Government–industry–civil society partnerships in integrated gene management*

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An integrated gene management practice encompassing biopartnerships, participatory forest management, community gene management, biosphere management, and genetic resources enhancement and sustainable use alone can result in the conservation and enhancement of natural resources and save humanity from a grim future. The need for combining the ecological prudence of traditional technologies with contemporary bio-, information, space and renewable energy technologies and the need to give due recognition to women's role are emphasized.

AT the outset, I would like to express my deep sense of gratitude to the Volvo Environment Prize Foundation for choosing me for this prestigious award. I accept it with humility on behalf of my numerous colleagues, students as well as the rural and tribal women and men with whom I work. Through the institution of this Prize, the founders of the Volvo Environment Prize Foundation have shown their deep commitment to fostering a better care of the Earth's ecosystems and their management. I wish to pay my tribute to all those connected with the management of this Prize for their dedication to the cause of a better today and tomorrow for all members of the human family.

We all live on this planet as guests of the green plants which help to convert sunlight into various agricultural commodities and of the farm families who toil in sun and rain to cultivate them. I wish to dedicate this lecture to the millions of rural and tribal families who not only conserve the world's rich bio-resources but also serve as the backbone of the global food and health security systems.

On the eve of the UN Conference on Environment and Development held at Rio de Janeiro in June 1992, the Union of Concerned Scientists published an open letter titled, 'World Scientists' Warning to Humanity', which stated that 'human beings and the natural world are on a collision course'. The letter stated further, 'if not checked, many of our current practices put at serious risk the future that we wish for human society and the plant and animal kingdoms, and may so alter the living world that it will be unable to sustain life in the manner that we know'. This warning was signed by over 1600 scientists from leading scientific academies in 70 countries. The list included 104 Nobel Laureates.

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Colborn, Dumanoski and Myers[1] in their book *Our Stolen Future* and James Morgan[2] in his book *The Last Generation* also provide a picture of the grim future that awaits the generations yet to be born, if we lose further time in restoring harmony between humankind and nature.

A Chinese proverb warns, 'if you do not change direction, you will end up where you are headed'. Since we do not want to reach where we are presently headed, what change of course should we bring about?

I wish to take biodiversity, one of the key components of our basic life support systems, as an example to illustrate what changes are needed in the management of our biological resources. It is now widely realized that the genes, species, ecosystems and traditional knowledge and wisdom that are being lost at an increasingly accelerated pace limit our options for adapting to local and global changes, including potential changes in climate and sea level. The Global Biodiversity Assessment published in 1995 by the United Nations Environment Programme[3] estimates that about 13 to 14 million species may exist on our planet. Of this, less than 2 million species have so far been scientifically described. Invertebrates and micro-organisms are yet to be studied in detail. In particular, our knowledge of soil micro-organisms is still poor. Also, biosystematics as a scientific discipline is tending to attract very few scholars among the younger generation.

Another important paradigm shift witnessed in recent decades in the area of management of natural resources is a change in the concept of 'common heritage'. In the past, atmosphere, oceans and biodiversity used to be referred to as the common heritage of humankind. However, recent global conventions have led to an alteration in this concept in legal terms. Biodiversity is now the sovereign property of the nation in whose political frontiers it occurs. Under the UN Convention on the Law of the Sea, nations with coastal areas have access to a 200 mile Exclusive Economic Zone (EEZ). For example, the ocean surface available to India under the EEZ provision is equal to two-thirds of the land surface available to the country. The Climate Convention and the Kyoto Protocol provide for both common and differentiated responsibilities to countries. Thus, the global commons can be managed in a sustainable and equitable manner only through committed individual and collective action among nations.

Biodiversity and human security

While we have some knowledge of variability at the ecosystem and species levels, our knowledge of intra-specific variability is poor, except in the case of plants of importance to human food and health security. The Global Biodiversity Assessment warns, 'unless actions are taken to protect biodiversity, we will lose forever the opportunity of reaping its full potential benefit to humankind'. What kind of action will help us to ensure not only the conservation of biodiversity, but also its sustainable use? I would like to discuss this issue with reference to the following three major threats to biodiversity in general, and agrobiodiversity in particular.

Habitat destruction

UNEP's Global Environment Outlook-2000 states, 'Reduced or degraded habitats threaten biodiversity at gene, species and ecosystems level, hampering the provision of key products and services. The widespread introduction of exotic species is a further major cause of biodiversity loss. Most of the threatened species are land-based, with more than half occurring in forests. Freshwater and marine habitats, especially coral reefs are also very vulnerable'. How do we arrest this trend and prevent further genetic erosion? I would like to summarize briefly the approach adopted in India as well as at our Research Centre in Chennai (Madras) to foster an Integrated Gene Management strategy in the country. We use the term *management* in the context of natural resources to include conservation, sustainable use and equitable sharing of benefits. It is only such a concept of management that can result in the conservation as well as enhancement of natural resources.

