THE ROLE OF BIODIVERSITY FOR SUSTAINABLE ENVIRONMENT

Mir Mehrdad Mirsanjari [a] , Mitra Mirsanjari [b]

[a] Department of Environmental Sciences, Faculty of Natural Resources and Environmental Sciences, Malayer University, Iran.

[b] PPSKHealth sciences, USM,Kubang Kerian, Malaysia.

[a] Corresponding author: mehrdadmirsanjari@yahoo.com

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Abstract: Scientific research on human-environmental interactions is now a budding sustainability science. The concept recognises that the well-being of human society is closely related to the well-being of natural ecosystems. Traditional knowledge is vital for sustainability of natural resources including forests, water, and agro ecosystems across landscape continuum spanning from households through farms, village, commons and wilderness. This article identifies recent developments in local knowledge research and interface this with the challenges that contemporary society faces and how local knowledge can be useful to address the biodiversity conservation. Humanity faces exceptional challenge of eroding natural resources and declining ecosystems services due to a multitude of threats created by unprecedented growth and consumerism. Also imperilled is the biodiversity and sustainability of the essential ecological processes and life support systems in human dominated ecosystems across scales. Indeed, human-domination of earth is evident in global change biodiversity extinctions and disruption of ecosystem functions. Ecological problems coupled with unequal access to resources results in human ill-being and threats to the livelihood security of the world's poorest.

Keywords: Biodiversity, Sustainable, Environment, agro-ecosystem

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. These are some of the useful attribute of local knowledge systems (Pandey, 2002a). 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, 2002a).

In India these systems can be classified in several ways: (a) Religious traditions: temple forests, monastery forests, sanctified and deified trees (b) Traditional tribal traditions: sacred forests, sacred groves and sacred trees (c) Royal traditions: royal hunting preserves, elephant forests, royal gardens etc. (d) 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: (a) Collection and management of wood and non-wood forest products (b) Traditional ethics, norms and practices for restraint use of forests, water and other natural resources(c) Traditional practices on protection, production and regeneration of forests (d) Cultivation of useful trees in cultural landscapes and agroforestry systems (e) 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).

Biodiversity in Sacred Cliffs

Cliffs are completely forgotten cultural landscape elements that support a variety of species of plants and animals in India. As humans have special fascinations to such areas often cliffs across the country are considered sacred. Cliffs elsewhere have been found to support undisturbed ancient woodland, dominated by tiny, slow-growing and widely spaced trees. Vertical cliffs often support populations of widely spaced trees that are exceptionally old, deformed and slow growing. Some of the most ancient and least-disturbed wooded habitats on Earth are found on cliffs, even if such sites are close to intensive agricultural and industrial development. The age of the trees on cliffs may indicate the age and growth rates of the entire plant communities on the cliffs. Cliffs across the world may support ancient, slow-growing, open woodland communities that have escaped major human disturbance, even when they are situated close to agricultural and industrial activity, which has destroyed or altered most other natural habitats (Larson *et al.*, 1999, 2000a & b; Peterken, 1996). Examples of such habitat in India abound. Cliffs in Udaipur and Kota districts of Rajasthan were surveyed (7 cliff with ancient vegetation). Cliffs were found to have more than 25 species of trees, several species of shrubs and herbs. Areas close to Bhopal have more than 50 cliffs in central India in a radius of about 100 kms. All the 7 cliffs surveyed in Rajasthan are sacred. They are often part of the sacred corridors along the riverbank escarpment with several meters of precipitous fall. Attempts have been made to regenerate the Gaipernath Cliff with the traditional species occurring in the area (*Lannea coromandelica*, *Boswellia serrata*, *Sterculia urens* etc. about 25 species). The result was very poor initially. But local ethnoforestry techniques of tucking the branch cuttings of coppicing species in whatever little crevices area may have were successful. Also, depositing the seeds (same species that occur) in crevices with the ball of moist earth has been found promising.

