India's biodiversity: Tasks ahead

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Biodiversity can be defined as species-richness (plants, animals and micro-organisms) occurring as an interacting system in a given habitat. The problem of biodiversity is essentially one of conflict resolution between the human-kind on the one side, and living organisms occurring on land, in freshwater bodies and marine environment on the other. The UNCED process helped to place the loss of biodiversity and its conservation on the global agenda, resulting in biodiversity becoming a household word.

There are two main functions of biodiversity. Firstly, on it depends the stability of the biosphere, which in turn leads to stability in climate, water, soil, chemistry of air, and overall health of the biosphere. Secondly, biodiversity is the source of species on which human race depends for food, fodder, fuel, fibre, shelter, medicine, etc. These, by and large, exist in the 12 Vavilovian Centres of Diversity[1]. Biodiversity is not only an important resource but also a strength of developing countries.

Biodiversity exists on earth in eight broad realms with 193 biogeographical provinces. Each biogeographical province is composed of ecosystems, which are constituted by communities of living species existing in an ecological region[2].

The developing countries, located in subtropical/tropical belt, are far richer in biodiversity than the industrial countries in the temperate region. The Vavilovian Centres of Diversity of crops and domesticated animals are also located in the developing countries.

Biodiversity is an irreplaceable resource: its extinction is forever. At present there is no way to recreate extinct plants and animals, notwithstanding what is presented in the breath-taking Spielbergian spectacle 'Jurassic Park'. Having become a buzz word, there is considerable myth and illiteracy associated with biodiversity. There is not only a need to formulate meaningful programmes for its conservation and sustainable utilization, but also to demystify this subject and make people knowledgeable about its tremendous implication for human survival. The conservation and sustainable utilization of this resource has to be central to all developmental planning in most developing countries, because economy in most of these countries is dependent on agriculture, horticulture, animal husbandry, fisheries, forestry, medicinals and the likes of these. The genes from wild ancestors of crops endemic to developing countries have made distinctive contribution in crop improvement, with considerable gain to the growers. Such examples have been listed by Witt[3], Khoshoo[4] and FAO[5]. The contribution of such genes has been considerable, which has made a difference, for the better, both in social and economic terms.

Biowealth: India's strength

India has a position in between developing and industrial countries: it is developed among the former, but developing among the latter. It is rich in biodiversity as relevant both to the health of biosphere in general and to agriculture, animal husbandry, fisheries, forestry and pharmaceutical industry in particular. It is backed by equally rich cultural diversity and indigenous systems of medicine, and knowledge and wisdom of the indigenous people, and is supported by a reasonably strong scientific and technological base. Biodiversity is indeed one of India's important strengths and is the bedrock of all bioindustrial development in the unusually large rural sector (5,76,000 villages with 76% of the country's population) of the country. However, the real value of biodiversity lies in the information that is encoded in the genes and molecules.

India has over 1,08,276 species of bacteria, fungi, plants and animals already identified and described (Table 1).

Out of these, over 84% species constitute fungi (21.2%), flowering plants (13 9%) and insects (49.3%). In terms of the number of species, the insects alone constitute nearly half of the biodiversity in India (Figure 1).

These species occur on land and in fresh water and marine habitats, or occur as symbionts in mutualistic or parasitic state with other organisms. In the world as a whole, 16,04,000 species of Monera, Protista, Fungi, Plantae and Animalia have been described so far. However, it is estimated that at least 179,80,000 species exist in the world, but, as a working figure, 122,50,000 species are considered to be a near-reality[6].

Based on the data on the already described species, India is tenth among the plant-rich countries of the world, fourth among the Asian countries (old USSR included), eleventh as far as number of endemic species of higher vertebrates (amphibia, birds and mammals), and tenth in the world as far as richness in mammals is concerned. Out of the 18 'hotspots' identified in the world, India has two: these are Eastern Himalaya and Western Ghats. The two areas contain 5332 endemic species of higher plants (3500 plus 1600 species, respectively), mammals, reptiles, amphibia and butterflies[6].

In addition, the country is a very important Vavilovian Centre of Diversity and Origin of over 167 important cultivated plant species and some domesticated animals. To name a few, the following crops arose in India and spread throughout the world: rice, sugarcane, Asiatic vignas, jute, mango, citrus, banana, several species of millets, spices, medicinals, aromatics and ornamentals, etc. India ranks sixth among the centres of diversity and origin as far as agri-biodiversity is concerned[1].