The Integrated Gene Management system includes *in situ*, *ex situ* and community conservation methods (Figure 1). The traditional *in situ* conservation measures comprising a national grid of National Parks and protected areas are generally under the control of government environment, forest and wildlife departments. The exclusive control of such areas by government departments has often led to conflicts between forest dwellers and forest-dependent communities, and forest officials. The non-involvement of local communities in the past in the sustainable management of forests has resulted in a severe depletion of the forest resources in India. It has become clear that sole government control alone will not be able to protect prime forests or regenerate degraded forests.

Participatory forest management: The Participatory forest management (PFM) procedure initiated first at Arabari in the state of West Bengal in India in 1972, largely at the initiative of a young Forest Officer, Ajit Kumar Banerjee, and later extended to the other states in the country, became a significant turning point in the history of forest management in India as well as other Asian countries (see Samar Singh *et al.*[4] and Poffenberger *et al.*[5]). The essential feature of this system is that the state and community become partners in the management of the forest resource. The state continues to own the resource but the benefits are shared. Access to non-timber forest products becomes an important avenue of sustainable livelihoods to the forest-dependent communities. *Thus, the community develops an economic stake in the preservation of forests, leading to conservation and sustainable use becoming mutually reinforcing components of a Forest Management Policy.* The experience gained in India during the last 25 years shows that the process of natural forest degradation can be reversed through PFM and that forests can provide to the local community non-wood forest products on a continuous or seasonal basis, if there is a more widespread understanding of their regenerating capacity. Since forests are the home for a large proportion of naturally occurring biodiversity, saving forests results in saving genes.

Community gene management: Both *in situ* on-farm conservation of intra-specific variability, particularly in plants of food and medicinal value and *ex situ* on-farm conservation through sacred groves have been part of the cultural traditions of rural and tribal families in India. In the *Old Testament* also, there are several references to sacred groves. Among the important trees usually preserved in Indian Sacred Groves are: *Ficus religiosa*, *Saraca asoca*, *Shorea robusta*, *Alstonia scholaris* and many other species of ecological, economic and spiritual value. Gadgil and Vartak[6] defined sacred groves as tracts of forest that have been completely immune from human

Government–community partnership in integrated gene management

Government		Community	
In situ conservation	*Ex situ* conservation	*In situ* on-farm	*Ex situ* on-farm
• Protected areas • National parks • Biosphere reserve	• Gene banks • Botanical gardens • Zoological gardens • Tissue culture and DNA libraries	• Land races • Intra-specific diversity	• Sacred groves • Arboreta

Figure 1. Integrated gene management system.

interference on the basis of religious beliefs. Unfortunately, several of these traditions are now tending to wither away. It is only by giving explicit recognition to the pivotal role of community conservation in strengthening ecological, food and health security systems that we can succeed in the revitalization of these traditions. In national integrated gene management systems, *in situ*, *ex situ* and community conservation methods should receive adequate and concurrent attention. A recognition and reward system, based on FAO's concept of Farmers' Rights and CBD's provisions for ethics and equity in benefit sharing, should become an integral part of national legislation in the fields of biodiversity conservation and plant variety protection.

Biosphere management: Methods of fostering the sustainable management of Biosphere Reserves were discussed at a conference convened by UNESCO in 1995 at Seville in Spain. The Seville vision states:

> 'Rather than forming islands in a world increasingly affected by severe human impacts, biosphere reserves can become theatres for reconciling people and nature. They can bring the knowledge of the past to the needs of the future.'

To convert the above vision into field level reality, we have been working for a shift in the nature of management of Biosphere Reserves in India. A brief description of the approach adopted is given below.

India has currently 85 National Parks covering 3.6 million sq km and 448 wildlife sanctuaries covering about 120,000 km^2 in the major biogeographic zones. The total extent of protected areas includes 5 designated as World Heritage sites, 9 biosphere reserves and 6 Ramsar sites. In 1994, the M.S. Swaminathan Research Foundation (MSSRF) conducted a detailed study of the threats to the Gulf of Mannar Biosphere Reserve in Tamil Nadu. The study showed that unless the livelihood security of the families without assets living in that area can be strengthened, unsustainable exploitation of biological resources will continue[7].

