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Indigenous Sustainability Science

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Nature-society interactions confront a range of challenges including maintenance of ecosystem services, conservation of biodiversity, and continuance of ecosystem functioning at local and global scale. Local people over thousands of years, have developed an intimate knowledge about landscapes they interact, inhabit and manage. Natural and social sciences are now converging into a novel discipline called sustainability science. Recognizing that transition to sustainability shall be a knowledge-intensive journey, this paper argues that a careful use of Indic resources provides options to design innovative policies and programmes for management of natural resources. Sustainability science of tomorrow shall be a basket of tools drawn across disciplines from the natural and social sciences, as well as local and formal knowledge systems. Equity of knowledge between local and formal sciences results in empowerment, security and opportunity for local people. Incorporation of people's knowledge into the resource management decisions, reduces the social barriers to participation and enhances the capacity of the local people to make choices to solve the problem. In order to facilitate the humanity s progress towards a sustainable future traditional knowledge systems and Indic traditions can contribute to local actions relevant to the sustainability of earth system as a whole.

KEY WORDS: Biodiversity conservation; climate change mitigation; ethnoforestry; Indic traditions; indigenous knowledge; multifunctional agroforestry systems; rainwater harvesting; sustainability science

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INTRODUCTION

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 (Chapin *et al.,* 2000) in human dominated ecosystems across scales (Vitousek *et al.,* 1997). Indeed, human-domination of earth is evident in global change (Ayensu *et al.,* 1999; Lawton *et al.,* 2001; Phillips *et al.,* 1998; Schimel *et al.,* 2001; Forest *et al.,* 2002), biodiversity extinctions (Bawa and Dayanandan 1997; Sala *et al.,* 2000; Singh, 2002) and disruption of ecosystem functions (Loreau *et al.,* 2001).

Ecological problems coupled with unequal access to resources results in human ill-being and threats to the food security of the world s poorest (Pandey, 1996; Balvanera *et al.,* 2001). The top 20% of the world's population consumes 85% of the world's income, the remaining 80% live on 15%, with the bottom 20% living on 1.3% of the world's income. The richest three persons on the planet have more wealth than the combined GDP of the 47 poorest countries. The richest fifteen persons have more wealth than the combined GDP of all of sub-Saharan Africa with its 550 million people (see, Serageldin, 2002, for an extended analysis). Although technically possible, but the annual incremental cost for controlling diseases is projected at $40 billion and $52 billion by 2015˚in 83 low-income and sub-Saharan African countries alone (Jha *et al.,* 2002).

To avert these threats, natural and social sciences have helped by acquiring and applying knowledge about ecosystem restoration and by strengthening the policy and practice of sustainable development.

Driven by the situation scientific research on human-environmental interactions (Stern, 1993) has developed into the new branch of knowledge known as the Sustainability Science (Kates *et al.,* 2001). The concept has developed on the basis of the recognition that the well-being of human society is closely related to the well-being of natural ecosystems. Sustainability science seeks to comprehend the fundamental character of interactions between nature and society, specifically the interaction of global processes with the ecological and social characteristics of particular places and sectors.

The importance of this evolving branch of knowledge is such that arguments have been advanced to institute a Nobel Prize for sustainability (Snoo and Bertels, 2001) along with the present awards for physics, chemistry, medicine, literature, peace, and economics. In fact, the suggestion is that prize for economics could be transformed into a Nobel Prize for Sustainability, because the three foundations of the concept of sustainability are the environment, economics, and social development. Alternatively, alternating prizes for economics, the environment, and social development have been suggested. It has been argued that instituting a Nobel Prize for Sustainability would give a high political and media profile for the discipline annually, and therefore an influential momentum for humankind (Snoo and Bertels, 2001).

In order to pursue humanity s progress towards sustainability seven core question have been framed that are expected to guide the research, actions and policy in the future. These are (Kates *et al.,* 2001):

1. How can the dynamic interactions between nature and society--including lags and inertia--be better incorporated into emerging models and conceptualizations that integrate the Earth system, human development, and sustainability?

2. How are long-term trends in environment and development, including consumption and population, reshaping nature--society interactions in ways relevant to sustainability?

3. What determines the vulnerability or resilience of the nature-society system in particular kinds of places and for particular types of ecosystems and human livelihoods?

4. Can scientifically meaningful "limits" or "boundaries" be defined that would provide effective warning of conditions beyond which the nature-society systems incur a significantly increased risk of serious degradation?

5. What systems of incentive structures--including markets, rules, norms, and scientific information--can most effectively improve social capacity to guide interactions between nature and society toward more sustainable trajectories?

6. How can today's operational systems for monitoring and reporting on environmental and social conditions be integrated or extended to provide more useful guidance for efforts to navigate a transition toward sustainability?

7. How can today's relatively independent activities of research planning, monitoring, assessment, and decision support be better integrated into systems for adaptive management and societal learning?

These questions have relevance across disciplines that contribute to natural resource management. Because we require broad participation of stakeholders and their knowledge systems, intellectual resource on which the sustainability science promises itself to build, therefore, must be pooled carefully. The fundamental concepts, policies and practice of sustainable development are subject of human ecology. Human ecology involves an understanding of how ecosystems are organized and function, how human social systems interact with natural systems, and how institutional mechanisms contribute to or conflict with sustainability (Marten, 2001). This paper is an effort in that direction.

Indigenous knowledge and Indic traditions, by virtue of their ability to modulate society s actions at the local context, have a vital role to play in combination with formal science and technology. The sustainability science, therefore, needs to take into account the contribution of Indic Traditions and local knowledge systems. Thus, the it will be useful to consider both formal systems of knowledge, such as proposed by Kates *et al.,* (2001), insights from industrial ecology (Karn and Baur, 2001) and the traditional knowledge systems (Gadgil *et al.,* 1993; Pandey, 1993, 1998, 2002a; Agrawal, 1997; Getz *et al.,* 1999; Cox, 2000; Gadgil *et al.,* 2000; Arunachalam, 2001; Udagaonkar, 2002) to foster a sustainability science that draws on the collective intellectual resources of the humanity (Figure 1).