A large number of institutions in India are involved in conservation and utilization of biodiversity. These fall under Ministry of Environment and Forests (Botanical and Zoological Surveys, Wildlife Institute of India, G. B. Pant Institute of Himalayan Environment and Development), Ministry of Agriculture (several institutes under Indian Council of Agricultural Research), and Ministry of Science and Technology (several institutes under Council of Scientific and Industrial Research). Between them, these three ministries are dealing with *in situ* conservation (biosphere reserves, national parks, wildlife sanctuaries), *ex situ* conservation (field gene banks, seed

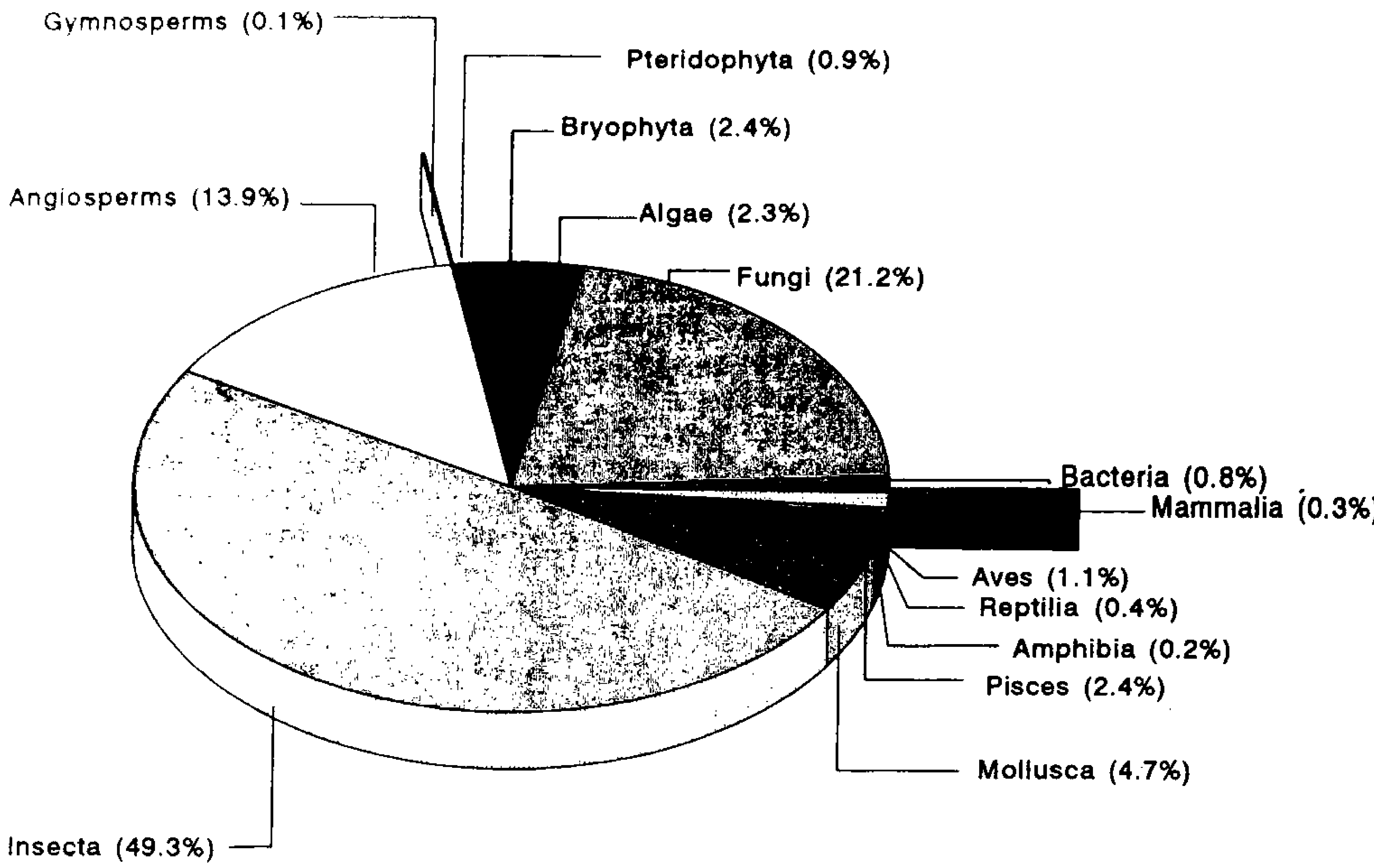

Figure 1. Diagram showing percentage of different biota in India. Source; BS1 and ZS1, 1994 (see also Khoshoo, 1990).

