WORKING PAPER 88/2014

PERSPECTIVES ON VALUATION OF BIODIVERSITY

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July 2014

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Price : Rs. 35

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Abstract

The economic value that biodiversity and ecosystems have is known to be very high. Despite this knowledge, we still find that there is large scale and significant loss of diversity of resources and ecosystems (CBD, 2010). This paper examines the economic significance of biological resources as relevant to various sectors, major drivers of loss of biodiversity and implications to human welfare. Through a case study approach of various methods used to value biological resources, the paper also shows that such methodologies get limited by information asymmetries, perceptional differences of different user groups and purposes for which valuations are undertaken. It also examines the various policy level initiatives that attempt to capture a true representation or 'value' of biodiversity. The paper concludes with a call for developing more nuanced and multidisciplinary approaches while developing valuation methods.

Keywords: *Economic valuation of biodiversity, stakeholder preferences, multistakeholder valuation, interdisciplinary approaches, biodiversity policy*

JEL Codes: *Q51; Q57*

ACKNOWLEDGMENT

I gratefully acknowledge the wonderful collegial opportunity provided by the Center of Excellence at the Madras School of Economics, through their visiting fellowship program, and would specially like to mention Dr Kavi Kumar, Dr. Zareena Begum, Dr. Paul Appasamy and Dr. U Shankar in this regard. I am also thankful to the different participants at the Seminar organized in relation to this paper for their inputs. Thanks are also due to my colleagues from the National Biodiversity Authority and the United Nations University-Institute of Advanced Studies (now Institute for the Advanced Study of Sustainability) for their co-operation and inputs.

INTRODUCTION

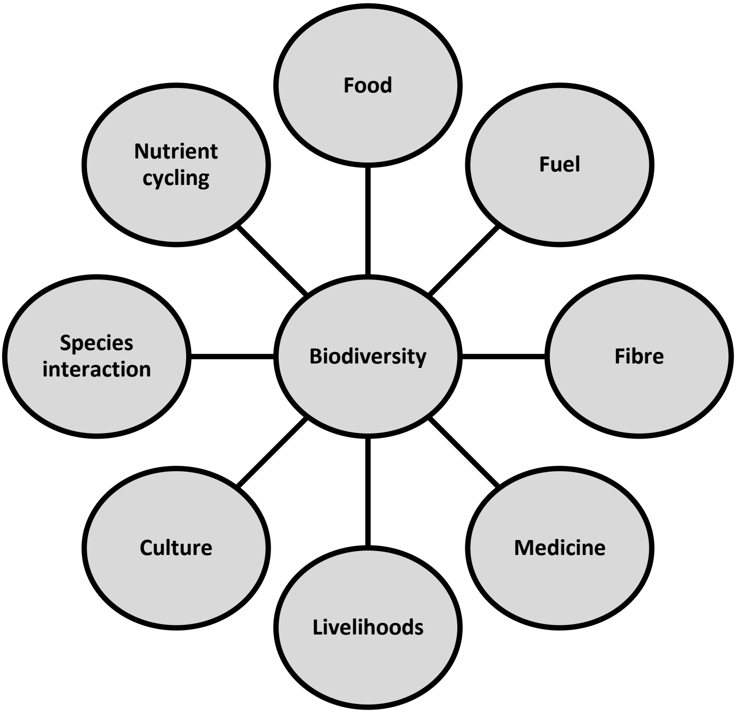
Biological or Bio-diversity refers to the "variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (CBD, 1992). Thus the remit of the term also encompasses the complex interlinkages and functionings within ecosystems that provide a basis for all productive human activities. Ecosystems in turn refer to " a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (Article 2 of CBD, 1992). They are exploited to meet various well-being needs, that may be of monetary economic significance or otherwise. The value of a biodiversity therefore is multidimensional and comprises of intrinsic, instrumental, monetary and non-monetary aspects. All these have a bearing on decisions made by individuals, societies and governments on using and conserving biodiversity and ecosystems.

This paper seeks to review various approaches used in valuing biodiversity and how these affect decision making. Each approach to valuation that is reviewed highlights a specific purpose that in turn determined the design of the study. In the next section, the paper highlights various concepts related to biodiversity, conceptualizations of the value of biodiversity and concludes highlighting how valuation exercises can influence decision making.

Ecosystem Services

The terms ecosystem services connotes an anthropocentric view of the various benefits (services) that humans receive from ecosystems. It is inherently economic in approach and provides a convenient categorization format that allows better articulation of trends in use and status of ecosystem services. Biodiversity is considered as a generator of ecosystem services (MA, 2005).

Figure 1: Schematic Representation of Various Benefits Obtained from Biodiversity



Source: Developed from the Millennium Ecosystem Assessment Report, 2005.

There are four broad categories of ecosystem services

- Provisioning: products obtained from ecosystem (Eg. food, fuel, fibre, medicine, genetic resources)
- Regulating: benefits from the regulation of ecosystem processes (Eg., air quality, climate, water, erosion, water purification, disease and pests, pollination, natural hazards)
- Cultural: non-material benefits (Eg., spiritual, aesthetic, knowledge, education, social relations, identity)
- Supporting: necessary for the production of all other ES (Eg., soil formation, nutrient and water cycling, photosynthesis)

Biodiversity is considered as a provider of ecosystem services, as the diversity of living forms and their inter-relationships give rise to a variety of benefits from within the ecosystems where they are found (Figure 1).

Regardless of the intrinsic values of biodiversity, maintenance of this diversity becomes crucial at least for the instrumental values human beings derive from them. As the Millennium Assessment Report and later the Global Biodiversity Outlook reports showed, we are losing this diversity at alarming rates and evidence points to anthropogenic factors as driving this loss (MA, 2005; SCBD, 2010). As the mainstream economic systems do not adhere to the idea of living in harmony with nature despite accepted notions of sustainable development, there is a clear need to demonstrate the *economic* value of biodiversity. This is what the concept of ecosystem services allows us to do.