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).

Farms themselves have domesticated biodiversity essential for survival and subsistence. One such example is by Kimata *et al.* (2000) form South India on the cultivation and process of domestication of *Brachiaria ramosa* cultivated in pure stands. Its grains are used in nine traditional food preparations in South India. Another crop *Setaria glauca* is cultivated in mixed stands along with little millet (*Panicum sumatrense*). In Orissa state and in Southern India the grains are used to make at least six traditional supplementary foods. The weedy forms of these species were found by the researchers growing with upland rice and some millets in diverse agro-ecological niches. The domestication process is supposed to have gone through three phases: first growing in association with weed and with upland rice and other millets; a secondary crop mixed with *kodo* millet; and finally as an independent crop.

Cultivation of Medicinal plants

There are numerous examples of medicinal plant cultivation by local people in India. Socio-culturally valued species find place in home gardens and courtyards. For example, Around the Nanda Devi Biosphere Reserve in the western Himalaya, the Bhotiya community, whose livelihood is depends on local natural resources, practices seasonal and altitudinal migration and stay inside the buffer zone for only 6 months (May-October). A survey in 5 villages in Pithoragarh District, found that Bhotiya people cultivate medicinal plants on their agriculture fields. Of a total of 71 families, 90% cultivated medicinal plants on 78% of the total reported cultivated area (15.29 ha). Around 12 species of medicinal plants were under cultivation. Survey also found that a family earned about Rs.2423 +/- 376.95 per season from the sale of medicinal plants in 1996 (Rs.38 = US$1 in 1996). Thus, supporting medicinal plant cultivation at high altitudes in the Himalayas may help to generate additional support to people as well as conserve the species in the wild (Silori and Badola, 2000, see also, Maikhuri *et al.* 1998). Another study (Satyal *et al.* 2002) on traditional knowledge of Kumaun Higher Himalaya found that Bhotia tribes use 34 species of medicinal plants native to the region. Among these, *Angelica glauca* and *Allium stracheyi* are narrow range endemic and *Allium stracheyi*, *Picrorhiza kurrooa* and *Nardostachys grandiflora* have been recorded in the Red Data Book of Indian Plants. Interestingly, the annual production of medicinal plants has been found to be comparable with the annual production of traditional crops. Thus, cultivation, and harvesting can help in livelihood security and *in situ* conservation of these species.

Similarly, juang and Munda tribes of the Keonjhar district of eastern India use 215 plants, belonging to 150 genera and 82 families (Mahapatra and Panda 2002). This suggests a wealth of traditional knowledge on biodiversity and herbal health care in tribes of eastern India. Tribes in the region are dependent on forests for other species as species of mushrooms, wild berries, tubers, and flowers that are included in their diet including cooking oil. Understanding of traditional knowledge on biodiversity of the region will be most helpful in planning for sustainable forest management.

Traditional Ethos

Similarly, in spite of the modernization, traditional ecological ethos continue to survive in many other local societies, although often in reduced forms. Investigations into the traditional resource use norms and associated cultural institutions prevailing in rural Bengal societies (Deb and Malhotra, 2001) demonstrate that a large number of elements of local biodiversity, regardless of their use value, are protected by the local cultural practices. Some of these may not have known conservation effect, yet may symbolically reflect, a collective appreciation of the intrinsic or existence value of life forms, and the love and respect for nature. Traditional conservation ethics are still capable of protecting much of the country's decimating biodiversity, as long as the local communities have even a stake in the management of natural resources.

Traditional ethos is reflected in a variety of practices including sacred groves and sacred landscapes. They are fairly well described (see for example, Deb *et al.* 1997, Pandey 1996 & 1998).