During 1996–1998, MSSRF initiated a proposal for bringing the Gulf of Mannar Biosphere Reserve, under a participatory management mode. The project proposal was considered by the Global Environment Facility (GEF) Council at its meeting held in May 1999. The GEF Council approved the proposal and commended it as a model project which deserves to be widely emulated by those preparing similar projects. The Scientific and Technical Advisory Panel (STAP) of GEF endorsed the project for approval with the following remarks:

> 'The project addresses a major challenge, namely the conservation of coastal biodiversity of the highest ecological value in a large area subject to considerable pressure from poor populations upon the sole resources that appear to be at their disposal. To meet this challenge, the project follows the only framework which can succeed, namely to combine the necessary protection of the threatened ecosystem and ecological processes with economic and social benefits which will meet the essential needs of local people, through providing appropriate institutional, financial and managerial arrangements.'

This proposal was submitted by the Governments of Tamil Nadu and India to GEF through UNDP for support.

The management structure through which people and Nature will get united in the Gulf of Mannar area is through a Gulf of Mannar Biosphere Trust. Representatives of fishermen and rural communities as well as all the principal civil society stakeholders will, together with government representatives, form members of the Trust. The Members of the Trust will hold this unique biological treasure in trust for present and future generations. Considerations of intra- and inter-generational equity will guide the work of the Trust, which will provide a horizontal dimension to the numerous vertically structured activities undertaken in this area both by Central and State governments and private sector organizations. It is hoped that the Gulf of Mannar Biosphere Trust, whose long-term sustainability will be ensured with the help of a Trust Fund, will show the way for promoting a management by partnership system of governance in all the other Biosphere Reserves in the country.

Project Tiger launched in 1972 with support from WWF-International was the first step in institutionalized efforts in the conservation of habitats of endangered animals. An all-India tiger census conducted in 1972 revealed only 1827 tigers in the country as against an estimated 40,000 at the beginning of the 20th century. The 1993 census placed the tiger population at 3750.

One of the tiger reserves is the Similipal Biosphere Reserve in Orissa. This reserve was set up in June 1994 and covers an area of 2750 km^2. Of late, threats to this reserve have increased due to both population pressure and commercial greed. Experience with participatory or joint forest management programmes in India has shown that wherever the local communities are fully involved as partners in saving forests, the results have been very encouraging.

It is proposed to develop a similar plan for the Similipal Biosphere Reserve in collaboration with the Government of Orissa. The outcome of this programme will be the establishment of a *Similipal Biosphere Trust* managed jointly by the major stakeholders.

A major need in such programmes is the strengthening of the livelihoods of the poor families living in the vicinity of the Biosphere Reserve. For this purpose, the Biovillage model of livelihood security will be introduced in the villages around the Reserve. The Biovillage concept of human-centered rural development aims to address concurrently the challenges of natural resources conservation and poverty eradication[8]. Market-driven livelihood opportunities will be identified and local families will be assisted in taking to them with the help of institutional credit. The steps involved are:

- Micro-level planning with GIS maps
- Micro-enterprises identified on the basis of market needs
- Micro-credit
- Enlisting the support of industry for contract cultivation by small farmers on the basis of buy-back agreements.

Genetic resources enhancement and sustainable use: The main approaches adopted are summarized in Figure 2. Some methods of promoting symbiotic biopartnerships between conservers of genetic resources and holders of traditional knowledge and the utilizers of knowledge and material are indicated in Figure 3. An example of the Community Gene Management system being implemented in the state of Orissa is given next, in order to indicate how such concepts can be operationalized at the village level.

Community gene management: Tribal and rural farming communities have a long tradition of serving as custodians of genetic wealth, particularly landraces often carrying rare and valuable genes for traits like resistance to biotic and abiotic stresses, adaptability and nutritional quality. Several land types that carry valuable genes are preserved by farmers for religious functions (Table 1) and they constitute valuable material for conservation and sustainable use. Local landraces are still being maintained largely by the tribal poor. They thus serve public good at personal cost.

Such poverty-ridden custodians of genetic wealth are increasingly confronted with severe socio-economic problems which are rendering the maintenance of their traditional conservation ethics difficult. *Steps are urgently needed to link their conservation efforts to the strengthening of their livelihoods.*

