop’s stubble, with little or no intermediate tillage. Later, crop rotation and maintenance of permanent or semi-permanent groundcover (live cover crop or crop residue mulch) are included as an integral part of this approach, now commonly known as conservation tillage. These techniques have proven to be equally suitable for small, medium, and large farms. Conservation tillage protects the upper soil layer from wind and water erosion and loss of ground moisture. It also improves soil biodiversity by providing a congenial environment for bacteria, insects and fungi. The abundance of soil organisms helps decomposition of mulch and its incorporation into soil as humus, contributing to stabilization of soil structure and enhancement of soil fertility. Maintenance of mulch is estimated to increase soil organic matter content by about 1 per cent every 10 year. The use of the conservation tillage in many parts of the country had led to the new phase in the agriculture for.eg, nearly half of the 401.72 million hectares that make up the total land area of South A s i a ’s Indo-Gangetic plains (IGP) — Bangladesh, India, Nepal, and Pakistan is devoted to feeding and providing livelihoods for 1.8 billion people. Rice and wheat are the staple food crops and contribute more than 80% of the total cereal production in these countries. This system is fundamental to employment, income, and livelihoods for hundreds of millions of rural and urban poor of South A s i a. Suitable thermal regimes for rice and wheat cultivation, development of short duration, nitrogen-responsive cultivars, expansion of irrigation, and the ever- increasing demand for food, were some of the driving forces for increased production through area expansion and intensification of the rice-wheat system during the Green Revolution period starting in the early 1960s. In the last four decades, high growth rates for food grain production – wheat 3.0%, rice 2.3% – have kept pace with population growth. Evidence is now appearing that further intensification of input use since the adoption of Green Revolution technologies has provided lower marginal returns, and the continued intensification of cropping in some situations is leading to degradation of the resource base through salinization, over-exploitation of groundwater, physical and chemical deterioration of the soil, and pest problems. Increasing adoption of resource-conserving technologies involving tillage and crop establishment options, such as minimum and zero-tillage systems for wheat planting in rice-wheat rotation, are enabling farmers to sustain productivity. Field results show that these technologies improve yields, reduce water consumption, and decrease negative impacts on the environment. When combined with integrated approaches to pest and disease control, these techniques provide options for sustainable intensification and diversification of rice-wheat systems. Strong research and development support by national and international agricultural research groups, including the private sector, along with socio-economic changes in the IGP countries are leading to rapid adoption of conservation technologies by farmers. It is estimated that over the last five years the area under minimum/zero-tillage for the establishment of winter season crops (wheat, maize, lentil, chickpea, peas etc.) has increased to nearly 2 million hectares (m.ha), mainly in India and Pakistan.

Integrated vegetation management in right of way :

Conservation technologies in agriculture are not limited to tilling practices, but also help to conserve natural resources and deliver benefits for the environment. Rapidly improving technologies for sustainable intensification of agriculture enable higher production from existing agricultural areas, which provides opportunities for broadening of biodiversity conserving areas. In non-agricultural situations, thousands of kilometers of rights-of-way (land set aside for use as highway or power-line corridors) must be maintained to allow access for maintenance workers and to prevent vegetation from growing into the power- lines. Integrated vegetation management (IVM) based on a combination of control options avoids the negative impacts of mechanized clearance and maintenance of these areas. Under IVM, the problem species are identified and reduced or eliminated using a combination of options including biological, chemical, cultural, and mechanical methods. The choice is based on effectiveness, safety, environmental impact and cost. Mechanical cutting may be appropriate in some situations, especially to reduce vegetation height and density.

With the removal of problem trees and other invasive weeds, space is created for the growth of desirable low-growing species comprising grasses, wildflowers, shrubs, and small trees. This mix of desirable species not only maintains itself, but also provides food and shelter for a wide variety of wildlife, adding to biodiversity.