Loss of Biodiversity and Consequences

A loss in diversity of biological resources affects the resilience of natural systems (Carpenter and Folke, 2006; UNEP, 2012). This means the capacity of the natural system to regain its functioning after a perturbance is negatively affected. Some consequences in terms of loss of human wellbeing, arising due to loss of biodiversity are mentioned in Table 1. A good example is the increase in forest fires in the Borneo islands due to draining of peat forests to undertake cultivation of rice (Suneetha *et. al.,* 2011a*).* The peat forests are valuable storehouses of carbon and are considered vital in playing a regulatory function of ecological processes. However with the Government of Indonesia's policy to convert part of the forests to rice farms under the million hectare rice project, the forests were drained off water for tillage. The land however became extremely dry and acted as a medium for fires to spread. Rockstrom *et. al.* (2009) identified that it was necessary to limit the loss of biodiversity to less than 10 extinctions per million species for humans to have a safe space (in addition to other components of what they termed as planetary boundaries).

Table 1: Some Consequences to Human Wellbeing in Terms of Loss in Ecosystem Services Due to Loss of Biodiversity

Services	Consequences
Provisioning	Food insecurities, lack of resources for healthcare, germplasm loss, low adaptation capacities
Regulating	Higher incidence of extreme events (floods, droughts, fires)
Supporting	Lower productivity of crops
Cultural	Loss of knowledge on use and management of biodiversity and ecosystems

Source: Adapted from Millennium Ecosystem Assessment, 2005.

Drivers of Biodiversity Loss

The OECD came up with the Pressure-State- Response model to explain changes to natural capital, such as ecosystems, biodiversity, etc. This was further modified to include Drivers-Pressures-Status-Impact – Responses (DPSIR) to understand the status of the condition of a natural asset, trends in its status, drivers and resulting pressures and their impacts on the resources. Some of the broad driving forces that affect biodiversity loss include.

- *Population growth and demand pulls*

  The most prominent cause identified is the rapid rise in the number of people, which increases pressure on various resources such as arable land, water, and various natural resources for food and various productive activities. The rates of extraction are often higher than the regenerative capacities of the resources, resulting in scarcities and quite often, irreplaceable loss (UNEP, 2012).

- *Homogenization of produce*

  Currently, people around the world consume only 15 major staples, 2/3 of which is constituted by rice, wheat and maize. This has vastly reduced the diversity of crops under cultivation (FAO, 1995).

Furthermore, the requirements of institutions such as standards set for agricultural products in trade (through the harmonization codes set under the World Trade Organization), have further narrowed the diversity of products that are produced for the markets. It is estimated that only eight crops are grown in almost three-quarters of the agricultural land in the United States of America.

- *Reduction in pluralistic approaches to primary production/ Unsustainable consumption and production processes*

  Traditionally, primary production was undertaken within a socio-ecological context. This means that while production was undertaken to meet social requirements, it was also done in line with ecological capacities. Over a period of time, with an over emphasis on total output and income as a measure of progress, countries have restructured their production systems toward commercial, high-input and more industrially oriented processes. In the process, there has been a loss of diversity in resources and introduction of new species in countries, cultivated for their commercial value and ultimately integrated as a staple with resultant reduction in native germplasm (Gu and Subramanian, 2012).

  Another trend that has been on the rise over the last few decades is the increasing propensity to waste resources. For instance, it is estimated that in the United Kingdom, around 25 percent of food that is fit for consumption is wasted (Lundquist *et. al.,* 2008). This results in loss of resources that go into the production process.

- *Policy drivers not sufficiently focused on ecological processes*

  National priorities to improve incomes have resulted in some misplaced policies that have had negative consequences both to the environment and human wellbeing. The conversion of large tracts of tropical forests to oil palm plantations in Malaysia and Indonesia is a good example (Fitzherbert *et. al.,* 2008).

- *Spread of invasive alien species*
  Economic loss due to spread of invasive alien species is a global concern. Spread of such species occurs either through natural processes or through introduction of exotic species in new lands where they take over the native population (UNEP, 2010).

Market Value of Biodiversity

The economics of natural resources has always been linked to international relations. The quest to control supply of biological resources is a historical one. For instance, the development of the trade routes of supply for spices or silk and the era of colonization were all linked to commercial use and control over a diversity of resources. Furthermore, such commercial use of bio-resources is still closely linked to the welfare of individuals and nations. Certainly there has been an increase in trade in different species with developments in transport and technology to process and extend the shelf life of biological products over extended periods of time.

Economic Implications for Different Stakeholders

Biological resources affect stakeholders at different levels in distinct ways. At the local level, it is linked to the livelihoods of proximate stakeholders including farmers, shamans (healers), collectors of non timber forest products and the like; can provide new economic opportunities and a basis for spurring entrepreneurship at the community level.

At the national level, it is linked to conservation goals , various development goals such as securing food security (that is dependent on germplasm availability, soil fertility and related ecosystem integrity parameters), health and energy security, equitable and broad based economic development, developments in Science and Technology and enabling securing national incomes.

At the international level, it is linked to global commodity chains, increased trade facilitation, innovations in different aspects of commerce, trade, value addition and mechanisms to support other countries (Aid).