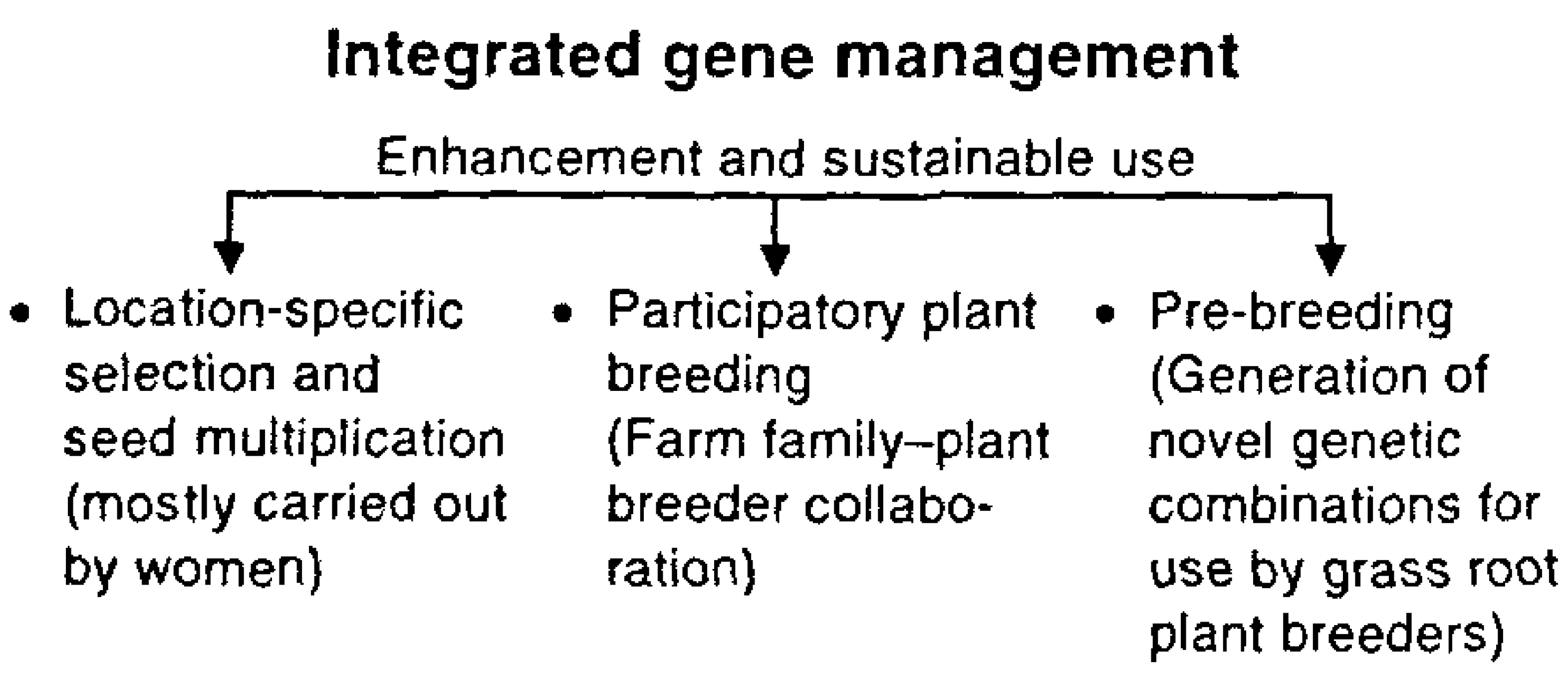

Figure 2. Approaches to genetic resources enhancement.

It is now widely recognized that the conservation continuum consists of the following three links.

In situ →	*In situ* →	*Ex situ*
Conservation of habitats	On-farm conservation by rural and tribal communities	Conservation through botanical and zoological gardens and cryogenic gene banks

While the two ends of this conservation chain (namely *in situ* and *ex situ*) receive support from public funds, *in situ* on-farm conservation by rural and tribal women and men largely remains unrecognized and unrewarded. Yet, this link in the chain is responsible for the conservation of valuable intra-specific variability.

MSSRF's partnership with local communities and government agencies is designed to strengthen this neglected component in the conservation chain. For this purpose, a Community Gene Management System (CGMS) is being developed, initially in 3 biodiversity-rich districts of the State of Orissa in India.

Structure of CGMS: CGMS comprises the following three steps.

- Field Gene Bank (FGB) at the village level
  In situ on-farm conservation by rural and tribal families
  Participatory breeding (selection)
- Area Seed Bank (ASB) at the level of a cluster of villages
  Conservation of representative samples of seeds in seed stores
  Insurance against total loss of seeds during drought years
- Community Gene Bank and Herbarium (CGB)
  Cryogenic preservation
  Evidence for getting tribal families reward and recognition under the proposed Plant Variety Protection and Farmers' Right Act.