Table 1. Number of species of bacteria, fungi, plants and animals

Taxon	Number of species	Percentage
Bacteria	850	0.8
Fungi	23,000	21.2
Algae	2,500	2.3
Bryophyta	2,564	2.4
Pteridophyta	1,022	0.9
Gymnosperms	64	0.1
Angiosperms	15,000	13.9
Insecta	53,430	49.3
Mollusca	5,050	4.7
Pisces	2,546	2.4
Amphibia	204	0.2
Reptilia	446	0.4
Aves	1,228	1.1
Mammalia	372	0.3
Total	1,08,276	100.00

Source: BSI and ZSI, 1994 (see also Khoshoo, 1990).

and other banks), and utilization (gene and drug prospecting), respectively. India is indeed uniquely placed as far as its biodiversity is concerned. But the country can no longer continue with tiger–bird–wildlife syndrome. These are important in their own right but are a miniscule part of the large spectrum that is now encompassed under biodiversity.

In most of the developing countries, biodiversity is generally attached as a frill to environment and forestry agencies, which have no experience in product development from biodiversity. Furthermore, developing countries have yet to comprehend the vast social, economic, scientific, technological, ecological and political potential of biodiversity. If this continues, these countries are likely to be left out in the race to conserve and sustainably utilize their rich biodiversity for the well-being of their people and the world at large. On account of concealed compulsions of the industrial countries, the developing countries may end up in exporting biodiversity as was done in the colonial times. The result would be disastrous.

Often, those responsible for conservation of biodiversity have no idea whatsoever about the work of those who are engaged in utilization, and vice versa. However, policy makers have to realize that conservation and sustainable utilization of biodiversity has to be central to all development planning in most developing countries because most of these countries are predominantly agricultural. There has to be a national commitment on this account. And, therefore, there is also an urgent need for coordination between various ministries, organizations and institutes working on different facets of biodiversity.

The recent agreement between INBio (Institute of Biodiversity in Costa Rica) and Merck (USA) is hailed throughout the industrial world as a landmark event. Under this agreement, extracts from wild plants, insects and microorganisms from Costa Rica are supplied for drug screening programmes to Merck (USA). In return, INBio has received from Merck over 1.35 million US dollars, and expects royalties on the commercial products that may emanate from this work. INBio is to contribute 10% of the budget and 50% of royalty to the Government of Costa Rica for its National Parks Service. Merck has also offered to provide technical assistance and training to help establish a drug research capability in Costa Rica. The Government of Costa Rica has given to INBio non-exclusive rights to bio-prospect. In brief, INBio represents an alliance between biologists/biochemists and businessmen[7].

Costa Rica has over 84,500 species of plants and animals in 51,000 square kilometer area. This number is more than what is found in Canada and USA combined[7]. It may be emphasized that, unlike India and some other developing countries, Costa Rica is not a Centre of Diversity and Origin of any cultivated plant or domesticated animal. There are also no indigenous people in Costa Rica, who normally are an important storehouse of knowledge and wisdom on plants and animals.

Pharmaceutical industry in the industrial countries is a very influential industry, and it has gone all out to publicize and, what is important, eulogize in press and over TV and radio the INBio–Merck approach. There is a growing feeling that this industry is attempting to influence public opinion in biodiversity-rich but technology-poor developing countries in tropics and subtropics of the world. Perhaps, the underlying idea may be to make these countries to follow the Costa Rican approach. Some developing countries are already on their way to doing so.

However, a visit to INBio convinces any one that, in its present form, it is something of a 'clearing house' rather than an R&D institute of any significance. The only programme they have is to inventorize the Costa Rican biodiversity. In the past also such work has been done by American biologists. One only hopes that INBio will grow scientifically and technologically so as to be able to take up such work independently.