Sectoral Distinctiveness

Sectoral variations are high with regards to costs related to development of bio-products, likely benefits generated per annum, life cycle of a product and the business process involved. In the biopharmaceutical sector, often used as a representative case for utilization of biological resources, the market value of the sector is around 430 billion USD over the life of a drug (considered to be around 20 years- the life of a patent). The costs involved in development of a drug also are high (1.2 billion USD average) (PhRMA, 2007) with a likelihood of success ranging from 1 in 10,000 to 1 in 50 or even less depending on the additional information obtained on use of a resource. Increasingly, the industry depends on a series of upstream developers to undertake different parts of the R&D related to drug development, referred to as shuttle development, to spread the costs and risks. A similar trend is also visible within the crop biotechnology sector.

However, in sectors such as the Nutraceuticals / Botanicals and the Cosmetics sector, costs of development can be contained within 10 million USD, while the life cycle of the product is around seven years. The industry depends on multiple suppliers of raw materials to develop specialized products based on prior evidence. Sectors such as ecotourism depend on the variety of life within well functioning ecosystems to generate revenue through tourist activities. This is increasingly becoming a popular economic activity. The mining industry which also depends on natural resources is a high revenue sector which usually is regulated by a separate set of regulations outside the purview of biodiversity and ecosystem regulations. The sector demonstrates increasing trends to vertical integration of different activities in the mining cycle (Table 2).

Table 2: Sectoral Market Values and Costs, Business Models of Major Industries Using Biological Resources

Sector	Market Value USD Billion	Cost of Production	Business Model
Biopharmaceuticals (incl. biotechnology)	430 (Datamonitor, 2005)	1.2 Billion (PhRMA Report, 2007)	Increasingly shuttle development
Botanicals/ Nutraceuticals	62 (Patwardhan *et. al.,* 2005)/11.7 billion (Freedonia, 2006)	< 10 million	Multiple suppliers – specialized production
Agricultural Biotechnology	6.2 billion (Financial Times, 2006) Biotech seed market: 5.3 billion (Crop Life International, 2005) Conventional seeds: 15 Billion (Syngenta, 2005)	100 to 200 Million	Public research bodies- conventional style Companies- following consolidation
Personal products and Natural Cosmetics	around 6 billion USD by 2008 (Cosmetic Design, 2008)	< 10 Million	Specialist companies- multiple suppliers
Ecotourism	Around 29 billion USD (Kirkby, C. *et al.,* 2011)		Specialized, usually decentralized systems
Mining	In trillions for each type – continues to grow – Role of emerging countries	Rising due to rising demand	Increasing trend to vertical integration

Sources: Pharmaceutical Research and Manufacturers of America, 2007;Patwardhan, et al 2005; Freedonia, 2006; Kirkby, CA et al 2010; http://www.syngenta.com/en/downloads/seeds_5.pdf; http://www.cosmeticsdesign-europe.com/news/ng.asp?id=60389-global-organic-cosmetic;

Bio-cultural Diversity and Market Segmentation

A noteworthy aspect related to biological resources is that their end use is not homogenous and hence subject to various perceptions of demand. A single resource could show different demand patterns depending on usage that is often determined by cultural contexts. For example, within the medical sector- Senna (Cassia senna) is a plant that has a high export value in India. However, it is hardly used either in mainstream traditional medical systems or traded actively in domestic markets- indicating that it is likely to be highly price sensitive in domestic markets. A plant such as Ashwagandha (Withania somnifera) is widely used in Indian systems of medicine, actively traded in domestic markets and has high export demand. Given that it is part of several medicinal formulations as a core ingredient, it is likely to be price insensitive at least in the Indian domestic market. Whereas, a plant such as Arogyapacha (Trichopus zeylanicus ssp. travencorius) has a high cultural value in the local context among the *Kani* tribals in south India – as both a medicinal herb and as a plant with sacred values. It was later developed into a medical formulation and gained a market value – but predominantly continued to be valuable in the local contexts (Suneetha and Chandrakanth, 2006).

Consider another example of a resource such as Tulsi (Ocimum sanctum). This is culturally a highly valued herb in India, and is also used extensively as medicine both in households and in traditional medicine industry. The extract also has a high export demand. Such resources that have multiple end uses and a high cultural value tend to be conserved actively (Suneetha and Chandrakanth, *ibid.*).

Nature of Markets for Biological Resources

Supply of several biological resources (whether floral or faunal) originates from wild or common property sources. Markets for biological resources generally tend to be almost opaque and oligopolistic . However, pricing of resources such as agricultural commodities is much regulated, compared to those used in other sectors.