One example from northeast India is particularly notable (see, Tiwari *et al.* 1998). The tribal communities of Meghalaya – Khasis, Garos, and Jaintias – have a tradition of environmental conservation based on various religious beliefs. As elsewhere in India, particular patches of forests are designated as sacred groves under customary law and are protected from any product extraction by the community. Such forests are very rich in biological diversity and harbor many endangered plant species including rare herbs and medicinal plants. Tiwari *et al.* (1998) identified 79 sacred groves and their floristic survey revealed that these sacred groves are home to at least 514 species representing 340 genera and 131 families. The status of sacred groves was ascertained through canopy cover estimate. About 1.3% of total sacred grove area was undisturbed, 42.1% had relatively dense forest, 26.3% had sparse canopy cover, and 30.3% had open forest. Notably, the species diversity indices were higher for the sacred grove than for the disturbed forest.

Another notable example is from peninsular India. Study (Ramanujam and Kadamban 2001) on two sacred groves, Oorani and Olagapuram, situated on the north-west of Pondicherry found a total of 169 angiosperms from both sites. The Oorani grove (3.2 ha) had 74 flowering plant species distributed in 71 genera and 41 families; 30 of them are woody species, 8 are lianas and 4 are parasites. The Olagapuram grove (2.8 ha) was more species-rich with 136 species in 121 genera of 58 families; woody species were fewer (21) while 9 lianas and 3 parasites occurred. Associated local knowledge, cultural and religious rituals of local people sustain such diversity.

Another tradition worth mention is use of plants in mural painting. Such paintings are found, for example, in the Ajantan mural art. The practice spanned a whole millennium from the second century B.C. to the eighth century A.D. The tradition continued up to the nineteenth century under the support of different dynasties in India, but declined by the end of that century. Nayar *et al.* (1999) note that the art is kept alive by a few artists in Kerala who practice even today the methods and techniques of mural paintings similar to those practiced by the Ajantan mural painters. Various plant species provided materials for mural painting. Such knowledge can be very helpful in providing livelihood security to practitioners.

Traditional water harvesting structures too are also habitat for a variety of species. Even if pond size is small, as is the case in about 60% (out of 1.5 million total tanks) in India (Pandey, 2001) it may still be useful habitat for many species in rural ecosystems. Indeed, the island biogeography theory – valid in numerous cases – suggesting that larger areas support more species did not stand in case of 80 ponds in Switzerland (Oertli *et al*., 2002).

Theoretical predictions and empirical support suggests that although intentional[4] conservation may be rare among small-scale societies as Smith and Wishnie (2000) have pointed out, but practices that actually result in what we today call 'sustainable use and management' of resources and habitats by local people is widespread globally that contribute to in biodiversity conservation and enhancement through creation of habitat mosaics (Smith and Wishnie, 2000).

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 (figure 1; table 1 & 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).

In view of accelerating biological and cultural landscape degradation, a better understanding of interactions between landscapes and the cultural forces driving them is essential for their sustainable management. We need environmental and cultural revolution, aiming at the reconciliation of human society with nature (Naveh, 1995).