A discussion on local knowledge is useful at this juncture for other reasons as well (Pandey, 2002a). First, inadequacy of economic incentives to conserve biodiversity as demonstrated recently by Kleijn *et al.,* (2001) compels rethinking classical utilitarian approach to resource management. Second, an emerging sustainability science (Kates *et al.,* 2001) will need all stocks of knowledge and institutional innovations to navigate transition towards a sustainable planet. Third, rediscovery of traditional ecological knowledge as adaptive management (Berkes *et al.,* 2000) and need to apply human ecological (Bews, 1935; East, 1936; Muller, 1974) and adaptive strategies for natural resource management (Bates, 2000) offers prospects for scientists to address the problems that beset conservation biologists and restoration ecologists. Fourth, there is an increasing realization that we need innovative ethics and policy to conserve biodiversity and maintain ecosystem functions (Tilman, 2000) and that such ethics need not come from the god; rather, society can cultivate them. Fifth, local knowledge systems are disappearing at a rate that may not allow us even to know what value, if any, such systems had (Cox, 2000; Brodt, 2001; Pandey, 2002a). Finally, in a thought provoking discussion, Cavalcanti (2002) notes that a limitation of economic development is that it is pursued without any considerations in practice as to its implications on ecosystems. The prevailing economic theories treat the economic process from a purely mechanistic standpoint. Different ways exist, however, to deal with the choices that humans have to make with respect to the allocation of resources, the distribution of its returns and the fulfilment of purposes of material progress. Indigenous, aboriginal or native ecological knowledge certainly is one of those ways, although 'primitive' peoples are considered brute, ignorant, having nothing to offer modern society in terms of its achieving its economic goals. To understand how 'primitive' societies solve their economic problems in a sustainable fashion is a serious challenge in this context. A better grasp of this issue could possibly be accomplished with the use of ethnoeconomics or ethnoecological economics (Cavalcanti, 2002).

Management of natural resources cannot afford to be the subject of just any single body knowledge such as the Western science, but it has to take into consideration the plurality of knowledge systems. There is a more fundamental reason for the integration of knowledge systems. Application of scientific research and local knowledge contributes both to the equity, opportunity, security and empowerment of local communities, as well as to the sustainability of the natural resources. Local knowledge helps in scenario analysis, data collection, management planning, designing of the adaptive strategies to learn and get feedback, and institutional support to put policies in to practice (Getz *et al.,* 1999). Science, on the other hand, provides new technologies, or helps in improvement to the existing ones. It also provides tools for networking, storing, visualizing, and analyzing information, as well as projecting long-term trends so that efficient solutions to complex problems can be obtained (Pandey, 2002a).

Local knowledge systems have been found to contribute to sustainability in diverse fields such as biodiversity conservation and maintenance of ecosystems services, tropical ecological and biocultural restoration, sustainable water management, genetic resource conservation and management of other natural resources. Local knowledge has also been found useful for ecosystem restoration and often has ingredients of adaptive management.

INDIC TRADITIONS AND LOCAL KNOWLEDGE SYSTEMS

What are the Indic Traditions? Essentially, I use the term here with reference to the dynamic traditions developed by the Indian culture over a period of long-term nature-society interaction. Indic traditions are expressed through textual as well contextual sources. The Indigenous knowledge is understood here as ethnoscience as defined by Hardesty (1977): the study of systems of knowledge developed by a given culture to classify the objects, activities and events of its universe.

Indic Traditions have been the subject of scholarly interest in a variety of disciplines. The Indic knowledge on medicine is widely recognized and we find a range of scientific literature spanning over 100 years. For instance, *Charak Samhita* was a subject of an excellent review by Hassler (1893) with generous admiration for the Indic sciences. Similarly, Rao (1985) refers how Vedic and other ancient literature provided foundation for the development of science in India. Recently, Narasimha (2001) discussed how mathematical notations have been encoded in terse verse to help protect the intellectual property in human memory. The application of this knowledge provided India an edge on science over other countries at one point of time in history. For example, Indian rockets were once the best in the world, and gave the Duke of Wellington a shock he never forgot (Narasimha, 1999).

Indic traditions also embody insights on social sciences. There seems a convergence between various theories of human cooperation in Indic traditions. Modern theories can both be applied to reinterpret Indic texts as well as provide new insights on Indic traditions. For instance, it has been shown experimentally (Fehr and Gachter, 2002), that key ingredient for human cooperation may be the altruistic punishment of free-riders by the more public-spirited individuals in the society. Although written in a different context on why humans cooperate, using the theory we can provide a fresh interpretation, for instance, of Bhagwatgita a prominent Indic Text as to why the legendary figure of ancient India, Arjuna, fought the war described in Bhagwatgita. This may indeed had been the altruistic punishment by Arjuna (the more public-spirited individual in the society of that time) to curb the free-riding. Another example is the value of patience (Fehr, 2002) that Indic traditions teach through ancient texts, folk-tales and proverbs. Indeed, as we shall discuss a little while later, proverbs make a fascinating field of inquiry that provide robust insights in a variety of disciplines.

Folk tales and poetry are another interesting category of Indic traditions, many of which contain robust scientific understanding. For instance, a recent study (Rasmussen *et al.,* 2002) on chemical communication in Asian elephants has validated the indigenous knowledge of Hindus in India. Ancient Hindu poetry describes the arrival of bees to gather sweetness from the temples of musth elephants. They say that in keeping with this poetic observation, we were struck by the powerful honey-like odour emitted by a captive 11-year-old male Asian elephant when he began secreting . This youthful musth is known as moda , a period that is characterized by mischievous and unpredictable behaviour. From the observations in the wild along with instantaneous chemical sampling and captive-elephant playback experiments, Rasmussen *et al.,* (2002) discovered that young, socially immature males in musth signal their naivety by releasing honey-like odours to avoid conflict with adult males, whereas older musth males broadcast malodorous combinations to deter young males, facilitating the smooth functioning of male society . The study is useful in an era of intense man-elephant conflicts as chemically modulating male behaviour may be one way to help the conservation of wild elephants. Moreover, the moda-musth emanations of young maturing elephants, as poetically observed by the ancient Hindus, have now been substantiated by modern scientific techniques (Rasmussen *et al.,* 2002).

There are environmental ethics that can be useful for natural resource management. Many people cherish the notion that ethics are revelations from the god. Others (Nitecki and Nitecki, 1993) suggest that ethics evolve through biological evolution a Darwinian view of evolution. Such philosophy, however, cannot conclusively explain why there exist different ethics in different cultures, faiths and nations. This also fails to explain why ethics undergo change over time. These and many other questions, however, can be answered by the theoretical position that considers the evolution of ethics as a process closely linked to cultural evolution (Ehrlich, 2002). In brief, culture is the product of the social process in human communities that evolve and apply norms acceptable to a majority in that context. The origin of norms is rooted in interactions with other individuals and the empathy or ability to imagine others viewpoint. Useful norms that promote human prospects are valued, retained and perhaps refined, shared, and passed on to the next generation as useful knowledge. Thus, the process of evolution of ethics is closely related to culture. This explains both for the diversity and change in ethics. Such a theory indeed is in consonance with the empirical studies (Pandey, 2002a), which demonstrate that new rules acceptable for the society can be crafted and innovative institutions can be created, or existing ones can be adopted or modified to face the contemporary challenges of sustainability.