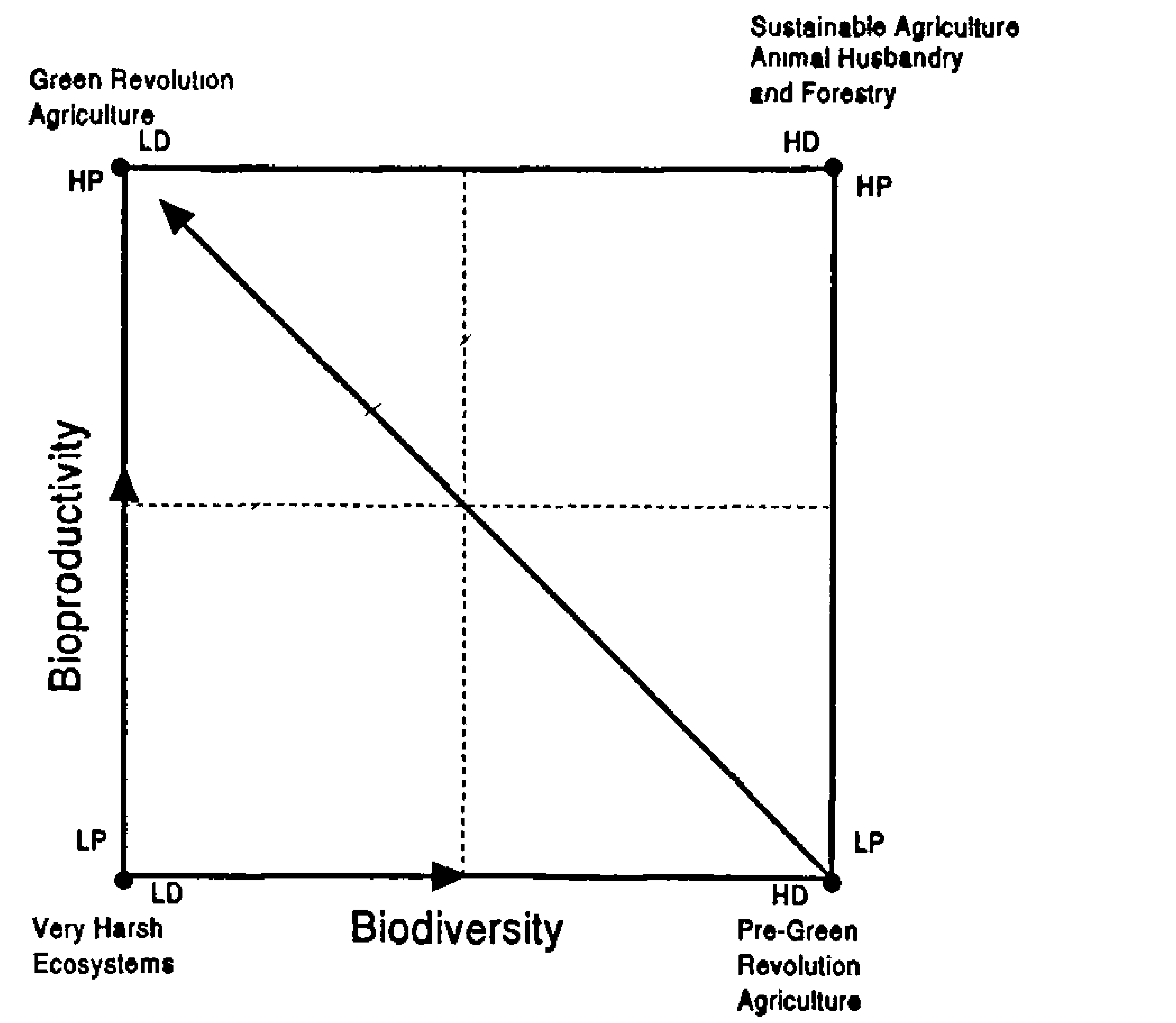

Figure 2. Relationship between biodiversity and bioproductivity.

Not so strong biotechnology: India's weakness

There are no two opinions about biodiversity being one of the very important assets of the developing countries. In fact, in 1930s, when the world was largely asleep, N. I. Vavilov of USSR was wide awake. His monumental studies showed that there have been some major centres of diversity and origin of crop plants and domesticated animals. Most of these centres fall in tropical–subtropical–hot-temperate belt, where most developing countries are located[8]. It is indeed ironical that while developing countries have given to the world all agri-biodiversity, they themselves have been areas of low productivity and high population density. This belt has also been the traditional 'hunger belt'. The industrial countries, by making use of the science of genetics and breeding, raised the productivity. A perusal of Figure 2 shows that low biodiversity and low bioproductivity have been prevalent in harsh ecosystems. Underlying the pre-Green-Revolution agriculture was high diversity and low bioproductivity. The world agriculture then moved to high productivity accompanied by low diversity and the result was Green Revolution. Today, we do realize that Green Revolution has paid its dividends and in many developing countries acute hunger is no longer a reality. However, it has not entirely been ecologically friendly. Green Revolution has also helped the developing countries to feed themselves and not go around with a begging bowl for food. Thus, it has also been a question of balancing immediate economic and social gain and a largely manageable level of environmental degradation and pollution. Among other things, sustainability in agriculture, animal husbandry, fisheries and forestry will depend on the ability to combine high productivity with high diversity. Agriculture all over the world has to move towards such a broad goal. Therefore, what is required is the clarity of vision regarding the relationship between biodiversity, bioproductivity and biotechnology.