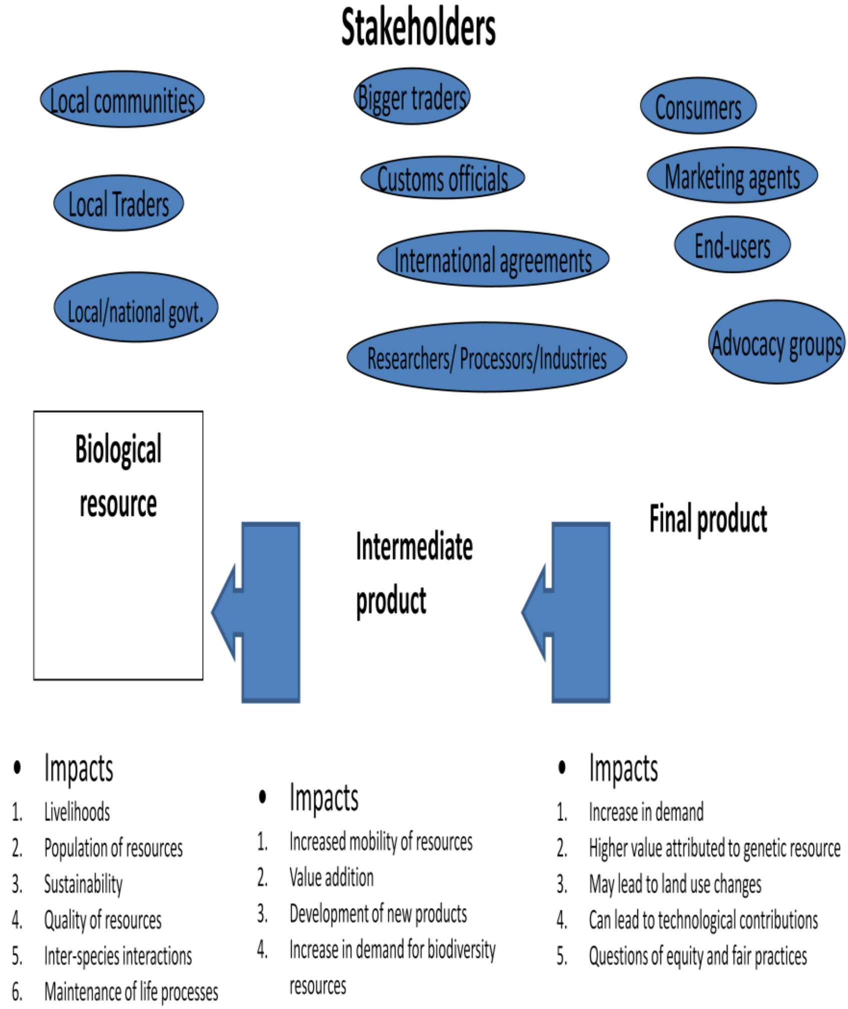
The pricing mechanism shows characteristics of an imperfect market. This is because the price difference in the price paid to the provider of the resource is not commensurate to the prices received at higher levels of the supply chain (Maraseni *et. al.,* 2006). Conversely, this has a negative feedback loop, as the providers tend to harvest unsustainably to get more income resulting in higher stress on wild populations of the resources.

What is noteworthy while examining a typical supply chain of a biological resource is that there are several sets of stakeholders at various levels who not only serve to add value in form or time to the resource, but also to regulate the movement of resources to ensure their sustainable use (Figure 2), illustrating that the flow of biological resources falls within the sphere of both conservation and economic priorities.

ECONOMIC VALUATION OF BIODIVERSITY

Biodiversity values vary depending on the use to which a resource is put – as most resources have multiple uses in different forms- for instance a resource could be used as an adornment, for cultural purposes, as a decoction in traditional medicine or as part of a pharmaceutical drug. Or in cases such as the ecosystems that sustain biodiversity, valuation approaches would need to account for the various services that would be lost in the event of their degradation or loss. Given that losses can be irreplaceable with high opportunity costs (such as loss of livelihoods, nutritional security, health security and other wellbeing needs), it is imperative that accounting methodologies be complemented with interdisciplinary approaches and ethical principles.

Figure 2: Supply Chain of a Biological Resource



Source: Adapted from Suneetha, 2010.

Economic Valuation of biological resources is often undertaken to find inherent value of the resources expressed in monetary terms. However, given that any kind of valuation is inherently anthropogenic in nature and purpose, a valuation exercise essentially serves to influence human decisions and perceptions on a resource. Such an exercise is especially required for policy decision making since the arguments for conservation or sustainable use and equity need to make economic sense over all ethical considerations. (TEEB, 2010).

Valuation of Biodiversity

Biodiversity values vary depending on the use to which a resource is put – as most resources have multiple uses in different forms- for instance a resource could be used as an adornment, for cultural purposes, as a decoction in traditional medicine or as part of a pharmaceutical drug. Or in cases such as the ecosystems that sustain biodiversity, valuation approaches would need to account for the various services that would be lost in the event of their degradation or loss. Given that losses can be irreplaceable with high opportunity costs (such as loss of livelihoods, nutritional security, health security and other wellbeing needs and ecological functioning), it is imperative that for a comprehensive valuation exercise, accounting methodologies be complemented with interdisciplinary approaches and ethical principles. In this context, it is also worth noting that a valuation exercise is primarily undertaken to find inherent value of a resource expressed in monetary terms. Often this becomes problematic as whatever be the basis of valuation- whether for implicit values or instrumental values, the exercise tends to be anthropogenic in nature, and will therefore be only an approximation with attendant biases. Nevertheless, it is precisely to address human motivations that such an exercise needs to be undertaken as information required for policy decision making for conservation or sustainable use of resources and equity need to make *economic sense* over all ethical considerations. (TEEB, 2010).

Methods to Assign Monetary Value to Biological Resource

A. Recursive Methods – involves attributing a share of value of final product to resource. Such an approach is illustrated through studies pioneered by Pearce and Moran (1994), Aylward (1998), and Simpson, Sedjo and Reid (1996).

Pearce and Moran (1994) attempt to capture the pharmaceutical value of an individual species of Biodiversity (and then extrapolating it to a general value for biodiversity) through the probability of developing a successful drug, 'p', the extent to which the host country (from where the resource/ knowledge is taken) is able to appropriate rents, 'a', the value of the drug developed, 'D' and the royalty commanded by the host nation, 'r'. Thus,

$$V_{mp}(L) = p.r.a.V_j(D)$$

$V_{mp}(L) =$ Value of medicinal plant L

$V_j(D)=$ market price of drug in world market or its shadow value given by the number of lives the drug saves and the value of a statistical life.

Simpson *et. al.* (1996) argued that it is necessary to estimate the marginal value of a species to encourage investment.

Assumptions:

1. Species are perfect substitutes
2. Hence, if all species are promising sources of leads, most would be redundant and hence marginal species close to valueless
3. Conversely, if no species is a likely source of lead(s), it is unlikely that any species will have value though the likelihood of two or more being redundant is low.

That is, marginal value of a species is negligible for very high or very low values of 'p' (the probability of commercial discovery).