INDIGENOUS KNOWLEDGE ON BIODIVERSITY CONSERVATION

In order to be effective, sustainability science 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).

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). These systems can be classified in several ways.

- Religious traditions: temple forests, monastery forests, sanctified and deified trees
- Indigenous 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 Indic 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
- Indigenous ethics, norms and practices for restraint use of forests, water and other natural resources
- Indigenous 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).

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 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).

Both theoretical predictions and empirical support validate that although voluntary conservation may be rare, sustainable use and management of resources and habitats by local people is widespread globally that indirectly results in biodiversity conservation and enhancement through creation of habitat mosaics (Smith and Wishnie, 2000).

INDIGENOUS KNOWLEDGE ON WATER MANAGEMENT

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, 2001), 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, 2002a).

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).

NATURE-SOCIETY INTERACTIONS IN ANCIENT TEXTS

Natural Resource Management has been in the traditions of the Indian society, expressing itself variously in the management and utilization practices. This evolved through the continued historical interaction of communities and their environment, giving rise to practices and cultural landscapes such as sacred forests and groves, sacred corridors and a variety of ethnoforestry practices. This has also resulted in conservation practices that combined water, soil and trees. Nature-society interaction also brought about the socio-cultural beliefs as an institutional framework to manage the resultant practices arising out of application of indigenous knowledge. The attitude of respect towards earth as mother is widespread among the Indian society (Figure 2).

Local knowledge has proved useful for forest restoration and protected area management in Rajasthan one of the driest regions of India with scanty rainfall.
Cultural landscapes in rural and urban areas and agroecosystems, created by the application of scientific and local knowledge, also support a variety trees, birds

and other species (Figure 3), and provide opportunity of integration of nature and society (Taylor, 2002).

Ancient texts make explicit references as to how forests and other natural resources are to be treated. Sustainability in different forms has been an issue of development of thought since ancient times. For example, robust principles were designed in order to comprehend whether or not the intricate web of nature is sustaining itself. These principles roughly correspond with modern understanding of **conservation, utilization**, and **regeneration**.

Conservation Principles: Atharva Veda (12.1.11) hymn, believed to have been composed sometime at around 800 BC, somewhere amidst deep forests reads: O Earth! Pleasant be thy hills, snow-clad mountains and forests; O numerous coloured, firm and protected Earth! On this earth I stand, undefeated, unslain, unhurt. Implicit here are the following principles:

- It must be ensured that earth remains forested.
- It must be understood that humans can sustain only if the earth is protected.
- To ensure that humans remain unslain and unhurt , the ecosystem integrity must be maintained.
- Even if vaguely, it also makes reference to ecology, economy and society concurrently.

Utilization and Regeneration Principles: Another hymn from Atharva Veda (12.1.35) reads: Whatever I dig out from you, O Earth! May that have quick regeneration again; may we not damage thy vital habitat and heart . Implicit here are the following principles:

- Human beings can use the resources from the earth for their sustenance,
- Resource use pattern must also help in resource regeneration,
- In the process of harvest no damage should be done to the earth,

- Humans are forewarned not against the use of nature for survival, but against the overuse and abuse.

Although not in modern terminology, the three segment of sustainability ecology, economy and society seem to get addressed simultaneously.

Similarly, water management and associated tree growing has been the subject of ancient text. Tanks have been the most important source of irrigation in India. Some tanks may date as far back as the *Rig Vedic* period, around 1500 BC. The *Rig Veda* refers to lotus ponds (*5.78.7*), ponds that give life to frogs (*7.103.2*) and ponds of varying depths for bathing (*10.71.7*). Reference to the tanks is also found in the *Arthashastra* of Kautilya[2] written around 300 BC (Rangarajan 1987: 231-233). The *Arthashastra* refers to the ownership and management of the village tanks in the following verses:

> Waterworks such as reservoirs, embankments and tanks can be privately owned and the owner shall be free to sell or mortgage them (*3.9.33*)[3].
>
> The ownership of the tanks shall lapse, if they had not been in use for a period of five years, excepting in case of distress (*3.9.32*).
>
> Anyone leasing, hiring, sharing or accepting a waterworks as a pledge, with a right to use them, shall keep them in good condition (*3.9.36*).
>
> Owners may give water to others in return for a share of the produce grown in the fields, parks or gardens (*3.9.35*).
>
> In the absence of owners, either charitable individuals or the people in village acting together shall maintain waterworks (*3.10.3*).
>
> No one will sell or mortgage, directly or indirectly, a bund or embankment built and long used as a charitable public undertaking except when it is in ruins or has been abandoned (*3.10.1,2*).

The earliest scholar to have commented on the relationship of tanks and trees is Var*a*hamihira who described the detailed technical instructions for the tank constructions in his famous work *Brahatsamhita* (550 AD):

> Without the shade of the trees on their sides, water reservoirs do not look charming; therefore, one ought to plant the gardens on the banks of the water (*55.1)*[4]

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[2] Kautilya was a political economist of ancient India who compiled the *Arthashastra* around 300 BC.

[3] Numbers refer to the book number, chapter and verse number and translation referred here is by Rangarajan (1976).

Commenting on the species to be planted on the embankments of the tank, after its construction, Var*a*hamihira writes:

> The shoreline (banks) of the tanks should be shaded (planted) with the mixed stands of Arjun (*Terminalia arjuna*), Vata (*Ficus benghalensis*), Aam (*Mangifera indica*), Pipal (*Ficus religiosa*), Nichul (*Nauclea orientalis)*, Jambu (*Syzygium cuminii*), Vet (*Calamus?*), Neep (*Mitragyna parvifolia*), Kurvak (*?*), Tal (*Borassus flabellifer*), Ashok (*Saraca asoka*), Madhuk (*Madhuca indica*), and Bakul (*Mimusops elengi*) (*54.119)*.

For example, there is a considerable overlap in the formal and scientific forestry policy and practice, which provides hope that indigenous knowledge systems can contribute to the management of natural resources (See table 1 and Table 2). It would be pertinent to quote Gadgil and Guha (1992: 51) in this context:

> Indeed one could argue that scientific prescriptions in industrial societies show little evidence of progress over the simple rule-of-thumb prescriptions for sustainable resource use and the conservation of diversity which characterized gatherer and peasant societies. Equally, the legal and codified procedures which are supposed to ensure the enforcement of scientific prescriptions work little better than earlier procedures based on religion or social convention .