Traditional knowledge on biodiversity conservation :

In order to be effective, efforts on biodiversity conservation can learn from the context-specific local knowledge and institutional mechanisms such as cooperation and collective action; intergenerational transmission of knowledge, skills and strategies; concern for well-being of future generations; reliance on local resources; restraint in resource exploitation; an attitude of gratitude and respect for nature; management, conservation and sustainable use of biodiversity outside formal protected areas; and, transfer of useful species among the households, villages and larger landscape. There are some of the useful attribute of local knowledge systems (Pandey, 2002). Traditional knowledge on biodiversity conservation in India is as diverse as 2753 communities (Joshi *et al.,* 1993) and their geographical distribution, farming strategies, food habits, subsistence strategies, and cultural traditions.

Local vegetation management :

Over thousands of years local people have developed a variety of vegetation management practices that continue to exist in tropical Asia (Pandey, 1998), South America (Atran *et al.*, 1999; Gomez-Pompa and Kaus, 1999), Africa (Getz *et al.*, 1999; Infield, 2001), and other parts of the world (Brosius, 1997; Berkes, 1999). People also follow ethics that often help them regulate interactions with their natural environment (Callicott, 2001). Such systems are often integrated with traditional rainwater harvesting that promotes landscape heterogeneity through augmented growth of trees and other vegetation, which in turn support a variety of fauna (Pandey, 2002).

In India these systems can be classified in several ways:

– Religious traditions: temple forests, monastery forests, sanctified and deified trees.
– Traditional tribal traditions: sacred forests, sacred groves and sacred trees.
– Royal traditions: royal hunting preserves, elephant forests, royal gardens etc.
– Livelihood traditions: forests and groves serving as cultural and social space and source of livelihood products and services.

The traditions are also reflected in a variety of practices regarding the use and management of trees, forests and water. These include:

– Collection and management of wood and non-wood forest products.
– Traditional ethics, norms and practices for restraint use of forests, water and other natural resources.
– Traditional practices on protection, production and regeneration of forests.
– Cultivation of useful trees in cultural landscapes and agroforestry systems.
– Creation and maintenance of traditional water harvesting systems such as tanks along with plantation of the tree groves in the proximity.

These systems support biodiversity, which is although less than natural ecosystems but it helps reduce the harvest pressure. For instance, there are 15 types of resource management practices that result in biodiversity conservation and contribute to landscape heterogeneity in arid ecosystems of Rajasthan. Environmental ethics of Bisnoi community suggest compassion to wildlife, and forbid felling of *Prosopis cineraria* trees found in the region. Bisnoi teachings proclaim: “If one has to lose head (life) for saving a tree, know that the bargain is inexpensive” (Pandey, 2002a).

In India, local practices of vegetation management perhaps emanate from the basic ecological concepts of local communities reflected in “ecosystem-like concepts in traditional societies” (Berkes *et al*. 1998). Two key characteristics of these systems are that the unit of nature is often defined in terms of a geographical boundary; and abiotic components, plants, animals, and humans within this unit are considered to be interlinked. Many local knowledge systems are similar in temperament to the emerging scientific view of ecosystems as unpredictable and uncontrollable, and of ecosystem processes as nonlinear, multiequilibrium, and full of surprises (Berkes *et al.,* 1998).

Farm biodiversity :

Throughout the Indian farms and field one finds strips of vegetation containing several species of plants and small animals. These strips are beneficial in several ways. Such strips on tropical lands have been found to accelerate natural successional processes by attracting seed-dispersing animals and increasing the seed rain of forest plants. Effects of these strips resemble the windbreaks on seed deposition patterns (Harvey, 2000). Isolated trees provide seed in the area for natural regeneration. The strips enhance seed rain, and connectivity. Because such strips trap large number of seeds of several species they help in further tree growth. Compared to open fields, farm boundaries with vegetation receive seed in greater densities and species-richness than open farms and pastures. All forms of seed dispersal help in the process but animal-dispersed (birds, bats, mammals etc.) seeds often occur in greater densities and species numbers. Presence of isolated trees and shrubs or remnant trees helps. Farm boundaries maintained throughout the country are often self regenerating and require only management as these barriers considerably increase the deposition of tree and shrub seeds within the cultural landscape. Indeed considerable biodiversity is found within these strips. This is a practice that needs to be maintained as it has several socio-economic benefits as well.