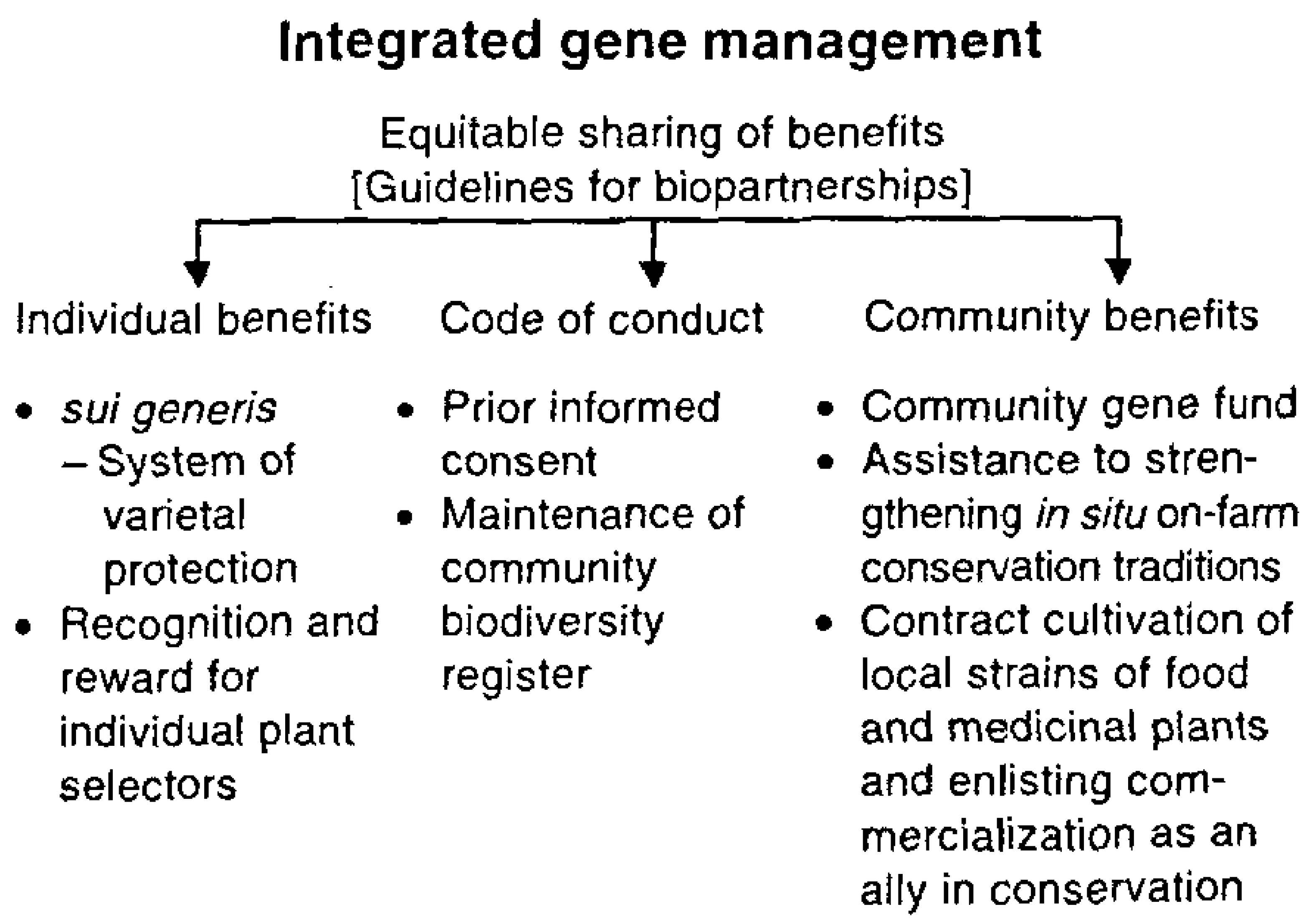

Figure 3. Promoting symbiotic biopartnerships.

Table 1. Some valuable land types preserved by Orissa tribal farmers for use in their religious functions

Rice variety	Predominant quality	Festival	Time of maturity (month)
Kalakrishna	Scented	All festivals	January
Tulsi (*Ocimum sanctum*)	Scented	*Chaitra Parva*	April
Haladichudi	White slender long grains, good taste	*Shakti Puja*	December
Machhakanta	White slender short grains, good taste	*Manabasa* and *Laxmi Puja*	November
Mer	Black grains with medicinal properties	Annual ceremony of forefathers	November
Deulabhoga	Bold and short grains, reddish tinge on cooking with mild scent preferred during worship at temples	Temple deities	December

FGBs are basically *in situ on-farm* centers of conservation. Landraces and location-specific plant genetic resources (PGR), usually identified on a participatory basis with the local families, are conserved in FGBs. The local landraces are periodically grown in their native habitats for seed renewal. They serve as effectively decentralized and highly cost-effective arms of a CGMS. Those FGBs which are situated at higher elevations are likely to have cooler and conducive climates for storing seeds without loss of viability. No expensive infrastructure is needed to set up FGBs. The FGBs would ensure *in situ on-farm* maintenance of landraces and preservation of the cultural and cropping practices under which PGR acquired their distinctive traits. The communities in natural resource areas would be stake-holders in the FGBs. They can then provide active support not only to prevent genetic erosion in those areas, but can add new genetic stocks as and when they discover them. FGBs serve the cause of both conservation and continuous evolution through selection, recombination and mutation.

