humanity has at its disposal. Current research in genetic engineering, for example, resulted in the international community's concern over grave issues that affected human dignity. This led to commendably prompt action by UNESCO, resulting in the unanimous adoption of the Universal Declaration *of the Human Genome and Human Rights.* UNESCO's International Bioethics Committee has been charged with the follow-up to and implementation of the *Declaration.* This illustrates that the ideal relationship between those who generate and apply scientific knowledge, those who fund it and finally those concerned with its impact can only be based on universal values. Otherwise, given the terrifying capacity of new forms of biological and chemical warfare and the scarcity of strategic resources (as a further example), we are all on a very short fuse.

Paradoxically, it is the advancement of science that has also resulted in some of our major problems, namely the arms race. If we could reach a global consensus on the inanity of devoting such massive resources to the capacity for destruction, military production and research capacity-building should, in principle, be at least partially converted to peaceful uses. There' have already been many practical and beneficial applications that resulted as a spin-off from military as well as space technology; there could be so many more. It is, however, unfortunate that there has been a steep increase in the percentage of expenditure on military R&D in industrialized countries, to the detriment of peacetime fundamental research. This comes at a time when research programmes aimed at the resolution of global issues are becoming increasingly cost intensive.

Global responsibility for environmental problems that impact the future of our planet is also becoming ever-more evident. Increased urbanization and certain levels of industrial and agricultural activity are causing changes in the biological, chemical and geophysical cycles that governed the world as we first knew it. We face previously unforeseen changes in the forms of air and water pollution, new epidemics, ozone depletion, drought and ecological disasters. The overall need for sustainable and integrated science policies and preventive action is imperative to the survival of this ever-increasingly interdependent and fragile world and its life-support systems.

It is only fitting that the United Nations has proclaimed the year 2000 the International Year for the Culture of Peace. The global scientific community that we represent can play an essentially constructive and beneficial role in the Culture of Peace with a lasting commitment to harnessing science to serve a more equitably balanced and sustainable world. There can be no lasting world peace if basic human needs are not met across the globe. It is imperative that all the Earth's nations commit themselves to humanist ethics in their use of science as part of a social contract. As there is no Utopia on Earth, the very future of humanity depends on the wise application of knowledge, much as it did, allegorically speaking, before we were turned out of the Garden of Eden.

In closing, it is worth noting that in the 20th century the strongest initiatives towards safeguarding the welfare of mankind usually came about at the end of great and destructive conflicts. We are now at a juncture of history at which the world cannot afford another global conflict. Science has advanced to such an extent that any major conflict could erase life as we know it. International consensus on a framework for scientific action, according to universal values, can provide us with the alternative and peaceful strategies to confront the challenges that threaten us and future generations.

In this sense, science holds the greatest promise for the well-being of humanity, provided modern man succeeds in using science to humanize himself and his natural environment, rather than exploiting it to dehumanize himself and destroy nature.

Forging an alliance between formal and folk ecological knowledge

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This presentation attempts to explore the context and ways of addressing the challenge of forging an alliance of formal and folk ecological knowledge, along with an example of a concrete attempt to develop methodologies for doing so.

Human interactions with natural living resources may be viewed along three dimensions; those of practices, knowledge and belief. Consider as an example, the interaction with trees of genus Ficus (Table 1).

Folk knowledge is primarily practical, experiential, localized knowledge. Folk systems do not involve a clear-cut distinction between knowledge and belief (e.g. folk may state that they know that nature spirits live in Ficus trees); nor do they insist that knowledge must ultimately be validated with reference to the empirical world. But folk systems do involve substantial information on entities and processes in the empirical world: they include models of the working of the

Table 1. **Human interactions with trees of the genus *Ficus***

	Practice	Knowledge	Belief
Folk	Strict protection and worship of *Ficus* trees	Qualitative understanding of significance of *Ficus* fruit as food for birds, bats, squirrels, monkeys	*Ficus* trees are abodes of nature spirits
Scientific	Partial protection of *Ficus* trees	Quantitative understanding leading to concept of keystone resources	Desirability of conservation of totality of biodiversity

world. In contrast, scientific systems insist on a separation between knowledge and belief; insist that models of the working of the world in the domain of knowledge lead to predictions that can be verified with reference to the empirical world, through deliberately designed experiments. Formal science has achieved many remarkable successes. In particular, simple systems have yielded much understanding through such an approach, for they may be described with the help of a small number of parameters, permitting design of replicated experiments to test predictions.