Table 1: Human ecological and indigenous perspective for biodiversity management

No	**Key challenges**	**Suggestions for policy and practice***
1.	Biodiversity Conservation and maintenance of ecosystem functions	• Application of the principles of sustainability science for forest management attempting to address the nature-society interaction will need an interdisciplinary approach as well as multiple stocks of knowledge and institutional innovations to navigate transition toward sustainable forest management (Pandey, 2002c). • Representation of all forest types in protected areas, both formal and ethnoforestry regimes, which are managed collaboratively (Reid, 2001) and link culture and conservation (**Byers *et al.*, 2001**). • Protection of natural forests against wild-fires, grazing, and unmanaged removals with the help of local strategies of herders, and resident communities (**Coppolillo, 2000).** As local people often have awareness about the application of fire, the different fire use practices
2.	Providing goods and services to the society	can be identified for grassland management. These practices reflect a well adapted production strategy. Policy decisions should as far as possible be flexible in the light of local understanding of fire use (**Mbow *et al.*, 2000) wherever possible.** • Preventing fragmentation and providing connectivity to conserve biodiversity in landscape continuum. Improvement of existing shifting cultivation methods with integration of traditional knowledge and new practices can be helpful in addressing the problem (Gupta, 2000). • Maintenance of gene pool diversity in natural and cultural landscapes (Saleh, 2000). Elements to conserve can be identified with the help of the local ethnoecological perceptions (**Johnson, 2000).** • Restoration of degraded forests with multiple use trees, shrubs and herbs along with regeneration regimes that necessarily combine rainwater harvest, direct seeding, resprouting, and plantations if needed.
3.	Social well-being of the people	• Maintenance of woody vegetation in ethnoforestry regimes in landscape continuum (households, cultural landscapes, agroecosystems, and wilderness). • Protection to a variety of woody vegetation management
4.	Economic well-being of people	regimes in agroecosystems to maximize social and economic benefits to the people as well maintenance of ecosystems functions such as natural pest control, pollination, carbon storage, regulation of hydrological cycle etc. • Protection to large trees in natural, cultural and human modified landscapes as well as agroforestry systems (Castro, 1991; Chandler, 1994; Chepstow-Lusty and Jonsson, 2000) as they act as seed source, conserve carbon pool, and act as habitat for seed-dispersing birds, small mammals, and other faunal species. • Soil conservation, and enhancement of soil fertility through conservation/restoration of woody leguminous species across landscape continuum. Swidden farming that is often central to the cultural identity of many indigenous people, continues to be viable in several cases, despite increasing population density and the continuing depletion of mature forests. By integrating commercially valuable perennial leguminous trees with crops, soil fertility can be maintained along with improvement to socio-economic condition of the people (**Iskandar and Ellen, 2000)**. • Community-based management regimes and common property management (Lu, 2001; Burke, 2001) built on the principle of equity of knowledge among stakeholders, and that rely capitalizing on

		natural recovery mechanisms will prevent further catastrophic shift and degradation and retain the multiple values of land. Community conservation initiatives seeking to make conservation worthwhile to local people have a strong economic dimension. But, the choices made by local landowners are not a simple function of the economic returns potentially accruing from a particular enterprise. They are as much or more influenced by who is able to control the different flows of returns from these different types of enterprise (**Thompson and Homewood, 2002)**. • Secure land tenure for indigenous people, who otherwise perceive conservation as luxury (**Marcus, 2001)**. • Maintaining the gender equity as a means to redistribute access to productive resources and household benefits **(Ahmed and Laarman,** 2000). • Institutional coordination of pastoral movements over formal tenure for pasturelands (**Fern�ndez-Gim�nez, 2002).** • The adoption of agroforestry is determined by the farmers' attitude to agroforestry, which in turn was shaped by information received through farmer-to-farmer and farmer-to-extension contact (**Glendinning *et al*., 2001)**. A clear extension programme, therefore, shall always be helpful for designing the multifunctional agroforestry systems. • Adaptive strategies for resource management (Bates, 2000)

*Column 3 provides consolidated suggestions because each one often addresses more than one key challenge.

Table 2: Indigenous forest management in India that protect biodiversity in landscape continuum (see figure 1 also)

Practices	Examples	Average Range of Area in Ha.
Sacred and sanctified Landscapes	Temple forests	5-10 ha.
	Sacred Corridors	10-200 ha. (1-2 km. long
	Sacred Groves	0.1 to 70 ha.
	Sacred Trees/Taboo trees	Isolated and sanctified trees
	Ethnoforestry Refugia	1-5 ha. (modern variants)
	Keshar-chhanta (saffron-sprinkled and sanctified) forests	50-500 ha. large forests
	Panchwati (tree grove)	0.1-0.5 ha.
Family and Village Forests	Rari (Village Woodlots)	20-150 ha.
	Family Farm Groves	0.5-1 ha.
	Charnot (wooded grazing lands)	1-50 ha.
	Kankad (village boundary forests)	2-5 ha. Strips
	Rundh (closed royal woodlands)	10-500 ha.
	Baugh (silvi-horti-gardens)	5-50 ha.
	Home gardens/dooryard garden	0.01 ha. 0.5 ha.
	Inhabited village groves	5-40 ha.
	Lakheta (wooded islands amidst traditional village ponds)	A grove of 10 to 50 trees
	Beed/Bir (traditional woodlot)	5-200 ha.
Agroforests	Several types	Extreme variation in area