Value of traditional agroecosystems in supporting the plant and animal diversity (see for example, Kunte *et al.*, 1998) is immense. Tree diversity in farms and agroecosystems is often the product of interaction of local and formal knowledge. A recent study by Shastri *et al.* (2002) provides interesting insights on the tree-growing practices and associated biodiversity in Karnataka. Shastri *et al.* (2002) found trees belonging to 93 species in a sampled area of 1.7 ha of Sirsimakki agro-ecosystem. Additional 44 species were noted on non-agricultural lands in the village ecosystem, which included *soppina betta*, minor forest and reserve forest. The overall agroecosystem had 556 trees/ha, while the non-agroecosystem had only 354 trees/ha. The overall, tree density of 418.8 per ha was present in the village. There were 144 species in the village ecosystem with 2238 individuals in the sampled area of 5.34 ha. The total number of species in non-agro ecosystem was 104 with 1286 individuals. Home-gardens are notable with 93 tree species in just about 1.7 ha. The number of tree species varies between 20 and 40 in home-gardens, indicating that home-gardens in Karnataka villages are highly biodiverse in comparison to those in Mexico and Brazil (Shastri *et al.*, 2002).

Formal conservation efforts in India have relied heavily on the recently declared official protected areas in various categories for biodiversity conservation. However, ancient and widespread human practice to set aside areas for the preservation of natural values in India can be seen in several examples of sacred groves, royal hunting forests, and sacred gardens (Gadgil, 1982; Pandey, 1991; Gadgil *et al.*, 1993; Kanowski *et al.*, 1999; Chandrashekara and Sankar, 1998). Several of these areas became national parks and wildlife sanctuaries in India and elsewhere (Pandey, 2001). It must be noted here that much of the India's biodiversity lies outside the officially declared protected areas. Indeed, biodiversity occurs in landscape continuum (Fig. 1; Table 1 and 2). Other areas protect ecosystem services such as the delivery of clean water or the supply of timber, or mitigate the expected adverse effects of over-clearing (Grove, 1992). Others protect recreational and scenic values and some have been planned to foster international cooperation (Hanks, 1997). Many of these areas meet the World Conservation Union's definition of a strictly protected area (IUCN categories I-IV) (IUCN, 1994).

Low intensity-agriculture :

Since low-intensity agriculture promotes biodiverse farms across landscape, such systems need to be supported and promoted. Agricultural intensification has been found to impact biodiversity in farms badly (Donald *et al.*, 2001). Crop-animal systems in Asia, where 95% of ruminants are found in the mixed farming systems is famous for diversity. Crop-animal systems are projected to see growth and remain the dominant system in Asia. Biodiversity in such mixed farming systems are vital for food production (Devendra, 2002). Crop-animal systems, in which livestock play a multi-purpose role, are the backbone of Asian agriculture. Increased productivity from livestock will be necessary in these systems to meet the increased demand for animal products, to alleviate poverty and to improve the livelihoods of resource-poor farmers (Devendra and Thomas, 2002). In the face of land degradation native farm vegetation will play a major role in the sustainability of the farming systems.

Incorporating traditional knowledge in practice :

Any attempt, endeavouring to integrate traditional knowledge for biodiversity conservation and sustainability of natural resources should be based on the principle that traditional knowledge often cannot be dissociated from its cultural and institutional setting. Regarding the cultural and institutional the following suggestions may be useful:

- Each programme aiming at the promotion of traditional knowledge should be based on the recognition that natural resource rights and tenurial security of local communities forms the fundamental basis of respecting traditional knowledge.
- More attention is needed on protection of intellectual property rights of traditional people.
- Innovative projects may need to be developed that aim at the enhancement of the capacity of local communities to use, express and develop their traditional knowledge on the basis of their own cultural and institutional norms.