PROVERBS AS INSTIITUTIONAL ENFORCEMENT MECHANISMS

Byers *et al.,* (2001) in a thought provoking paper suggested that a strategy that integrates the conservation of culture and nature may be more effective in conservation of local resources than the one that ignores local traditional beliefs, values, and institutional structures. Indeed, as referred earlier, proverbs provide an illuminating insight on the nature and culture interaction among rural people.

Proverbs can provide insights for the participatory management of natural resources in much the same way as modern theories of human cooperation. There

[4] Arrangements of the verses are based on the Bhat (1981); translation of the relevant Sanskrit text of the *Brahatsamhita* is by the author.

is almost a perfect overlap between objective explanations provided to us by the scientific studies, and folk-proverbs on human behaviour.

Human behaviour has been the subject of researchers' curiosity for a very long time (Yerkes, 1914) giving rise to various theories of human cooperation. For instance, notwithstanding the tragedy of commons (Hardin, 1968 & 1998), people can indeed curb free-riding and manage resources successfully through a variety of institutional mechanisms (McCabe, 1990; Ostrom *et al.,* 1999; Berkes *et al.,* 1989; Ruttan, 1998; Trawick, 2001; Milinski *et al.,* 2002). Community cooperation is although essential for sustainability of commons, theories on cooperation have seldom taken into account local proverbs that influence human behaviour in rural society. Indeed, many of these theories are also reflected in community-proverbs (Loeb, 1952; Weber *et al.,* 1998; Shapin, 2001; Pandey, 2001) that can provide further insights on community-based restoration. Particularly, insights on the mechanisms when the 'tragedy of the commons' ceases to be a tragedy (Milinski *et al.,* 2002) through community-based mechanisms are useful for crafting indigenous sustainability science.

Kin-selection (Axelrod and Hamilton, 1981; Griffin and West, 2002) predicts that humans cooperate easily with people who are genetically related to them. West *et al.,* (2002) in a recent review suggest that individuals are predicted to behave more altruistically and less competitively toward their relatives, because they share a relatively high proportion of their genes. As a result, by helping a relative reproduce, an individual passes its genes to the next generation, increasing their Darwinian fitness. However, competition between relatives can reduce, and even totally negate, the kin-selected benefits of altruism toward relatives (West *et al.,* 2002). The useful proverbs that describe the theory of kin selection are embedded in local contexts. For instance, a blind person, given the responsibility to distribute relish to the crowd always repeatedly finds his kin to give . Nominal selection (Oates and Wilson, 2002) anticipates that names in common will promote altruistic behaviour. This indeed is the case in a proverb: alike people flock together .

Reciprocity and reciprocal altruism rule the roost not only in the scientific studies (Trivers, 1971; Axelrod and Hamilton, 1981), but also command high respect in human ecological studies (Gurven *et al.,* 2000) and the proverbial cooperation. The robust example of reciprocal altruism is evident in an interaction between two neighbours, one of who suggests the other: dance my beloved neighbour to my tune and I will do the same to yours . Another proverb used in reciprocal context is when a priest and his followers interact: people give alms befitting to the verse recital. In other words, as you chant so shall you get. Beyond a direct possibility of reciprocity humans often help others even if this altruism is unlikely to be returned by the recipient (Alexander, 1987; Nowak and Sigmund, 1998; Wedekind and Milinski, 2000). This is echoed in several modern studies (Wedekind, 1998; Ferriere, 1998) as well as proverbs: respect and ye shall be respected ; give and ye shall get , and serve and ye shall eat the sweet.

Cooperation without reciprocity suggests that cooperation can arise when people donate to others who may be similar to themselves (Riolo *et al.,* 2001), but they would not like to acknowledge the expectation: perform ye the noble deed and assume to have thrown it in a well. Another saying suggests people: you have given offering to god, worry not who consumes.

There are numerous folk sayings that admonish humans to uphold their image. Scientific theory predicts that helping or not helping someone impacts his or her image within a group, that decide an individual's reputation and status , that others may take into account in future dealings (Wedekind and Milinski, 2000). The evolution of fairness among the people, in the same way as the evolution of cooperation, is therefore connected to reputation (Nowak *et al.,* 2000). Reputation, thus, has a very high premium in the society. A proverb suggests, if reputation goes only the ashes remain , therefore let the million go, if it goes to save the reputation. Similarly, a proverb suggests people not to lend to individuals but to their reputations .

A recent study suggests that key factor for human cooperation could be the altruistic punishment of free-riders by the more public-spirited people in the society (Fehr and Gachter, 2002). This is not uncommon in folk theories: you shall be respected only if people fear you. Similarly, if you possess the stick people will dance to your tune , because those who deserve a slap are often deaf to good words.

Thus, parallel to the scientific theories there are several proverbs in currency that are near equivalents of the scientifically derived theories. Perhaps, innate desire to punish the free-riders (Fehr and Gachter, 2002), or to help the needy (Weiss *et al.,* 1971) is a reward in itself. Altruism in folk theory is expressed both in terms of help and punishment that finally brings cooperation for the management of common pool resources. There are always some people in society who like to help others no matter what , and like to punish free-riders no matter what.

Intensive studies on proverbs can help addressing some of the core questions of sustainability science. In particular, systems of incentive structures, rules, norms, and information that can most effectively improve social capacity to guide interactions between nature and society toward more sustainable trajectories may also be found in these proverbs.

INTEGRATION OF INDIC AND FORMAL SCIENCE

Are there any possibilities of integration of science and ethnoscience? Empirical evidence suggests in affirmative.

Indic traditions and local knowledge have often paved the way for many discoveries in science. For example, progress of science in India has built on the foundations of knowledge and wisdom that was created in ancient times on a variety of disciplines including metallurgy, mathematics, medicine, surgery and natural resource management (Rao, 1985; Gandhi, 1982; Tunon and Bruhn, 1994). Traditional skills, local techniques and rural craft provide a wide spectrum of knowledge in India, and since knowledge cannot be fragmented (Gandhi, 1982) we have to take the validated local knowledge into account together with science for evolving a robust sustainability science. Sharp boundaries between formal and local systems of knowledge, and natural sciences and social sciences may indeed be imaginary. Perceived confines may just be the unexplored domain that defies cognition for want of interdisciplinary explorations. This is however changing, as Wilson (1998) notes, disciplines are being rendered "consilient". Scientific community is increasingly realizing that there is a continuum between artificially dichotomized aspects of science: objective versus subjective, value free versus value laden, neutral versus advocacy (Rykiel, 2001). This disciplinary mosaic will have profound impact on science and policy development.

Since local knowledge systems in India are still being practiced among the masses, they can contribute to address the challenges of forest management (Pandey, 1998), sustainable water management (Pandey, 2001), biodiversity conservation (Pandey, 2002a), and mitigation of global climate change (Pandey, 2002b&c). Ecological consequences of climate change (McCarty, 2001; Pandey, 2002c; Walther *et al.,* 2002) require that we access all stocks of knowledge for mitigation strategies.