Source: Pandey (2001*b*) 1·2

TRADITIONAL KNOWLEDGE, WATER, AND BIODIVERSITY

Simple local technology and an ethic that exhorts "capture rain where it rains" have given rise to 1.5 million traditional village tanks, ponds and earthen embankments that harvest substantial rainwater in 660,000 villages in India (Pandey, 2001a), and encourage growth of vegetation in commons and agroecosystems. If India were to simply build these tanks today it would take at least US $ 125 billion (Pandey, 2002*a*).

Humans have virtually appropriated fresh water. Humanity now uses 26 percent of total terrestrial evapotranspiration and 54 percent of runoff that is geographically and temporally accessible. New dam construction could increase accessible runoff by about 10 percent over the next 30 years, whereas population is projected to increase by more than 45 percent during that period (Postel *et al*., 1996).

Over thousands of years societies have developed a diversity of local water harvesting and management regimes that still continue to survive, for example, in South Asia, Africa, and other parts of the world (Agarwal and Narain, 1997). Such systems are often integrated with agroforestry (Wagachchi and Wiersum, 1997) and ethnoforestry practices (Pandey, 1998). Recently it has been suggested that market mechanisms for sustainable water management such as taxing users to pay commensurate costs of supply and distribution and of integrated watershed management and charging polluters for effluent treatment can solve the problem (Johnson *et al.*, 2001). Such measures are essential although, but they are insufficient and would need to draw on the local knowledge on rainwater harvesting across different cultures (Pandey, 2001).

Rainwater harvesting in South Asia is different from other parts of the world in that it has a continued history of practice for at least over 5000 years. Similarly, Balinese water temple networks as complex adaptive systems are also very useful systems (Falvo 2000). Although hydraulic earthworks are known to have occurred in ancient landscapes in many regions, they are no longer an operational systems among the masses in the same proportion as in South Asia. For instance, remains of earthworks and water storage adaptations are found in Mayan lowlands in South America (Mann, 2000). Such systems had been used for prehistoric agriculture in Mayan lowlands (Turner, 1974; Coe, 1979), and for fish culture in Bolivian Amazon (Erickson, 2000).

Rainwater harvesting have been found to be scientific and useful for rainfed areas (Li *et al.*, 2000). For instance, a validation comes from the Negev. Ancient stone mounds and water conduits are found on hillslopes over large areas of the Negev desert. Field and laboratory studies suggest that ancient farmers were very efficient in harvesting water. A comparison of the volume of stones in the mounds to the volume of surface stones from the surrounding areas indicates that the ancient farmers removed only stones that had rested on the soil surface and left the embedded stones untouched. According to results of simulated rainfall experiments, this selective removal increased the volume of runoff generated over one square meter by almost 250% for small rainfall events compared to natural untreated soil surfaces (Lavee *et al.*, 1997).

One of the principle tree genus growing in association with tanks and ponds in India is *Ficus* which is culturally valued throughout the country. It is a keystone genus and supports a variety of other species. Records of frugivory from over 75 countries for 260 *Ficus* species (approximately 30% of described species) suggest that in addition to a small number of reptiles and fishes, 1274 bird and mammal species in 523 genera and 92 families are known to eat figs (Shanahan *et al.* 2001).