There is an urgent need for the integration of traditional and formal sciences. Following considerations may be useful in this regard:

- Development of methods for mutual learning between local people and the formal scientists.
- State forest policies and sustainable forest management processes need to give full attention to ethforestry and local institutional arrangements to incorporate traditional knowledge in forest management and development projects.
- Traditional knowledge and traditions can contribute to the preparation of village microplans, which are prepared for eco-development, joint forest management and rural development. The plans should be based on both geographic and traditional community boundaries rather than only on

administrative boundaries.

– Revival of the traditional water management systems that have served the society for hundreds of years but are currently threatened.
– There is a clear need to integrate traditional and formal sciences for participatory monitoring, and taking feedback to achieve adaptive strategies for management of natural resources.

In spite of the value of traditional knowledge for biodiversity conservation and natural resource management there still is a need to further the cause. The following consideration may be useful in this respect:

– Encouraging the documentation of indigenous knowledge and its use in natural resource management. Such documentation should be carried out in participation with the communities that hold the knowledge. Due attention should be given to document the emic perspectives regarding IK rather than only the perspectives of professional outsiders. The documentation should not only consist of descriptions of knowledge systems and its use, but also information on the threats to its survival. People's biodiversity registers are a case in point (Gadgil 1994 and 1996, Gadgil *et al.,* 2000). The program of People's Biodiversity Registers promotes folk ecological knowledge and wisdom by devising a formal means for their maintenance, and by creating new contexts for their continued practice. PBRs document traditional ecological knowledge and practices on use of natural resources, with the help of local educational institutions, teachers, students and NGOs working in collaboration with local, institutions. Such a process and the resulting documents, could serve a significant role in "promoting more sustainable, flexible, participatory systems of management and in ensuring a better flow of benefits from economic use of the living resources to the local communities" (Gadgil *et al.,* 2000).
– Facilitating the translation of available and new documents describing Indic traditions such as ancient texts on medicinal plants, into local languages and dissemination of these documents amongst local people. Such a translation is indeed required because texts are often available in languages (e.g. Sanskrit) not understood by many in contemporary India. On the other hand, translation of local knowledge into formal scientific terminology will provide space to external researchers, policy makers, and practitioners to comprehend and support people's knowledge systems and initiatives.
– Facilitating the exchange of information amongst practitioners of local knowledge.
– Developing clear and concise educational material on traditional knowledge systems to be used in communication programmes to impart information regarding the merits and threats to indigenous knowledge systems to both policy makers and the general public.

Scientific institutions have an important role to play in supporting the knowledge systems. As has been pointed out earlier, it is now recognised that a dichotomy between local and formal systems of knowledge is not real, and that any knowledge is based on a set of basic values and beliefs and paradigms. Therefore, there is a definite need to further develop systematic insight into the nature and scope of traditional knowledge. The following activities may be useful in this regard:

– Developing curricula and methods for providing formal training and education in traditional knowledge systems to agencies, researchers and practitioners who work in collaboration with communities. In this context, the Indian Himalayan Region, which represents a unique biogeographic entity, new initiatives by G.B. Pant Institute of Himalayan environment and development have yielded positive results (Dhar *et al.,* 2002).
– Developing research projects aimed at assessing the possibilities and constraints of using traditional knowledge under specific conditions. Such research projects should move beyond the first generation research projects, which aimed at demonstrating the value of local knowledge systems by focusing on successful cases of application. Second generation re research projects shall focus on comparing application of knowledge systems across a range of circumstances and across disciplines to craft the traditional sustainability science.
– Developing new methods for incorporating local knowledge systems in natural resource management regimes through action research.