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 (Vanclay, 2001; Rawal and Dhar, 2001; Madhusudan and Karanth, 2002) ecosystems.

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; Pandey, 1996, 1998; Berkes, 1999; Collins and Qualset, 1998; Ramakrishnan *et al.,* 1998; Medin and Atran, 1999; Nazarea, 1999; Posey, 1999; Hartley, 2002).

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.

Stricter enforcement of protected areas again is gaining currency as a management proposal due to perceived failure of people-oriented approaches to safeguard biodiversity. But, Brechin *et al.,* (2002) have argued that 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. A single stock of knowledge is inadequate to address the challenges that sustainability science faces today (Pandey, 2002a).

Sustainable Water Management

Revival of local rainwater harvesting globally could provide substantial amounts of water. 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 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.

Multifunctional Agroforestry Systems

The origin of agriculture in diverse environments through domestication of several plant species (Pope *et al.,* 2001) gave rise to ethnocultivars that are still grown across the world. Within a relatively short geological time frame, Neolithic man and woman, domesticated all the major cereal grains, legumes, and root crops that the world's people depend on for most of their calories and protein (Borlaug, 1983). Crop improvement was in the hands of farmers who used and generated ethnocultivars using the local knowledge (Pandey, 1998) upon which depends the cornerstones of modern plant breeding were laid by Darwin and Mendel in the late 19th century (Borlaug, 1983). As the knowledge of genetics, plant pathology, and entomology have grown during the 20th century, plant breeders have made enormous contributions to increased food production throughout the world (Borlaug, 1983).

Khush (2001) notes that it took almost 10,000 years for food grain production to reach 1 billion tons, in 1960, and only 40 years to reach 2 billion tons, in 2000. This unprecedented increase resulted from the creation of genetically improved crop varieties, combined with the application of improved agronomic practices. However, it must be noted, as both Western and traditional systems of knowledge contribute to the growth of the society (Pandey, 1996; Agrawal, 1997; Arunachalam, 2001; Udgaonkar, 2002), the genetic material to breed improved cultivars has, in innumerable cases, been taken from the traditional crop varieties. Thus, there has been a knowledge continuum in which scientists have benefited from local knowledge systems.

Terrestrial biological diversity in wilderness, agroecosystems and cultural landscapes is supported by solar energy captured by plants growing in soils providing the foundation for human societies through production of food and renewable forms of energy. Variations in plant productivity, resulting from differences in inherent soil fertility, variations in climate and weather, and differences in chemical inputs and agricultural practices, produce patterns of biological diversity that are associated with the agricultural component of economic productivity. It has been argued ecological processes lead to a generally negative relation between the diversity of plant species and potential agricultural productivity at both local and global scales (see for example, Huston, 1993). One implication of this negative relation is that preservation of areas of high plant biodiversity does not require the sacrifice of productive agricultural lands (Huston, 1993), and the other is that diversity on farms can enhance the overall productivity due to pest control in agroecosystems.

Food security and biodiversity conservation can be enhanced due to greater income through intensified agroforestry practices as well as enhancement in the yield of products and services from biodiversity-rich agroecosystems. For example, approximately 4 million ha of agroforests in Indonesia not only yield rubber valued at US$ 1.9 billion but may also contain 250-300 species of plants (Leakey, 1999; Mc Neely and Scherr, 2001).

Small-scale farming systems are remarkably resilient (Brookfield, 2001), and their perceived constraints can be overcome by contribution of science and technology (DeVries and Toenniessen, 2001) while retaining their usefulness.

A rich diversity in forests and agroforests results in more productivity. A number of controlled experiments have demonstrated that primary productivity seems to be higher with greater biodiversity (Tilman *et al.,* 1996, 1997; Hector *et al.,* 1999), Similarly, losses of biodiversity may hamper the ability of ecosystems to sequester carbon (Sala, 2001) because plant species diversity controls the magnitude of the increase in carbon fixation as levels of atmospheric CO_2 increase (Reich *et al.,* 2001). Enhanced biomass accumulation in response to elevated levels of CO_2 or nitrogen, or their combination, is less in species-poor than in species-rich assemblages.

Agroecosystems also protect and support medicinal plants. Herbal medicine has become a topic of increasing global importance, with both medical and economic implications. In developing countries, as much as 80% of the indigenous populations depends on traditional systems of medicine and medicinal plants as their primary source of healthcare. Within the European Community, herbal medicines represent an important share of the pharmaceutical market, with annual sales in the range of US$7 billion. In the United States, the sale of herbal products has increased from $200 million in 1988 to more than $3.3 billion in 1997 (Mahady, 2001).

Agroforestry systems, in some cases, support as high as 50-80% of biodiversity of comparable natural systems (Noble and Dirzo, 1997), and also act as buffers to parks and protected areas. The landscape mosaics created by the interplay of rainwater harvesting and consequent growth of vegetation in agroforestry systems (Pandey, 2001) acts as corridor providing avenues for dispersal and gene flow in wildlife population (Hale *et al.,* 2001). The mosaics have significant conservation value in countryside (Daily, 2001; Sekercioglu *et al.,* 2002; Estrada and Coates-Estrada, 2002).

A survey of the avifauna in Costa Rica (Daily *et al.,* 2001) involving eight forest fragments (0.3—25 ha) and 13 open-habitat sites (1.0 ha each) in the agricultural landscape found that out of the 272 locally available bird species, 149 (55%) occurred in forest habitats only. Of the remaining 123 species, 60 (22% of the total) occurred both in forest and open habitats. Sixty-three species (23%) occurred in open habitats only including three non-native species (1%). Thus, a large proportion of the native bird fauna occurs in agricultural landscape. Countryside habitats may buy time for the conservation of some species, and may even sustain a moderate fraction of the native biota.

Agroforestry systems create landscape structure that is important for the biological pest control. For example, population of rape pollen beetle (*Meligethes aeneus*), an important pest on oilseed rape (*Brassica napus*), had increased mortality resulting from parasitism due to presence of old field margin strips along rape fields. Presence of adjacent, large, old fallow habitats had an even greater effect. In structurally complex landscapes, parasitism was higher and crop damage was lower than in simple landscapes with a high percentage of agricultural use (Thies and Tscharntke, 2000).