The model:

Given R= revenues and C= search costs, Expected return to a single sample= $pR - C.$

If testing for use meets with success in first trial, the value of a collection of n species (in independent Bernoulli trials) is,

$$V(n) = pR - C + (1-p)(pR - C) + (1-p)^2(pR - C) + \cdots . + (1-p)^n(pR - C)$$

$$= \frac{pR - C}{p}\ (1 - (1-p))^n$$

The expected value of an additional species, $v(n)$ for any given use is ,

$$v(n) = V(n+1) - V(n) = (pR - C)\ (1-p)^n$$

Taking the partial derivative of $v(n)$ w.r.t p to solve for p, Simpson *et. al.* (1996) obtained the probability of discovery that maximizes the marginal value of a species as:

$$p^* = \frac{R + nC}{(n+1)R}$$

Inserting p^*in the equation for $v(n)$ gives the marginal value of a species at $p^{*.}$ This value is considered as an upper bound as the true p could be different from the estimated p^*.

Now, if

λ= number of new potential products identified

r= discount rate for future returns

then,

$$v(n) = \sum_{t=0}^{\infty} \lambda\ (1+r)^{-t}(pR - C)(1-p)^n$$

$$= \frac{\lambda}{r}(pR - C)(1-p)^n$$

Using estimated p^* = 0.000012, the upper bound estimate for expected value of marginal species, $v(n)$, was obtained as \$9431. The authors used these parameters to compute the willingness to pay (WTP) to preserve a hectare of land in 18 biodiversity hotspots.

Aylward (1998) assumes a royalty model to capture the pharmaceutical value of biodiversity in the Costa Rican case study. Results from this model are then plugged into a linear model that finally gives an estimate of the pharmaceutical value. Data was obtained from surveys of the international pharmaceutical industry and the case of Costa Rica's INBio and Costa Rica's system of protected areas.

The model accounts for the Net Private Returns and Net Social Returns assuming a discount rate of 10 percent, taking into account the private costs of 'producing' the biotic samples and the social costs of developing taxonomic information for each species screened.

Model Specification:

$$\boldsymbol{NPR = TRY + F - CC^p}$$

$$\boldsymbol{NSR = TRY + F - CC^p - CT^s - CP^s}$$

where,

$\boldsymbol{NPR}$	=	Net Private Return
$\boldsymbol{NSR}$	=	Net Social Return
$\boldsymbol{TRY}$	=	Total Royalty payment
$\boldsymbol{F}$	=	Sample Fee
$\boldsymbol{CC^p}$	=	Private costs of collection
$\boldsymbol{CT^s}$	=	Social costs of taxonomic information- is based on the argument that information on the identity of species, its habitat and use are primary for any pharmaceutical bioprospecting activity.
$\boldsymbol{CP^s}$	=	Opportunity cost of Biodiversity protection -involves the direct cost of protection and the opportunity cost of land allocated to what is termed as 'production of biodiversity'

Derivation of Royalty Paid per Biotic Sample

Considering the life of a drug= Period till patent expiration (PE), the net present value of Gross revenues of sale of a drug during PE is given by

$$GR = \sum_{t=0}^{PE} \quad S_t(1+r)^t$$

where,

$\boldsymbol{S_t}$	=	$\boldsymbol{S_o(1+\infty)^t}$
$\boldsymbol{S_t}$	=	expected real value of sales in year t
$\boldsymbol{S_o}$	=	expected real value of sales in initial year t_o
∞	=	real rate of growth in price of pharmaceutical product
$\boldsymbol{r}$	=	rate of discount

Royalties are paid on Net Revenues *(NR)*

TRY on a successful drug= λ NR=λ(1-∂) GR

where λ= expected rate of royalty.

NR= (1-∂) GR, where $0<\partial<1$

∂= distribution costs (expressed in percentage).

The study inferred that NPR is positive, though not substantially high. It however vindicates the reason for pharmaceutical prospecting since there are good chances of financial gains. However, the negative NSR indicates that economic returns from pharmaceutical bioprospecting alone are insufficient to justify the establishment of protected areas in developing countries. It is to be kept in mind that the value would vary with change in royalty values and costs of preservation. Hence, other economic benefits viz., Ecotourism, Watershed management etc will have to compensate the difference in costs. Aylward further demonstrates that the type of distribution mechanism can offset the costs incurred in various activities viz., collection and taxonomic costs in developing countries.

Data Requirements: Data related to value of end product/ rental value of land used, probability of success, discount rates, life time of product were used to arrive at the values of biological resources.

B. Composite Values and Indexed Approaches to Valuation

Development of an index prioritizing the qualitative and quantitative methods could be one comprehensible approach to emphasize the relative importance of a species. Cooper (2001) forwarded this argument while trying to estimate the value of plant germplasm that is used in plant breeding activities. The aim of the research was to identify the value of germplasm through its relative commercial benefits to different countries and thereby decide how much should individual nations contribute towards a global fund in order to ensure "benefit sharing" with source countries of germplasm. Here, different nations were only considered as various stakeholders. Cooper concludes that data insufficiency hinders valuation procedure due again to multiplicity of stakeholders. Development of a composite index through proxy observable macro variables was felt to be more indicative of the utility derived by different nations from germplasm collections. The variables include quantitative variables like Value of agricultural output, Agricultural gross domestic product, Gross domestic product, Seed industry profits and revenue, Value of commodities produced using improved technology like Green revolution, royalties earned on agricultural patents, expenditure on agricultural research and development and non-monetary variables like plant protection titles used, No. of landraces used in agriculture, domestic origin patents used in agriculture, matrix of varietal and parental exchanges, and diversity measures. A relative weighing of the indicators against the sum total of the index provides the rate at which each country should contribute to the fund (i.,e a country's contribution to the fund = Total Fund value $* \frac{Indicator_{\ l}}{\sqrt{\sum_{l}^{N} \ Indicator_{\ l}}}$. This allows in deciding that those countries that have a higher relative score with respect to the indicators will pay more to the fund.