However, complex systems characteristically require a very large number of parameters for their specifications; every manifestation of the system therefore tends to be unique, rendering replication and experimentation very difficult. As a result, formal science has made very limited advances over folk knowledge in the understanding of behaviour of natural living systems. Most notable of these advances is our understanding of evolution through natural selection. This is a powerful principle, but it only helps appreciate the world after the fact; it has few predictive capabilities; it cannot, for instance, tell us why a primate, rather than a carnivore or a dinosaur, developed symbolic language and capabilities of reasoning.

In particular, we have no ecological generalizations of value in predicting space- and time-dependent behaviour of natural living systems. Hence, systems of management of natural living resources have barely progressed beyond folk systems based on rules of thumb.

As examples, consider systems of conservation of living resources. Among both folk and modern systems of conservation are those (a) based on maintenance of refugia, or localities where biological communities are provided a high level of protection, and (b) special levels of protection provided to specific life history stages. Thus folk systems of conservation include sacred groves and ponds; modern systems include wildlife sanctuaries and national parks. Folk as well as modern systems include protection to life history stages such as birds breeding in a heronary. The science of ecology provides theoretical justification for such practices, but goes little beyond that. The simple rules of thumb derived from folk-level knowledge are thus in a way on a par with modern scientific understanding as far as underpinning conservation practices is concerned. Obviously, the field of management of natural living resources is a particularly appropriate field for an inter-cultural dialogue between folk and scientific knowledge systems.

A major scientific attempt to progress beyond this stage of folk knowledge is the notion of maximum sustainable yield (MSY). Its operation in comparison with folk systems may be summarized as in Table 2 and Figure 1.

Table 2. **'Maximum sustainable yield' – folk systems vs scientific approach**

	Practice	Knowledge	Belief
Folk	Reduce harvests if resource population has become very low	Populations at low levels may decline drastically under continued harvests	Humans part of a community of beings; should respect nature
Scientific	Exploitation at maximum sustainable yield levels	Quantitative models of dynamics of harvested populations	Humans hold dominion over nature; may exploit it to further human aspirations

However, exploitation under such MSY regimes has in very many cases led to over-harvest and resource collapse. This failure of science to generate adequate prescriptions for sustainable use derives from the weakness of the scientific knowledge base, e.g. models of dynamics of harvested populations have not been adequately validated empirically. For instance, many of these assume a parabolic relationship between stock or population at a given time and recruitment. If one actually plots the empirical data, however, there is little basis for the validity of such a postulate (Figure 1).

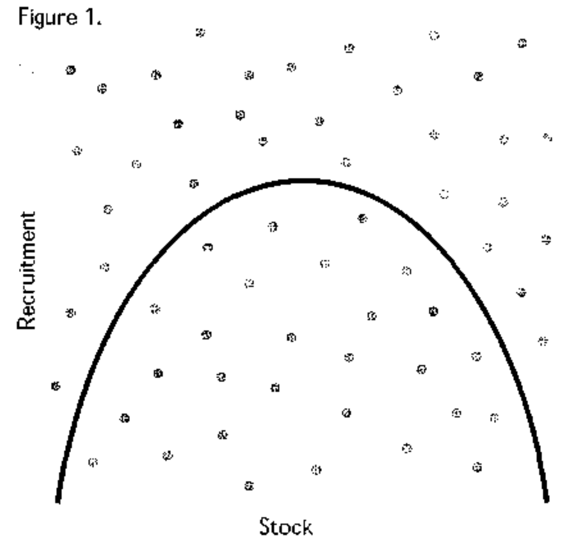

Figure 1.