Many agroecosystems are unfavorable environments for natural enemies due to high levels of disturbance. Habitat management, for conservation of biological control, is aimed at favoring natural enemies and enhancing biological control in agricultural systems. The goal of habitat management is to create a suitable ecological infrastructure within the agricultural landscape to provide resources such as food for adult natural enemies, alternative prey or hosts, and shelter from adverse conditions. These resources must be integrated into the landscape in a way that is spatially and temporally favorable to natural enemies and practical for producers to implement. The rapidly expanding literature on habitat management is reviewed with attention to practices for favoring predators and parasitoids, implementation of habitat management, and the contributions of modeling and ecological theory to this developing area of conservation biological control. (Landis *et al.,* 2000).

In small-scale, subsistence agriculture in the tropics and the subtropics, traditional farming practices have evolved that provide a sustainable means of reducing the incidence and damage caused by pests including nematodes. The biodiversity inherent in multiple cropping and multiple cultivar traditional farming systems increases the available resistance or tolerance to nematodes (Bridge, 1996).

Often traditional farming systems are legume-based which have reduced carbon and nitrogen losses from ecosystems (Drinkwater *et al.,* 2001). Agroforestry systems produce a diverse landscape structure that supports populations of natural enemies of the agricultural pests. This helps in the biological pest control. CAST (1999) estimates that natural enemy populations that live in natural and semi-natural areas adjacent to farmlands control more than 90% of potential crop insect pests. The estimated cost of substitution of biological pest control service to pesticides for may be worth $54 billion per year.

In tropics, Dixon (1995) estimates that one ha of sustainable agroforestry can provide goods and services which can offset 5-20 ha of deforestation. Additionally, 1400 million ha of croplands and agroecosystems may be providing ecosystem services worth US$ 92 $ha^{-1}yr^{-1}$ as pollination, biological control, and food production amounting to total US$ 128 $x10^{9}$ yr^{-1} at the 1994 prices (Costanza *et al.,* 1997). Agroecosystems are also an essential component of developmental intervention for rural livelihood in developing countries (Mathur and Pandey, 1994).

Agriculturally induced successional pathways often lead to dominance by leguminous trees and therefore serve as a mechanism for increasing N oxide emissions from tropical regions (Erickson *et al.,* 2002). In regions where green revolution has not been able make any dent due to lack of soil fertility indigenous agroforestry may be answer. Sanchez (2002) suggests that Africa's food insecurity is directly related to inadequate food production due to lack of soil fertility, in contrast to South Asia where food insecurity is primarily due to poor distribution and lack of purchasing power. The most suitable soil fertility replenishment measure to augment nitrogen and phosphorus approach to overcome hunger in Africa is through agroforestry systems. Leguminous trees interplanted into a young maize crop and allowed to grow as fallows during dry seasons accumulate 100 to 200 kg N ha^{-1} over the period from 6 months to 2 years in subhumid tropical regions of East and Southern Africa. The on-farm production of firewood reduces encroachment onto nearby forests and woodlands, helping preserve their remaining biodiversity. The diversity of plant species grown in these farms mitigates the effects of pest attacks and market price fluctuations. These agroforestry systems are also robust, suffering less of a decrease in crop production when droughts hit because the soils are more porous and hold water better.

Management of the soils in Africa has always been a challenge (Lal, 1987). Enhanced food crop production, with low-input cropping for acid soils of the humid tropics (Sanchez and Benites, 1987) combined with local agroforestry systems has long been a useful alternative to shifting cultivation in humid tropical regions that continue to experience severe population pressures. For each hectare of land managed in a highly productive manner, there may be less need for clearing additional tropical forests to meet food demands (Sanchez *et al.,* 1982). Integration of persistent perennial, woody and herbaceous species, with traditional agriculture provides satisfactory drainage control to ameliorate existing outbreaks of salinity in several areas (Dunin, 2002).

Agroforestry could be the developmental path for areas where it has a long history and accumulated local knowledge. For instance, an alternative and far superior model for Amazonian development is one in which agricultural land is used intensively rather than extensively--whereby high-value agroforestry and perennial crops are favored over fire-maintained cattle pastures and slash-and-burn farming plots (Laurence *et al.,* 2001). Such systems, along with biotechnology, ecotourism, integrated local development, education, health, and sanitation are now seeking to break the poverty circle (Silveira, 2001).

In India various soil management practices to enhance soil organic carbon content have been suggested including reduced tillage, manuring, residue incorporation, improving soil biodiversity, and mulching (Rastogi *et al.,* 2002). However, the most useful path to enhance soil fertility is through agroforestry (Pandey, 2002b) and improvement in shifting cultivation to support biodiversity (Gupta, 2000).

PURSUING PROGRESS TOWARD SUSTAINABILITY

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

1. Each programme aiming at the promotion of indigenous knowledge should be based on the recognition that natural resource rights and tenurial security of local communities forms the fundamental basis of respecting indigenous knowledge.

2. More attention is needed on protection of intellectual property rights of indigenous people.

3. Innovative projects may need to be developed that aim at the enhancement of the capacity of local communities to use, express and develop their indigenous knowledge on the basis of their own cultural and institutional norms.

There is an urgent need for the integration of Indigenous and formal sciences (see figure 1). Following considerations may be useful in this regard:

1. Development of methods for mutual learning between local people and the formal scientists.

2. State forest policies and sustainable forest management processes need to give full attention to ethforestry and local institutional arrangements to incorporate indigenous knowledge in forest management and development projects.

3. Indigenous 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.

4. Revival of the traditional water management systems that have served the society for hundreds of years but are currently threatened

In spite of the value of indigenous 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:

1. 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.

2. Facilitating the translation of available and new documents describing Indic traditions into local languages and dissemination of these documents amongst local people.

3. Facilitating the exchange of information amongst practitioners of local knowledge.

4. Developing clear and concise educational material on indigenous 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 validation of the knowledge systems. 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 scientific insights into the nature and scope of indigenous knowledge. The following activities may be useful in this regard:

1. Developing curricula and methods for formal training and education in indigenous knowledge systems for education and training.

2. Developing research projects aimed at assessing the possibilities and constraints of using indigenous 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 research projects shall focus on comparing application of knowledge systems across a range of circumstances and across disciplines to craft the indigenous sustainability science.

3. 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 in sustainability science. Tribal s bag (Cox, 2000) and ancient texts (Tunon and Bruhn, 1994) may still be the best way to screen for new 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).

Even the most guarded scientific journals have opened up avenues to accommodate studies on local knowledge systems. This field is no longer a cautiously guarded realm of anthropologists alone. It is now a field of study with significant body of knowledge across disciplines. Accepted as firmly now, is the view that scientific and technological expertise of the North can learn from time-tested practices of other cultures for sustainable development (Harding, 1998) among the professional association of scientists. Indeed, repositories of local knowledge are proving increasingly valuable, as conventional Western paradigm for development is being re-examined.