Although the 'gene and drug rush' is inevitable, it should not take place in a policy vacuum. The central issue is that formulation of policy in gene-rich/technology-poor (or deficient) countries is necessary in order to avoid what could result in 'gene imperialism'. The INBio experience, if implemented without thought and care, could prove to be the thin end of the wedge. Therefore, each country must ensure that such agreements do not hurt conservation, sustainable utilization, development and equity in biodiversity. Biotechnology is inherently knowledge-intensive and having good biotech infrastructure would lead to value addition to the products from biodiversity in the general area of agriculture, animal husbandry, fisheries, forestry and medicine.

At the same time, the institutional structure that controls biotechnology should not overshadow those institutions that deal with conservation of biodiversity, and on no account should ignore the rights and privileges of the local communities. While the former involves upstream science and technology, the conservation area is largely languishing even for simple and time-tested scientific and technological inputs.

Technology transfer in biotechnology requires a certain minimum amount of technical and legal capability, which most developing countries lack at present. Therefore, considerable competence and skill are needed in the whole range of subjects starting with taxonomy, genetics, plant breeding, molecular biology, microbiology, biochemistry, fermentation technology, biochemical and process engineering, economics, law and, last but not the least, training of local communities in modern conservation skills is also a must. Furthermore, if the scientific and technological efforts in conservation and sustainable utilization are not properly focused, failure to achieve tangible results is a certainty. For promotion of biodiversity conservation and sustainable utilization, all developing countries must not only take to capacity building but also work towards innovation, acquisition and adaptation of relevant biotechnologies, legal aspects, trade secrets, intellectual property rights (IPRs), patents, petty patents, and plant breeders' and farmers' rights. This has to be supported by a proper economic and political climate, and proper balancing between those who conserve and those who use biodiversity. Thus, the right kind of technologies are needed to harvest returns from agriculture and drug industry. At the same time, there is a need to empower local people to conserve and use biodiversity and participate in management. The whole exercise has to be done objectively and not in an ecofundamentalist manner.

While a whole range of revised laws on protected areas, wild life, land use, forestry, water, mining, grazing, etc., promote conservation of biodiversity, they do not promote their sustainable utilization. Thus, there is a need for an all-encompassing law on biodiversity that should take into account its deep interconnection with biotechnology and remove all inadequacies. This would be one tangible step towards sustainable bioprospecting.

The relationship between biodiversity and biotechnology is depicted in Figure 3. The countries of the world can be divided into four groups: (a) biodiversity-poor and biotechnology-poor; (b) biodiversity-poor but biotechnology-rich; (c) biodiversity-rich but biotechnology-poor; and (d) biodiversity-rich and biotechnology-rich. To the first group belong countries in the Middle East (e.g. Saudi Arabia), to the second group belong USA, Japan, Germany, France, Sweden and UK; the third group comprises southern countries like Indonesia, India, China, Malaysia, Brazil, Mexico and others in the tropical/subtropical belt, and there is no country which falls in the fourth group. At present there is a flow of biodiversity from the third group (South) to the second group (North). The extent and nature of flow of biotechnology from North to South is not commensurate with the flow of biodiversity from South to North. This is an unequal exchange and will remain so till such time as countries of the South become self-reliant in biotechnology. An important factor underlying this exchange is that while some countries (like India and China) do have the capability to enter the fourth group (rich both in biodiversity and biotechnology), the countries of North can never make it to the fourth group in the real sense of the word. The reason is that they do not have any worthwhile agri-biodiversity growing naturally, although they do have excellent *ex situ* facilities in the form of field gene banks, seed and other banks. The latter do not have the advantage of long-range ecological processes and organic evolution that operate under natural conditions and constantly refine and update biodiversity through mutation, recombination and natural selection. These are the three cardinal elements of organic evolution In essence, biodiversity stored in industrial countries is in the form of 'gene morgues', because advantages conferred by exposure to the process of natural selection are not available. In contrast to *in situ* conditions, organic evolution is virtually at a standstill or halted under *ex situ* conditions Therefore, in all biobanks, germplasm is *preserved* and not conserved in space and time. However, both *in situ* and *ex situ* conservation are necessary to complement and supplement each other.