BIODIVERSITY CONSERVATION

Strategies employed for conservation and management of natural resources prominently rely on nature reserves, national parks, wildlife sanctuaries and other such categories of protected areas (See for example, Inamdar *et al.*, 1999; Sarkar, 1999; Myers *et al.*, 2000; Pimm *et al.*, 2001; Roberts *et al.*, 2002; Sechrest *et al.*., 2002; Briers, 2002; Wilson, 2002). Protected-area-alone approach for nature conservation, however, has serious flaw (Pandey, 1993) as it has further exacerbated the problem of human-animal conflicts, and a majority of reserves have failed to achieve the conservation goals in marine (Tupper, 2002) as well as terrestrial (Rajpurohit, 1999, Vanclay, 2001; Rawal and Dhar, 2001; Madhusudan and Karanth, 2002) ecosystems. Such an approach has also "led to conflicts between the local communities and the management authorities" (Ashish Kothari, *pers. comm.*)

Further, application of island biogeography theory to conservation practice has been contended since long. As Simberloff and Abele (1976) note "theoretically and empirically, a major conclusion of such applications – that refuges should always consist of the largest possible single area – can be incorrect under a variety of biologically feasible conditions. The cost and irreversibility of large-scale conservation programs demand a prudent approach to the application of an insufficiently validated theory." Protecting biodiversity in protected areas indeed has remained a challenge across nations.

On the other hand there are detailed accounts of a variety of mechanisms and contexts through which local people conserve and maintain biodiversity across landscape continuum (see for example, Arnold and Dewees, 1997; Kothari 1996, 2000; 2002; Kothari *et al.* 2001; Kothari and Anuradha 1999; Pandey, 1996, 1998; Berkes, 1999; Collins and Qualset, 1998; Ramakrishnan *et al.*, 1998; Medin and Atran, 1999; Nazarea, 1999; Posey, 1999; Venkataraman, 2000; Hartley, 2002; Daniels and Vencatesan, 1995; see figure 1).

Practice to set aside areas for the preservation of natural values such has sacred groves of Asia and Africa and royal hunting forests in India are some historical examples (Kanowski *et al.*, 1999; Chandrashekara and Sankar, 1998) of nature conservation. Several of these areas became national parks and wildlife sanctuaries in India and elsewhere.

Consensus that seems emerging is that we might need multiple conservation and sustainable management approaches (Dinerstein and Wikramanayake, 1993; Chandrashekara and Sankar, 1998; Schellnhuber and Wenzel, 1998; Margules and Pressey, 2000; NRC, 1999; Clark, 2001) Under these circumstances, instead of an exclusive approach, both protected areas and community areas seem complementary strategies.

As the human and livestock population grows and natural resources decline command-and-control management of natural resources tends to become the norm. Stricter enforcement of protected areas again is gaining currency as a management proposal due to perceived failure of people-oriented approaches to safeguard biodiversity. Unfortunately, such an approach usually results in adverse consequences for natural ecosystems and human welfare in the form of collapsing resources, social and economic conflict, and loss of biological diversity (Holling and Meffe 1996; Meffe *et al.* 1998). Additionally, this resurgent focus on authoritarian protection practices largely overlooks key aspects of social and political process including clarification of moral standpoint, legitimacy, governance, accountability, learning, and external forces (Brechin *et al.* 2002). A single stock of knowledge is inadequate to address the challenges that sustainability science faces today (Pandey, 2002a).

Water Harvesting and Biodiversity Conservation

Revival of local rainwater harvesting globally could provide substantial amounts of water for nature and society. For example, a hectare of land in Jaisalmer, one of India's driest places with 100 millimeters of rainfall per year, could yield 1 million liters of water from harvesting rainwater. Even with the simple technology such as ponds and earthen embankments called tanks, at least half a million liters a year can be harvested from rain falling over one hectare of land, as is being done in the Thar desert, making it the most densely populated desert in the world. Indeed, there are 1.5 million village tanks in use and sustaining everyday life in the 660,000 villages in India (Pandey, 2001).