Approaches to assign composite values to biological resources broadly relate to valuation of resources and valuation of resources as they relate to human wellbeing. Below is an illustration of how such approaches have been used in the different contexts.

a. **Assigning Composite Values to Resources**

In a study that attempted to examine relative values of medicinal plants based on their importance to different sets of economic stakeholders in south Indian states of Kerala and Tamilnadu (government, traders, healers, traditional pharmaceuticals), Suneetha and Chandrakanth (2006) incorporated quantifiable and evocative responses that implied both monetary and non-monetary reasons for attributing different values to a medicinal plant resource.

As parts of the data obtained were evocative in nature, the value of a medicinal plant was expressed through a Value index, representing the perceptions of the stakeholders. An index helps to compare between different species over several (multiple) stakeholders and thereby do a composite prioritisation exercise between plant species. It helps to rank species by providing a relative weightage that can then be used to even base decisions on investment decisions on different species. Hence although it may not provide a true magnitude of the value of a species, it does provide an indicator of the relative value of a species. Accordingly, a Value index was worked out for a medicinal plant. For this, scores were provided for the different variables identified as important by the various stakeholders and summing the individual scores. To a great extent, this can be used as a method to prioritise investment on specific plants, although technology and evolution of substitutes and innovations in products, processes and use of medicinal plant resources could alter some priorities. The index was worked out for a list of eighteen plants, which were selected from a list prepared by Sub- Group on Medicinal and Aromatic Plants for the Tenth Five Year Plan. Data were collected for the year 2001.

Value Index= $\sum I_{ij}$

where,

I_{ij} = Individual score of i^{th} variable for j^{th} species

The different scores for each variable for each species were organized into a contingency table and subjected to Simple Correspondence Analysis. The results of the Analysis give the relative contribution of the various factors to the variability in the data. This therefore helps to identify the distinguishing factors for each species. It further provides relative weights for the individual scores as co-ordinate values.

The different individual scores for each variable are then weighed by the individual weights or co-ordinates 'a_i' assigned by the analytical procedure for each factor or influencing variable for each species. Summing over these weighed scores for the different factors gives the total score for a species.

Total Score for j^{th} species= Value Index= $\Sigma I_{ij} * a_i$

A comparison between the relative values of different species will help to identify species that are of interest to the different stakeholders.

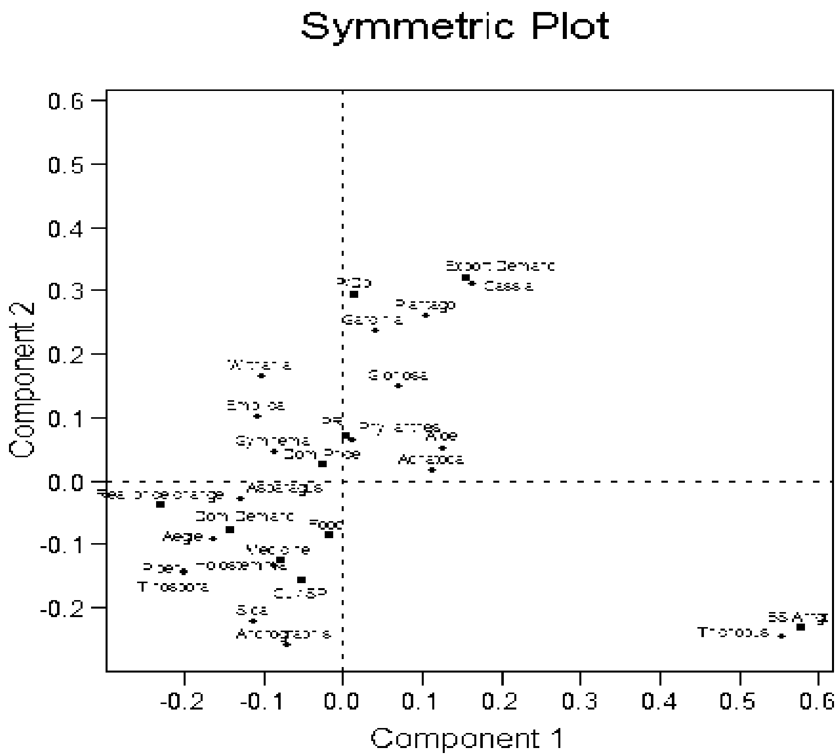
The analysis helps to classify the medicinal plant species based on market variables and on conservation variables.

Market Value of a Species= Scores of {Intellectual Property Rights regulations + Domestic Market Demand + Change in real price+ Domestic Market Price + Change in Real Price + Export Market Demand + Ratio of international price to domestic price}.

Conservation Value of Species= Scores of {Non monetary values (Food+ Medicine+ Cultural/ Spiritual values) + Benefit sharing effects}.

The selected species are then ranked based on the scores obtained in each case. Furthermore, it is possible to cluster species based on their values to different stakeholders. As illustrated by the figure below, The below figure provides an illustration of such clustering based on the analysis – there are at least 4 clusters-one, that groups together species with high export value; second, those that have high export value, domestic demand in Indian markets and cultural values; thirdly, those with high domestic demand (where many species Figure) and finally, species which have not yet entered the markets in a big way but have high cultural significance (Figure 3). Such an exercise allows policy makers to also make informed decisions on investing in different species depending on various interests.