Several FGBs can be linked to an ASB taking into account factors like distance, communicability, conservation space and the like. There could be 2 to 3 seed banks in a district. The ASB will help to strengthen coping mechanisms for facing the problem of seed scarcity caused by drought-induced crop failures. The ASB would be managed by a committee of the stakeholders. Logically this committee can monitor IPR issues such as prior informed consent and benefit sharing. One or more ASBs will be linked to the CGB. The CGB would hold *ex situ* the seed stocks of landraces, etc., along with herbarium sheets and other information needed to get the primary conservers reward and recognition under the proposed Indian Act for Plant Variety Protection and Farmers' Rights. The CGB could deposit duplicate sets of accessions in the National Gene Bank (NGB) of the National Bureau of Plant Genetic Resources at New Delhi.

The operational efficiency, low transaction costs and conservation potential of such a network will encourage their replication and implementation at the state and national levels. Thus, an effective integrated national gene management system can be built up.

The CGMS is being introduced in three predominantly tribal districts of Orissa, namely Koraput, Khandamal and Kalahandi. The Koraput district is a primary center of origin (particularly of the *aus* ecotype) of rice. Though genetic variability in rice has been well chronicled, there is a need to purify the seeds of landraces, multiply and evaluate them as they are direct and indirect sources of valuable genes.

Among the millets, finger millet (*Eleusine coracana*) has been popular as a tribal crop for use as staple. *Sorghum* is another crop generally grown by the tribal families in their backyards and the grains are used as 'pop' sorghum. The rich variability in 'pop' sorghum needs to be conserved and used sustainably. Among the pulses, (i.e. grain legumes), perennial types of *Cajanus cajan* are widely cultivated. They are well adapted to rainfed condition and poor soils.

The Khandamal district is located in the central Kalahandi in the south-western and Koraput in the southern region of Orissa. These tribal districts have been chosen for fostering the growth of the first community-centered Integrated Gene Management System in India.

Science and society – A new social contract: The primary partners in this project are the economically and socially underprivileged tribal women and men. In addition to the revitalization of the traditional conservation ethic of local communities, such a system will help to implement the conservation and equitable sharing provisions of the Convention on Biological Diversity (CBD, particularly articles 8 and 15). The CGMS provides an opportunity for fostering symbiotic partnerships between rural/tribal women and men and scientists in areas like participatory breeding and the development of new varieties adapted to local conditions using novel genetic combinations provided by genetic enhancement centers.

Alien species invasion

Alien invasive species are posing a serious threat to biodiversity conservation worldwide. Such species include introduced weeds, invertebrate and vertebrate pests and plant and animal diseases. The growing volume of trade and new trade routes are increasing the prospects for the unconscious introduction of alien invasive species. The problem is particularly serious in developing countries due to inadequate quarantine arrangements. The existing sanitary and phytosanitary measures are proving to be insufficient to eliminate the risk of introduction of invasive species through food grain shipments by 'Aid agencies', as well as through trade in horticultural and agricultural products and animal pets.

Article 8(h) of CBD calls upon the parties to the Convention to 'prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species'.

The water hyacinth, which is a native of the Amazonian region, and which has now spread worldwide, is a good example of an aggressive alien invasive species. In many countries, thick mats of water hyacinth impede navigation, fisheries, displace native aquatic flora and fauna, and interfere with irrigation, dams and hydroelectric power generation.

The north-eastern region of India is classified as a mega-biodiversity area. Unfortunately, this region has also become a 'hot spot' area with reference to threats to biodiversity. The region is characterized by the continued prevalence of shifting cultivation leading to the depletion of forest resources. Alien invasive species like *Eupatorium*, *Mekenia* and *Lantana* have spread fast in the post-shifting cultivation areas. Unique mammals like *Mithun* are now finding it difficult to get adequate food, since the alien species are non-edible. This is one of the causes for the dwindling population of *Mithun*.