In the Negev Desert, decentralized harvesting through the collection of water in microcatchments from rain falling over a 1-hectare watershed yielded 95 cubic meters of water per hectare per year, whereas collection efforts from a single large unit-rather than small microcatchments – 345-hectare watershed yielded only 24 cubic meters per hectare per year (Evenari *et al.*, 1982.). Thus, 75% of the collectible water was lost as a result of the longer distance of runoff in larger watershed. Indeed, this is consistent with local knowledge distilled in Indian proverbs: "capture rain where it rains" (Pandey, 2001). This is also inconsonance with Water and civilizations with a promise of using history to reframe water policy debates and to build a new ecological realism (Priscoli, 1998).

There is an urgent need to policy innovations on rainwater harvesting that has been found useful by many studies (Boers and Ben-Asher, 1982). In the cities, rainwater could be harvested from building rooftops for residential use, and any surplus could be channeled through bore wells to replenish the groundwater, avoiding loss to runoff. However, if rainwater harvesting is to be used to their full potential, policy innovations must include institutional changes so that such resources are effectively managed (Ostram *et al.*, 1999; Pandey, 2000).

In Rajasthan, tanks and ponds have been a mainstay of rural communities for centuries. Strategies for tank rehabilitation (such as proposed for 1200 large tanks in Rajasthan) must not treat tanks only as flow irrigation systems; such an approach is very likely to result in a flawed strategy. A strategy that considers tanks as multiple-use socio-ecological entities, and which recognizes multiple stakeholder groups is more likely to enhance the social value of tanks (Shah and Raju, 2002).

In order to fully reward the context specific cultural resources, such as local knowledge, government subsidies need to be removed to allow market mechanisms to run their course and surplus revenue generated can be given to the communities who own the systems such as tanks.

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.

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.

Equity of knowledge also provides opportunity for local people to participate in the management of local affairs with global implications. It also provides the opportunity for self-determination. The process of acquisition, transmission, integration, and field application of traditional knowledge on tree-growing with formal science promises to enhance the productivity and efficiency of managing the natural resource. Human ecological perspective is vital in crafting the sustainability science for natural resource management.

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).

Nonetheless, it needs to be reiterated that formally trained scientists as well as researchers on traditional knowledge systems have often misinterpreted the process of what is often referred as validation. The term 'validation' need not be understood from a narrow reductionist perspective of disciplinary confines. It can, and should, draw on complimentarity and the "*consilience*" across local and formal systems. Thus, both formal and local methods, as well as local people and formally trained scientists, shall contribute to comprehend the data, information and knowledge. In collaborative efforts of such kind perhaps everyone involved may stand to benefit. Both local people as well as external experts need access to the latest scientific developments and see if it can help improve existing conservation knowledge and practices. The policy makers need ready access to the science as well as understanding the difficulties of its application (Kohm *et al.* 2000).

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)[9]. 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 (see, Utkarsh *et al.* 1999 for further discussion).

Ultimately, it does precious little to present models, concepts, and results of studies in academic discourses if those efforts are not tested under real conservation situations (Kohm *et al.* 2000). Conservation scientists must make a transition from "staid observer to participant at some level" (Meffe 1998). Gone are the times when scientists could afford to say that their work is to create knowledge, transmit it and leave application to policy makers and practitioners. Scientists shall have to collaborate with people to put forth new hypotheses that incorporate aspirations of formal and local systems of knowing and modify their methodologies accordingly. I would, therefore, forewarn against the futile philosophical arguments that engage in the questions of supremacy of one faith over the other, or, a particular knowledge system over the other. Humanity needs to go beyond disciplinary divide and find a common ground across cultures, faiths and disciplines (Pandey, 2002a).

Collective wisdom of humanity for conservation of biodiversity, embodied both in formal science as well as local systems of knowledge, therefore, is the key to pursue our progress towards sustainability.

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