Figure 3: Clustering of Medicinal Plants Based on Attributes of Value Index



Source: Suneetha and Chandrakanth (2006).

b. **Assigning Composite Values to Resources in Relation to Human Wellbeing**

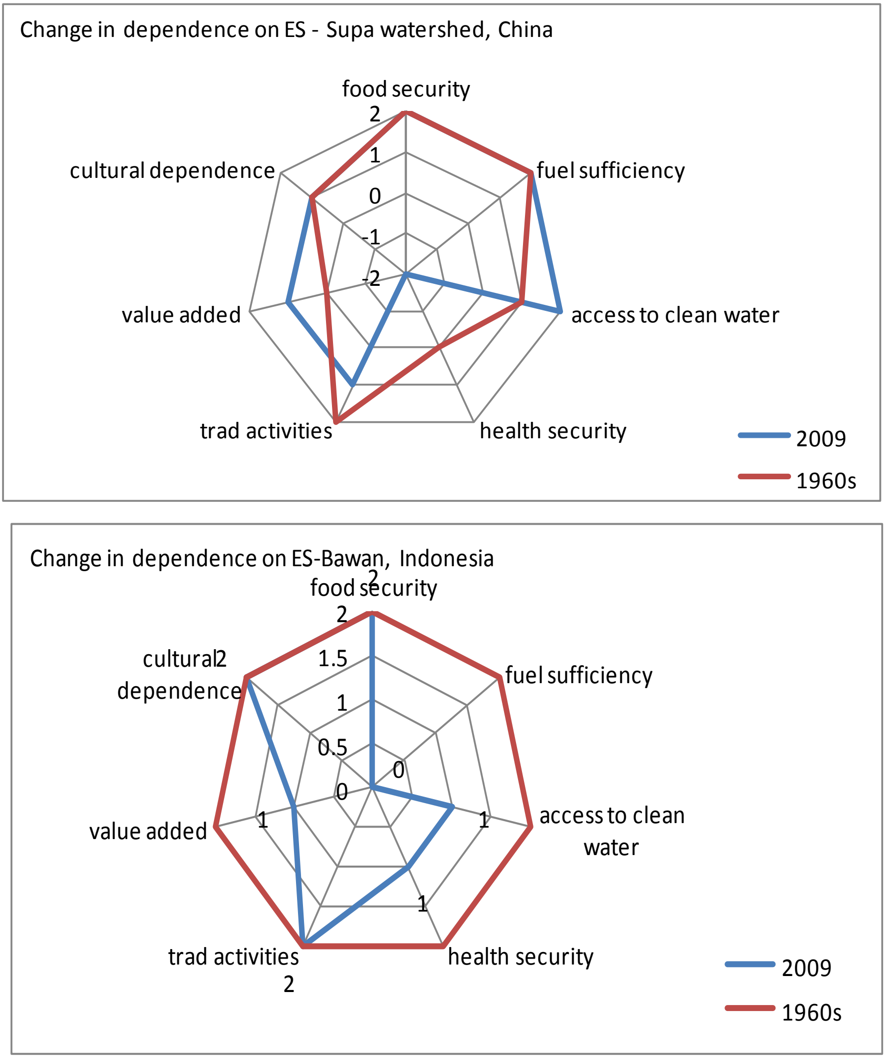
As pointed out by Limburg *et. al.* (2002), the applicability of economic welfare valuations in the context of ecosystem utilization is hampered by changes to preferences and perspectives from new information, thereby suggesting that such uncertainty may best be captured through appropriate indicators that provide clear directions for policy decisions and implementation. The MA approach also highlights the need to focus on trade-offs, using indicators to enable land use decisions (Hassan *et. al.,* 2005). An analysis of three case studies (Suneetha *et. al.,* 2011) in watershed areas of China, Japan and Indonesia examined.

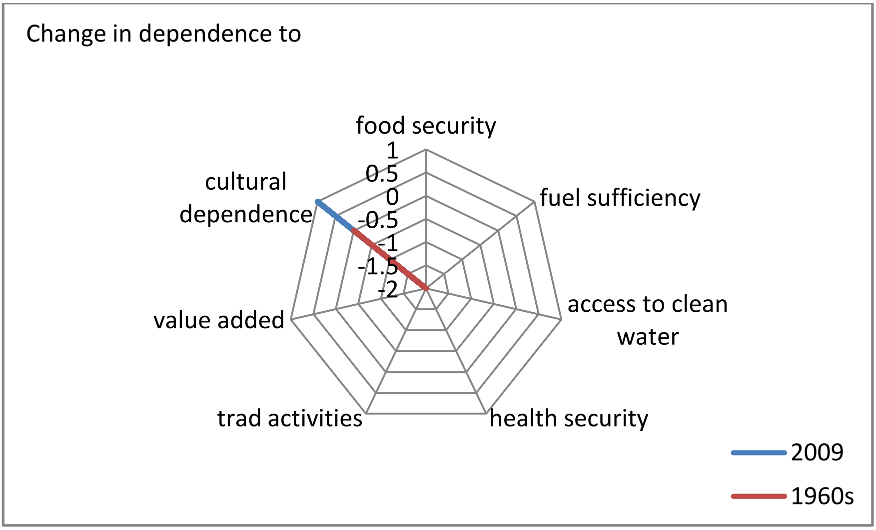
- Changes to ecosystem services over a 50 year period
- Changes in dependence of well-being of the proximate population on Ecosystem services
- Changes to Resilience of :
  - ecosystems
  - human well-being

Data from Remote sensing maps of the areas were integrated with data from primary surveys that included quantifiable and evocative responses. Data for changes to land-use, GIS data was obtained from LANDSAT images; Data related to slope, precipitation and natural events such as floods were obtained from appropriate records ; for socio-economic data, participatory rapid appraisal (PRA) methods were followed in a multi-stakeholder forum involving major actors from within the ecosystem.