Every country, as proposed under Article 8(h) of CBD should develop a strategy for the prevention, control and ultimate eradication of alien invasive species. Biological control and where feasible, finding economic uses for such species, will help in managing the menace posed by such species.

This is also an area where the opportunities provided by recombinant DNA technologies may help. The possibility of causing seed abortion through approaches popularly christened as 'terminator mechanism' could be explored in the case of species such as *Parthenium* which also cause human health problems like dermatitis. Since such research may not be of interest to private sector R&D institutions, research on the control of alien invasive species through genetic modification techniques will have to be supported from public funds.

Genetic homogeneity

Genetic homogeneity associated with mono-cropping and modern agriculture leads to the replacement of large numbers of local varieties with a few high yielding strains. The dangerous consequences of covering large contiguous areas with one or two genetic strains are now well known. Varietal diversification and crop rotations involving crops with non-overlapping pest sensitivity are important for sustainable agriculture. The transition from 'green revolution' to an 'ever-green revolution' involves the substitution of a commodity-centered approach to a farming systems approach. The farming systems approach involves the adoption of mixed farming (crop–livestock–fish) methodologies, based on an integrated natural resources conservation strategy. Participatory breeding including the use of novel genetic combinations arising from genomics and molecular breeding will help to combine advances in yield and quality with location-specific adaptation.

In most developing countries, particularly in India and China which have fifty per cent of the global farming population, continuous advances in farm productivity per units of land, water and energy are essential for sustainable food security. Hence, there is need for developing and disseminating ecotechnologies, based on appropriate blends of traditional wisdom and technologies with bio-, information, space and renewable energy technologies. The ecological prudence of the past and the fruits of contemporary innovation can then be combined in a symbiotic manner.

With the growing privatization of plant breeding and expansion of proprietary science, it is important that *an ecologically, economically and socially sustainable farming systems policy* is developed for each agro-ecosystem. Such a policy will have to be developed jointly by farming families, official extension agencies and private sector companies. Unilateral introduction in large areas of one or two genetically modified strains of important food crops could cause irreparable harm in a few years' time both to food security and technological credibility. The pathway to an ever-green revolution on the farm is the adoption of integrated natural resource and gene management strategies.

Summary and conclusions

Biodiversity management: Transition from social exclusion to inclusion

The threats to biodiversity arising from habitat destruction, alien species invasion and genetic homogeneity are increasing worldwide. While on the one hand, species extinction is taking place unabated, the realization that national and global food, health, livelihood and environmental security systems depend upon the conservation of biodiversity is also growing. Genomics and molecular breeding have opened up uncommon opportunities for creating novel genetic combinations which can help humankind to face new challenges arising from population increase and potential adverse changes in temperature, precipitation, ultraviolet-B radiation and sea level. A time has come when further analyses of the causes of biodiversity loss alone are not enough. Effective and implementable methods of stopping further genetic erosion and fostering the rehabilitation of degraded ecosystems in megabiodiversity regions are the need of the hour. The remedial action which needs to be taken will have to be different in the following three methodologies of conservation.

- *In situ conservation through a national grid of protected areas*

In this system of conservation, the following paradigm shift in management systems will be needed to ensure the achievement of goals for which the protected area networks exist.

Participatory management of forests and habitats rich in biodiversity: Participatory systems of forest management involving both the forest dwellers and forest-dependent communities, and the government forest and wildlife departments will have to be fostered. Unless the livelihood security of local communities and the ecological security of protected areas are linked symbiotically, conservation will be a lost cause under conditions of poverty and deprivation. Local communities should have access to non-wood forest products, so that they develop an economic stake in the conservation of the forests.

Biosphere trusts: Unique biosphere areas should be managed in a manner that all the stakeholders hold the Biosphere *in trust* for the generations yet to be born. Management of the biosphere in a trusteeship mode will result in every group of stakeholders understanding their rights and responsibilities.

Harmonizing conservation and commercialization: Commercialization can become an important instrument of conservation, if commercial companies, such as pharmaceutical firms, will help rural and tribal families to cultivate on contract rare medicinal plants. This will help them to source the raw material they need, without directly exploiting plants growing in forest canopies. Many important medicinal plants are now in the *Red Data Books* of several developing countries due to the unsustainable exploitation of such plants from the wild. Domestication of economically valuable *Red Data Book* species will help the cause of conservation, while at the same time meeting the needs of the commercial user.