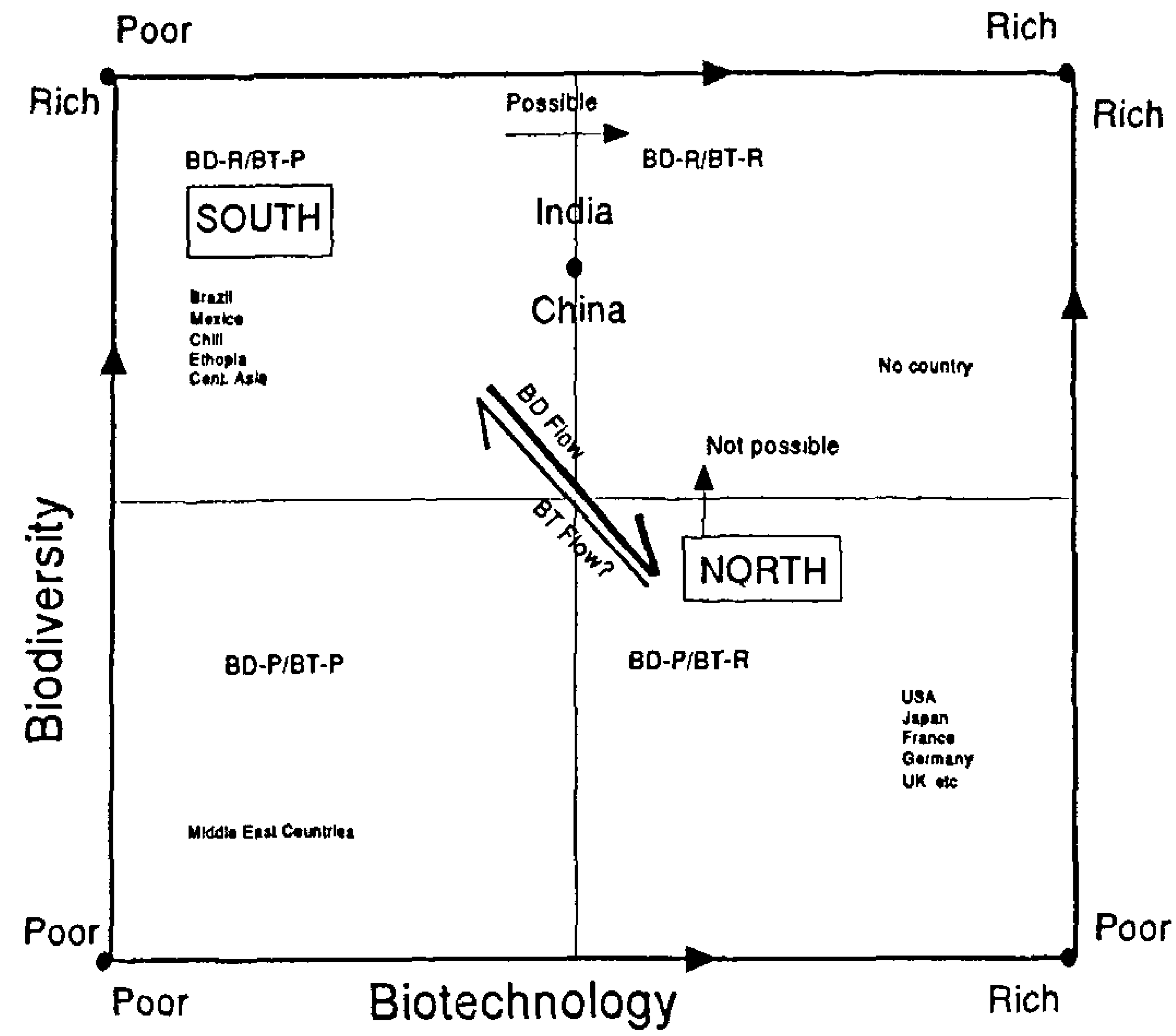

Figure 3. Relationship between biotechnology and biodiversity.

Gene-rich/technology-poor developing countries must, therefore, come together and reach an understanding regarding the various aspects, including scientific and technological, economic, social, cultural and legal issues, and collection, supply and costing of the raw material of biodiversity. Today the cost of biodiversity is the cost of collection and travel involved If these countries remain divided (as they are today) regarding their stand on prospecting for new genes and drugs and IPR, and compete among themselves, even the type of benefits that INBio has been able to get from Merck (USA) will no longer be forthcoming.