All data were later indexed and scored and mapped for trends in changes to biophysical parameters (viz., changes to forest area, volume of species from forests, soil quality, flood frequency),and socio-economic parameters (viz., food self sufficiency, fuel sufficiency, water quality, health security, tenure rights, livelihood dependence and cultural dependence). The results provided some useful policy relevant insights especially indicating the specific ecosystem demand patterns , utilities and trade-offs derived in different socio-ecological contexts and underscoring the fact that policies need to be sensitive to ground specificities.

Figure 4: Changes in Dependence to Wellbeing in 3 Socio-Ecological Contexts





There is a renewed interest in understanding the values of biological resources, as the futility of a production-oriented progress with scant regard for natural capital is being underscored (TEEB, 2010). It is also noteworthy that valuation exercises tend to focus on resources and ecosystems, than on variability of life- Biodiversity. There are studies that have examined the importance of biodiversity in terms of germplasm values to the economic progress of a country or of a sector (Hein and Gatzweiler, 2006). Linking the values of biodiversity to broader sustainability goals including adaptation to climate change or availability of various ecosystem services to different sets of stakeholders requires a much more nuanced and interdisciplinary approach. The new IPBES (Integovernmental Platform for Biodiversity and Ecosystems Services) process in fact aims to provide such a conceptual framework for future assessments of ecosystems and services. Efforts are underway to develop a guide on value conceptualization and valuation of biodiversity taking into account the multiple dimensions related to biodiversity and ecosystem services (or nature and natural resources), and to use it in assessment processes for changes to biodiversity and ecosystem service and Human wellbeing (for more information see www.ipbes.net) . As the multidimensional metric(s) or unit(s) need to capture complex interactions between natural resources and nature and human systems, attempts are on to synergize approaches and methods used by different disciplines including anthropology, ecology, biology, economics, sociology, philosophy, psychology, geography among others.

POLICY CONCERNS AND MAJOR POLICY INITIATIVES

Several intergovernmental and national policies have been framed to address various issues related to conservation of biodiversity, ensure they are sustainably used to achieve development aspirations and enable equitable transactions between different stakeholders involved in the value chain of bio-resource trade. Major intergovernmental policy organizations working in this context include:

- The Convention on Biological Diversity, Convention on International Trade in Endangered Species and other Biodiversity related conventions – focus on conservation of resources, knowledge associated, trade and markets and ethics and equity
- The Food and Agriculture Organization of the United Nations (FAO) – conservation of agrobiodiversity, issues related to conserving germplasm of plants, animals and fostering good practice in sharing of resources
- UNESCO through various conventions , International Labour Organization – focus on human rights related issues, ethics of use of biological resources for human purposes
- Intergovernmental Platform for Biodiversity and Ecosystems Services (IPBES) – concerned with assessment on status of biodiversity and ecosystems and development of approaches that make the plural values of biodiversity more visible

- The World Trade Organization (WTO) and related agreement on Trade related Intellectual Property Rights (TRIPS Agreement) - deal with ownership over genetic resources, traditional knowledge
- The United Nations – focus on harmony between humans and nature, promote concepts of green economy, sustainable consumption and production activities, development of Sustainable Development Goals following up on the Millennium Development Goals.

At the national level, India is one of the pioneering countries that has taken policy and regulatory measures to conserve biodiversity and ensure equity among different stakeholder groups through various laws such as the National Biological Diversity Act, 2002; the Plant Variety Protection and Farmer's Rights Act, 2001; and the Patents Amendment Act, 2005. The policy coherence amidst the different instruments to promote innovative research on biological resources, and at the same time ensure conservation and sustainable use of different kinds of biological resource is certainly an appreciable effort. The Biological Diversity Act is implemented through a 3-tiered structured at the national level (by the National Biodiversity Authority), state (State Biodiversity Boards) and local (through Biodiversity Management Committees) to deal with issues related to accessing biological resources for different purposes and sharing benefits arising from their commercial use in an equitable manner with different sets of stakeholders.

There are several other agencies of intergovernmental and non-governmental nature (such as IUCN) that contribute to setting policy agendas related to biodiversity and ecosystems. There are also several drivers related to growth and development whose impacts often run counter to environmental concerns. Despite the advancement in multilateral agenda setting, non-synchronicity of policies and regulations continues to hamper efforts at conservation and sustainable use. A big reason continues to be undervaluationof the value of biodiversity and ecosystems and the natural environment. While research shows that this does result in impairment of human wellbeing, they need to be represented better in mainstream analytical frameworks. It is a welcome development that indicators to capture natural and material wealth are being developed by agencies such as the World Bank (through the WAVES project) and through the UNSEEA (UN System of Environmental-Economic Accounting). This would allow countries to have a more robust approach towards valuing wealth in broader and meaningful terms.

CONCLUDING REMARKS

Biodiversity and the economics of various biological resources have been integral to the welfare of nations. Over time, however, the natural abundance of several resources – whether from land or water – have reduced or degraded, resulting in difficult consequences to human wellbeing. The Economics of Biodiversity is closely linked to the economics of information. This is because a better notion of value can only be obtained when use of the resource and its contribution in the value chain is sufficiently understood.

Despite a multiplicity of policies, guidelines and regulations at the international and national levels, it is still a matter of concern that we are losing biodiversity at a fast rate. This basically comes down to a disproportionate discounting of the value of diverse and natural resources in relation to produced capital. It is to overcome this barrier, and enable making the values of biodiversity more visible that sensitive valuation of biodiversity and ecosystems need be conducted.

Choice of appropriate tools of valuation is important to arrive at informed decisions related to conservation and utilization of biological resources. This choice needs to be determined by questions of what resources are being valued, their scarcity, their form of use, towards what purpose is the resource being utilized, its social and cultural values and relevance in national and global markets in respective sector. This then implies that there is a need for more layered, multidimensional and interdisciplinary approaches of analysis. It also indicates that wrong choices can indeed lead to irreversible natural states that can negatively affect our wellbeing.

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