The 1992 Convention on Biological Diversity requires that every Contracting Party should respect, preserve and maintain knowledge, innovations and practices of indigenous 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 indigenous knowledge on tree-growing with formal science promises to enhance the productivity and efficiency of managing the natural resource. Human ecological perspective (Table 3) is vital in crafting the sustainability science for natural resource management.

What is, however, to be guarded is the danger of romanticizing the local knowledge, and guarding the tendency to draw general conclusions without validating the claims. Only that data, information and knowledge which stands the rigours of scientific validity is the true knowledge held by the humanity I also 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. We need to find a common ground across cultures, faiths and disciplines. (Pandey, 2002a).

Collective wisdom of humanity, 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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Table 1: Ingredients of Sustainability in Ethnoforestry Practices

Goal	Considerations	Resultant Practices
Sustainable development	Societal well-being	➔ Traditional institutions ➔ Indigenous environmental ethics ➔ Social capital (seed networks etc.) ➔ Self-restraint, compassion and altruism
	Economic well-being	➔ Planting and nursing useful trees ➔ Conserving water for multiple use ➔ Saving seed for the next year ➔ Variety of ethnoforestry practices ➔ Traditional markets
	Ecological well-being	➔ Sacred forests and groves ➔ Protection ethnoforestry ➔ Production ethnoforestry ➔ Ethno-agroforestry ➔ Farming, trees and water conservation

Table 2: Ethnoforestry practices and their equivalent scientific forestry prescriptions

Contemporary prescription for sustainability	Example of management	
	Ethnoforestry	Formal forestry
1. Ecological Well-being		
(A) Conservation and maintenance of the ecosystems		
(i) Representative sample	Sacred groves, sacred ponds, sacred forests, sacred streams, sacred, temple forests, sanctified forests,	Preservation plots, wildlife sanctuaries, national parks and biosphere reserves, forest management unit (FMU)
(ii) Protected Area Network (regional, national and global)	Occurrence of above types of practices widely in villages of Mewar form a network	Network of 4 national parks and 24 sanctuaries, covering an area of 0.96 million ha, which constitutes 2.80% of the geographic area of the Rajasthan; Network of 7 wildlife sanctuaries covering 1960.83 km^2 area in Mewar
(iii) Biodiversity conservation in agroecosystems	Protection of wide range of species in agroecosystems of Mewar including 9 genera that that are represented by just one species in India Birs, home gardens, bagicha (Mango and Mahua gardens), trees near water sources, hakat rakhat etc.	Different forms of social forestry, community forestry and agroforestry
(iv) Multiple species and patchiness management	All the ethnoforestry practices maintain a diversity of species and a diversity of habitat patches as described above	Selection felling, rotation felling, leaving some areas completely protected
(B) Maintaining the species		
(i) Protection to the species prioritised for biodiversity conservation (protection to all individuals of the threatened species)	Protection to species such as Ficus benghalensis, *Ficus religiosa*, *Elaeocarpus sps*., *Adansonia digitata*, *Feronia limonia* (all trees) and herbs such as *Occimum sanctum* etc. Also several taboo species.	Protection to large sized plus trees to obtain genetically superior seeds and tissue; Retaining NWFP trees under many silvicultural systems while carrying out the felling. Protection to key-stone species that afford food, shelter and nest site to cavity-nesting birds and other wildlife. Protection to flag-ship species
(ii) Controlling over-exploitation	*Keshar Chhanta* (sanctification of forests) and several practices demonstrate the restrained use of resources such as harvest quotas, closed seasons, protected life history stages, protection to species, protection to entire communities in a locality	Ban on hunting and fishing, and felling of many species critically endangered. Special projects launched: Project Tiger at Ranthambhore and Sariska Tiger Reserves; Restriction on harvest of bamboo and fuelwood from many forest blocks of Mewar
(iii) Ex-situ conservation	Sacred Mango and Mahua orchards raised near temples by planting different landraces brought by devotees. Traditional ethnocultivars and	Botanic gardens and arboretum, zoological gardens, germplasm banks; breeding resistant crop varieties etc.

	medicinal plants of several species brought and planted in home gardens	
2. Social Well-being		
A. Effective policy and law		
(i) Prevalent policy and law	Community norms, values, prescriptions, religious teachings, taboo, beliefs prevail in Mewar to provide a local policy and law	National Forest Policy (1988) Rajasthan Forest Act Wildlife (Protection) Act JFM resolution 1991, 2000 etc.
(ii) Effective institutions and mechanism to ensure compliance of policy	Traditional village institution; *Bhopa ji*; community councils with mechanisms such as socio-cultural gatherings; *hukka-pani* injunction, and mechanism to expel from *biradari* (*bav ro danda*);	Forest Department at different levels with mechanism to arrest and produce in court of law; Meetings of the village forest protection and management committees; reward and punishment (*raj ro danda*);
B. Equity and Social justice		
(i) Equity and justice	Inter and intra generational concerns	Inter and intra generational concerns
(ii) Mechanism	As in 2.A (ii) above, but more of self-restraint	As in 2.A (ii) above, but more of coercion
3. Economic Well-being		
A. Products		
(i) Product multiplicity	Secondary concern, but practices designed to yield multiple products from the same area for subsistence	Primary concern, but practices were designed to yield limited but marketable products
(ii) Main thrust	Non-wood forest products	wood products, but changes are underway for about a decade
(iii) Harvest and yield	Sustainable use practices with wide safety margins in socially just and dignified ways	Sustained yield, but changes are underway for about a decade towards sustainable management for multiple products and ecosystems services in socially just circumstances.
B. Services		
(i) Ecosystem services	Variety of services almost overlapping with formal forestry, but at small scale	Variety of services almost overlapping with formal forestry, but at large scale