It is, therefore, imperative that a multilateral mechanism is created. One step towards this may be the placing of this matter on the Agenda of the G-15 countries, where other gene-rich/technology-poor developing countries are also invited, or the G-15 is itself appropriately widened to include such countries. The joint group must explore the possibility of working out a multilateral agreement like the OPEC (Organization of Petroleum Exporting Countries). In such a venture, teething troubles are inevitable, particularly because, unlike oil, genes are still to be recognized as strategic materials. Past experience with biologicals like rubber, coffee, cocoa, tea, palm oil and jute is not encouraging. The time for such a multilateral mechanism is most appropriate because of the tremendous global upsurge of interest in natural products and vegetarianism. Industry would be ready to make investments in this area because gene and drug screening technology itself has reached a level of perfection.

The extent and nature of capability in biotechnology will determine the capability of the country to conserve and sustainably utilize biodiversity. Conservation no longer means simply building a fence around an area, but involves considerable amount of upstream biotechnology. The longer a country takes to make such a transition, the farther the country would be from reaping the harvest from its rich biodiversity.

Intellectual property rights (IPRs)

The threat of 'Star Wars' has receded perhaps for good, thanks to the international developments during the last few years Open markets have taken over and are filling the void. Today, the threat of 'Seed Wars' is indeed real. A scramble for prospecting for new genes for biotechnology and biomolecules for drug industry has begun. In this process legitimate traditional rights of farmers and indigenous people could be jeopardized. One only hopes that it does not lead to 'gene/drug imperialism' and end in developing countries exporting biodiversity to industrial countries and in return importing products from them, a situation reminiscent of the colonial times.

Under IPRs, transformed microorganisms, plants and animals can be patented and become exclusive private property. Such organisms are the result of genetic engineering. In this regard the developing countries need a strong infusion of modern biotechnology and considerable capacity building in this area.

The declared objective of USA is the adoption of a uniform and strong IPR law throughout the world. In the absence of a proper biotech base, a developing country cannot match an industrial country although the former may be far richer in biodiversity. The Convention on Biodiversity has helped to place IPRs on the top of the agenda of policy and decision makers. Furthermore, access to genetic resources and transfer of biotechnology are treated on the same plane. Thus, an element of reciprocity has been introduced. However, it remains to be seen if, in lieu of the transfer of biodiversity from the developing countries, there would be transfer of biotechnology from the industrial countries. The world is moving towards prospecting of biodiversity, and the developing countries have to ensure that there is sustainability in extraction of the same, because loss of biodiversity is forever.

As of today, IPRs and patenting are inequitable. They help the rich and not the poor, the industrial and not the developing countries, and the sophisticated and not those who possess traditional/indigenous knowledge and wisdom. Such an imbalance has to be corrected so as to make IPRs more equitable and conservation-oriented.

One good thing about IPRs is that it would stimulate R&D and acquisition of biotechnology. A country with a strong biotechnology capability can be more self-reliant and be in a strong position to bargain and negotiate royalties. The prerequisite for this is an R&D infrastructure of the right kind. Countries such as Japan, Germany, Sweden, France, USA and even UK, with no worthwhile biodiversity, are today dominating the IPRs issue because they already have excellent biotech capability.

There are two categories of materials involved. The first includes all the wild relatives of cultivated plants and domesticated animals, ancestral species, land races and traditional varieties, which, more often, have low productivity but high diversity. These constitute the raw and unimproved genetic pool, which is critical to the future needs and aspirations of the human race. One marvels at the ingenuity and innovativeness of our remote ancestors, who picked up the right kinds of wild grasses and other grains, legumes, tubers, vegetables, fruits, fibres, medicinals, fish, cattle, sheep, goat, horse, donkey, etc., and made productive cultivated plants and domesticated animals out the same. Thereafter, there have been no new additions of crops or domestic animals but there has been considerable improvement in their production and productivity. Similarly, many pharmaceutical plants and products were first discovered by the indigenous people after large-scale trial-and-error experiments and intensive observation. All these are not ordinary intellectual achievements and innovations, but these have never been rewarded or paid for. However, everyone today takes these for granted and wants to grab all such materials together with the local technical knowledge and wisdom built around such a solid foundation. This is done only to reap the benefits for themselves.

The second group of materials is the improved and high-yielding cultivars produced by geneticists and breeders for commercial purposes, and the chemicals isolated, refined, tested and commercialized by pharmaceutical companies. Underlying this is hard sciences of genetics, breeding, pharmaceutics and upstream biotechnology.

The first group is regarded as an ownerless resource and a common heritage of the humankind, and is non-patentable, while the second group is patentable, along with plant breeder's rights, trade secrets, IPRs and what not. The first group has been treated as public property and has never been rewarded. The second group is treated as private property and is rewarded and awarded. Is this justifiable?