- *Ex situ* conservation

The management of Gene Banks, Botanical and Zoological Gardens and other *ex situ* conservation centers should be restructured so as to include the equity and ethics principles enshrined in the CBD. Provisions for prior informed consent and equity in benefit sharing should be incorporated in voluntary codes of conduct. Gene Bank Managers should ensure that the accessions maintained by them for public good research are not used in a monopolistic manner. Material and Knowledge Transfer Agreements should form the basis for the supply of the material and knowledge gathered from the primary conservers of genetic resources and holders of traditional wisdom.

- Community conservation

Urgent steps are needed, particularly in countries in which centers of diversity/origin of economic plants occur, for the revitalization of the *in situ* on-farm and *ex situ* on-farm conservation traditions of tribal and rural families. No further time should be lost in introducing a recognition and reward system for giving social prestige to the conservation ethics of farming and rural families. Since such recognition will be for entire communities and not individuals, community systems of recognition and reward should be developed. These should be accorded legal status through *sui generis* systems of Plant Variety Protection and Farmers' Rights. Community Gene Funds based on a cess on all agricultural produce can be established for rewarding communities who, through *in situ* on-farm conservation, have helped to maintain rich intra-specific variability in economic plants. Also, a CGMS comprising of FGBs, ASBs and CGB could be organized.

Alien species invasion

With increasing liberalization of trade in food grains and other agricultural commodities, the threat posed by alien species invasion to native biodiversity is increasing. A global strategy for the control of such invasion comprising the following collaborative steps is urgently needed.

- Improving sanitary and phytosanitary measures
- Introducing effective methods of biological control
- Finding economic uses for the invasive species, so that local communities can participate in their removal
- Mobilizing the new tools of genetic engineering to render such aggressive weeds sterile and thereby incapable of sexual propagation.

An integrated strategy for managing the problems created by alien species will help eliminate the threats to native terrestrial and aquatic biodiversity.

Genetic engineering research to introduce infertility in aggressive invasive species like *Parthenium*, *Mekenia*, *Eupatorium*, and *Lantana* will have to be supported from public funds, since such research will not attract the attention of commercial companies. If research priorities are entirely dictated by market opportunities, orphans will continue to remain orphans. Scientific progress will then have little meaning for the poor and the public.

Avoiding genetic homogeneity in farming systems

Since the time modern plant breeding started with the rediscovery of Mendel's laws of inheritance in 1900, it has been known that genetic homogeneity in crop plants enhances genetic vulnerability to pests and diseases. There is therefore apprehension among scientists about the potential adverse impact of growing GM varieties of crops like rice, wheat, maize, potato and soybean over large contiguous areas. Commercial biotechnology companies recommend a *refuge* area in conjunction with pest-resistant GM crops, in order to promote a resistance management strategy which will help to prevent the breakdown of pest resistance in the GM variety. Nevertheless, proprietary control of new strains may lead to a situation where the same genetic strain is widely grown.

Sustainable agriculture needs for its success a wide range of locally adapted varieties. Under the integrated gene management strategy, participatory breeding with farm families should be encouraged. Also, institutions working for public good should create novel genetic combinations under a well-designed pre-breeding programme and make such material available to grass root farmer breeders who could incorporate the novel genetic traits for resistance to biotic and abiotic stresses in locally adapted varieties. Thus, advanced molecular breeding techniques can be brought to the service of resource-poor farm families. In this manner, the techniques of pre-breeding and participatory breeding can be blended in a manner that the requirements of ecological, economic and social sustainability are concurrently satisfied.

Gender dimensions of biodiversity management

It is important that in all the above aspects of a community-centered integrated gene management strategy, gender roles in all aspects of genetic resources conservation, sustainable use and equitable sharing of benefits are given attention. Women in many developing countries are the primary seed selectors and savers. Their contributions to the evolution of a biodiversity conservation ethic should be fully recognized in any system which is designed to operationalize the equity in benefit sharing provisions of CBD.

If we promote worldwide a community-centered integrated gene management strategy, we will soon stop hearing about vanishing species and vanishing landscapes and habitats. None of the policies and procedures I have suggested is difficult to implement. What is needed is as much interest in preventing species extinction and biodiversity loss, as in the chronicling of threats and preparation of *Red Data Books*.

Today, Governments and the scientific community often play the dominant role in organizing and managing structured *in situ* and *ex situ* conservation measures. By recognizing that conservation efforts represent a continuum, with rural and tribal families performing a vital function in preserving precious genetic variability in important plants and farm animals, we will be able to attend to all the links in the conservation chain. Community conservation is a value-added link in the conservation system, since local families not only conserve but add value to the conserved material through selection and information.

Let me conclude with the hope that if the 20th century was a period of understanding and chronicling threats to biodiversity and bioresources both in land and water, the 21st century will be one where the threats are terminated and benefits harnessed for a better common present and future for humankind.

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