Table 3: Human ecological perspective for natural resource management

<table>
<tr><th>No</th><th>Key challenges</th><th>Guiding suggestions emanating from human ecology</th></tr>
<tr><td>1.</td><td>Biodiversity Conservation and maintenance of ecosystem functions</td><td rowspan="2">• 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 towards a 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 concerning can be identified for grassland management. These practices reflect a well adapted production strategy. Policy decisions should be more flexible in the light of local understanding of fire use (Mbow et al., 2000).
• 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.
• Maintenance of woody vegetation in ethnoforestry regimes in landscape continuum (households, cultural landscapes, agroecosystems, and wilderness).
• Protection to a variety of woody vegetation management 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,</td></tr>
<tr><td>2.</td><td>Providing goods and services to the society</td></tr>
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<table>
<tr><td>3.</td><td>Enhancing the capacity of terrestrial carbon storage in trees, woody vegetation and soils</td><td rowspan="2">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)</td></tr>
<tr><td>4.</td><td>Social and economic well-being of people</td></tr>
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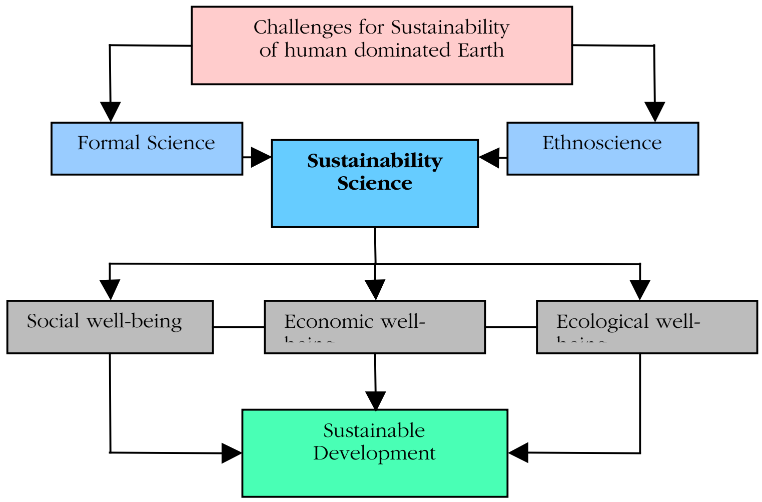

Figure 1: Integration of knowledge systems to craft the sustainability science

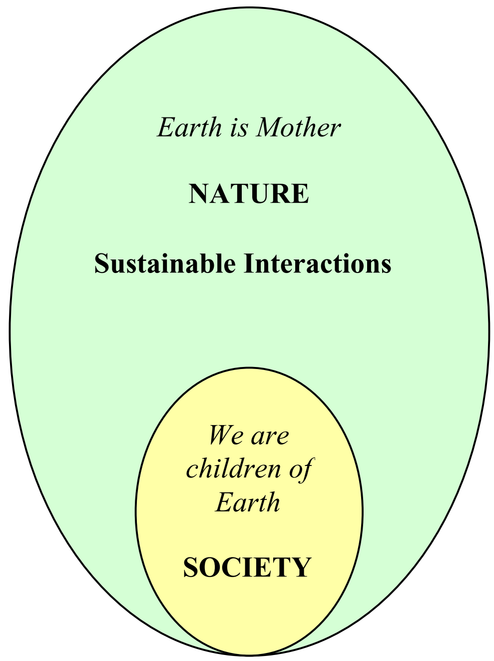

Figure 2: Local perception of nature and society in India. The attitude of respect for nature is due mainly to the way the Indian society lived and interacted with nature, and continues to uphold the view that earth is mother and we are her children . Source: *Atharva Veda,* 12.1.12.

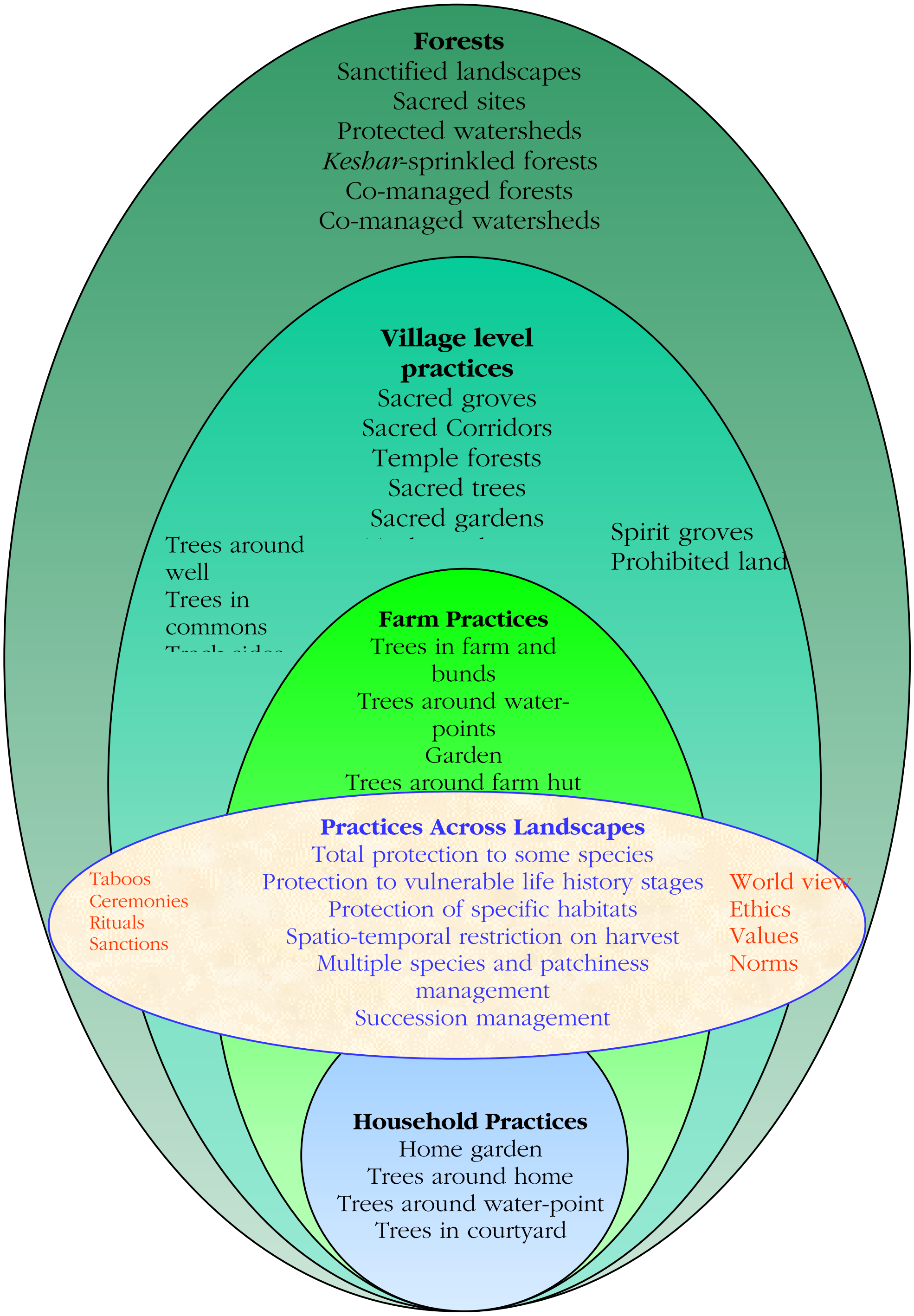

Figure 3: Conservation of biodiversity in landscape continuum, Rajasthan