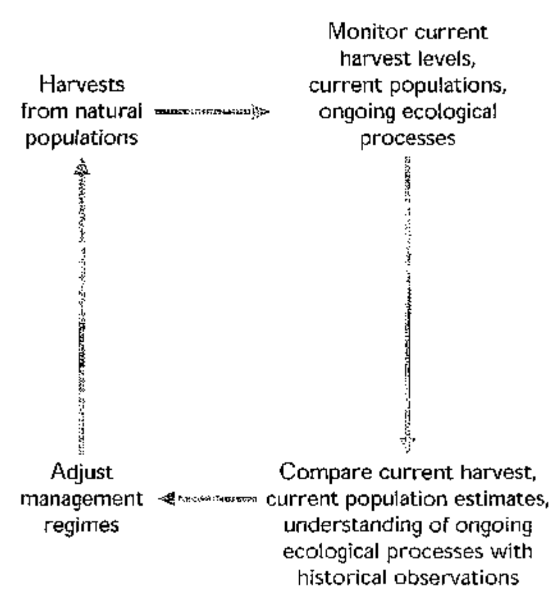

Figure 2. **Adaptive management**

Furthermore, there are strong forces in the modern economy resisting reductions in harvest levels in response to signals of depletion of resource populations. These economic forces take advantage of the uncertainty of the scientific knowledge base of dynamics of resource populations to push for continued exploitation at constant, high levels. In response, scientific management of natural living resources is now turning to a new paradigm, that of 'adaptive management', which may be visualized as in Figure 2.

It is evident that historical observations that constitute natural experiments on the natural living resource systems being managed are a critical input to the adaptive management regimes. This is because adaptive management depends on assimilating all available information on locality and time-dependent variation in system behaviour. In many developing countries, large numbers of people are dependent on harvests from natural living resources to sustain their livelihoods. Therefore, in the course of pursuing their own subsistence, these people continually observe the behaviour of the actors on the ecological theatre of their own localities; indeed they accept themselves being one among the company of such actors in the living world. This 'practical' or 'experiential' (not necessarily only traditional) knowledge is of obvious relevance to adaptive management.

The 'ecosystem people', stakeholders strongly dependent on local natural resources for their livelihoods, are being increasingly brought in as partners in programmes of co-management of natural living resources. In this context, social scientists have made major contributions to the design of institutions of co-management. On the other hand, while natural scientists have made some contribution to appropriation of knowledge of ecosystem people as in the development of new drugs, they have made little contribution to developing good systems of co-management of 'practical' and 'scientific' ecological knowledge. This is a significant challenge for the new millennium.

The overall system of co-management may be visualized as in Figure 3. Such a co-management system calls for a strong mutualistic relationship between scientists and the ecosystem people. A mutualistic relation between scientific and local communities requires that the scientific community appreciate folk knowledge, invariably mingled with folk beliefs, in terms of the categories of objects populating the natural world, as well as the processes operating. It is very necessary that scientists develop an understanding of folk models of specific processes such as the hydrological cycle, or ecological succession, or impacts of human harvests of biomass or fire. In addition, it is important to record location-specific environmental histories, as well as folk perspectives on how natural resources ought to be managed. Such folk knowledge/belief systems will inevitably show tremendous variation over space and among different human communities; the environmental histories too will be highly locality specific, as will be the perspectives on management of natural resources. To record all of this in a comprehensive fashion, and then to establish appropriate links with scientific knowledge, is a great challenge that would have to engage many components of society at large, along with the professional scientific community. Teachers and students in educational institutions at all levels could play a vital role in such an effort; such involvement would greatly enrich their learning experience. This documentation should be an ongoing process, a continual exercise of monitoring the state of the global environment in a highly decentralized participatory fashion.

In India we have made a modest beginning in such an effort through the compilation of People's Biodiversity Registers in 52 village clusters in different parts of the country (Gadgil, 1998; Gadgil et al., 2000). This has met with a very encouraging response from local people, non-governmental organizations, students and teachers, and follow-up programmes have recently been initiated in several hundred localities.

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Figure 3.