Conclusion :

Along with science, local technologies (Gandhi, 1982) and people's knowledge systems such as ethnoforestry have an important role to play for biodiversity conservation and sustainability. Tribal's bag (Cox, 2000) and ancient texts (Tunon and Bruhn, 1994) may still be the best way to screen for new herbal medicines that may be useful in the treatment of diseases in the era of global climate change. Village communities and other small-scale societies residing continuously over a territory create, transmit and apply comprehensive knowledge about the resources contained in the territory. In villages where women take active part in natural resource management including agriculture and forestry they develop repositories of local knowledge that is continuously applied, tested and improved over time (Harding, 1998).The 1992 Convention on Biological Diversity requires that every contracting party should respect, preserve and maintain knowledge, innovations and practices of traditional and local communities and promote the wider application with the approval and involvement of the holder of such knowledge, innovations and practices and encourage the equitable sharing of the benefits. As nations implement the Convention on Biological Diversity (CBD) work programs, apply its guidelines, and execute national strategies, its influence on science is likely to grow. CBD-compliant national laws and policies already set priorities for research and affect the way in which scientists can access and use genetic resources (Kate, 2002).By acknowledging and making use of peoples' knowledge we shall also promote the principle of equity of knowledge (Pandey, 1998). Equity of knowledge between local and formal sciences results in empowerment, security and opportunity for local people. If the state and formal institutions incorporate people's knowledge into the resource management decisions, it reduces the social barriers to participation and enhances the capacity of the local people to make choices to solve the problem. Traditional societies have accumulated a wealth of local knowledge, transmitted from generation to generation. Experience has taught them how the water, trees, and other natural resources should be used and managed to last a long time. Equity of knowledge can also enhance the security in its broadest sense. By capitalizing on the collective wisdom of formal and traditional sciences, we shall be able to help people address the problem of global warming as well as to manage the risks they face because of the destruction of the local resources. Collective wisdom can help in the planning and implementation of suitable programmes for managing the agroforests (Pandey, 2002b). This results in ecological, economic, and social security. There has been a concern that care needs to be taken to distinguish valuable knowledge from myth (Nature, 2000). This may be useful from a different perspective as well: that the useful knowledge is not lost. Identification of science behind traditions (Arunachalam, 2001) is a more constructive endeavor than entering into the 'indigenous vs. scientific' or 'traditional vs. western' arguments (Agrawal, 1997). Scientists need not encounter traditional knowledge systems uncritically, just as local people need not approach formal science uncritically. Politically strident advocates of local knowledge systems as well as formal science have done more harm than good by defending the exclusive truth claims on the part of their discipline. "Exclusive truth claims – assertion of epistemological privilege – are now not tenable either on the part of science or local knowledge systems" (Pandey, 2002a).

Indeed, there are numerous examples where local knowledge derived from long-term nature-society interaction has been extremely useful in validating scientific hypotheses and suggesting new research directions (see for example a recent analysis by Kimmerer (2002), among others; see also Robertson and Hull (2001). Likewise, formal scientific methods have been extremely valuable in validating the traditional ethno-pharmacological knowledge by identifying the active ingredients (chemicals) in plants used in ethnomedicine. One such example of significant contribution that established the ancient-modern concordance came with the isolation of the hypertensive alkaloid from the sarpagandha plant (*Rouwolfia serpentina*), valued in Ayurveda for the treatment of hypertension, insomnia, and insanity. Several such isolations of active ingredients have been made since then (Dev, 1999; Mishra *et al.* 2001). Another example pertains to the conservation of ethnomedicinal species that are also globally traded, and, therefore, have become endangered in India. "A reasonable degree of scientific rigour" is required to assess the threat status of species to be banned in trade (Ved *et al.*, 1998) as well as to monitor, learn and craft strategies for context specific adaptive management by using formal and local sciences. The important issue to be guarded here is that the benefits must go to the community.

Intellectual Property Rights are now being extended to beyond the conventional domain of mechanical and chemical innovations to include biological resources. National Biological Diversity Act of India in response to our commitment to the Convention on Biological Diversity and intellectual property rights must, therefore, devise operational mechanisms to share benefits of commercial applications of traditional knowledge on biodiversity with local communities. Also useful shall be to ensure a harmonized basket of rules made under the Patent Act, Protected Plant Varieties Act and the Biological Diversity Act (Utkarsh *et al.*, 1999).

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