There is, therefore, an urgent need for a special multidisciplinary institutional mechanism for attending to IPRs more objectively and more aggressively. This has to take cognizance of the prevailing national and international situations and, above all, enlightened self-interest of the country The country has to be objective and cannot afford to be puritanical about these issues.

Need for a coordinating mechanism

The age of an ecosystem harbouring biodiversity is at least 100 years plus. Who will provide a long-range unbiased perspective on biodiversity for decision making? It has to be a think-tank of hard-core informed scientists, technologists, economists, legal experts, sociologists and other professionals.

There is a need for a coordinating body which would advise on conservation and sustainable utilization of biodiversity, which at present is the responsibility of different ministries, organizations and institutes. Such a body should also see the entire spectrum of *in situ* and *ex situ* conservation from genes/molecules to ecosystems as a continuum. In other words, such a body must treat the work of botanic gardens/arboreta, zoos/zoological parks, aquaria, herbaria, musea, the whole range of field gene banks and seed and other banks, and protected areas as a single network. Such a grid has to be properly orchestrated for the good of the country. In addition, it should organize research and development, and teaching, training, demonstration and extension programmes on different aspects of biodiversity, including its economic evaluation[9,10].

Any plan on management of biodiversity must take into account the whole spectrum of issues ranging from tenurial security of the protected areas network (on land, lake and marine locations), conservation of biota, rights and privileges of the indigenous people (who have the traditional knowledge), biotechnological aspects of IPRs and many other scientific and technological, social and economic, and legal and political aspects. Many of these issues may seem to be having competing interests, and need to be balanced nationally as also internationally to the best long-term interest of the country.

At present the Wildlife Boards in many countries (including India) oversee the conservation of biodiversity. For all practical purposes these boards are defunct and have lost their legitimacy because, in contrast to wildlife, the concept of biodiversity is all-encompassing. There is an urgent need to have some coordinating structure to look into the planning on a holistic basis of scientific, technical, social, economic, legal, political and international dimensions of biodiversity. The present author advocates constitution of a National Biodiversity Conservation Board in place of Wildlife Board in order to measure up to the modern challenges and responsibilities.

There are some basic questions that need to be answered in-depth, taking into account the contemporary global thinking and developments in the area of biodiversity, together with their relevance to the developing countries so that these are in their best interest. In this connection it may be pointed out that it would be most appropriate if the countries do not take to an ecofundamentalist approach Some of the important questions are listed below.

Who should own the biodiversity of a country? Is it a public or a private resource? Can one own natural genes and biomolecules and have exclusive rights on these? Should bioprospecting for genes and drug molecules and their utilization be a public and/or private industry? What should be broadly the contours of the policy on conservation and sustainable utilization of biodiversity? How should the stake of local and indigenous people be strengthened in conservation? How does the country use biodiversity to take pro-active action to mitigate the adverse effects of the possible global climatic changes? How should biodiversity be valued in fiscal terms, and what should be the mechanism for collection and sale (including pricing) of material for scientific research and commercial purposes? What should be the stand of the country on IPRs, which in simple terms means private ownership, and can IPRs apply to wild habitats, species and products of nature? Should discoveries and innovations in biodiversity be patented? Is it possible to promote equity under IPRs between those who possess the long-standing indigenous knowledge and those who innovate in the future? How should the indigenous knowledge and wisdom be compensated because considerable innovation has gone into it over the years? What should be the role of the government in any agreement on biodiversity driven by market forces? Should private industry (seed or drug companies) interested in gene and drug prospecting be asked to help in conservation? How is a country's technology policy (including biotechnology) conducive to biodiversity conservation and sustainable utilization?

There has to be a debate (not an endless one) on these questions, where enlightened self-interest of the country is placed at the top. Only when the country is clear about the stand it should take on the foregoing questions, comprehensive policy framework, strategy and a total management plan on biodiversity could be prepared. This should cover the whole spectrum of activities, from collection regimes to the end use, and from basic science and technology to product development.

The final point

The nations of the world are increasingly moving towards a situation where they can bargain. A country like India needs tools and strength to bargain. In the area of biodiversity, the bargaining power is directly proportional to the strength in biotechnology. Imagine a situation if India had not taken up work in space and nuclear sciences and in missile technology! Surely, we would have been tossed from one end to the other. Let this not happen to biotechnology, for this science is critical not only for managing the use of biodiversity and for enhancing bioproductivity but, above all, also for the overall bioindustrial development of unusually large number of villages in our country. The choice is left to us.

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