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Report

Economic Value of Biodiversity in Sri Lanka: A Case Study on Pharmaceutical Prospecting

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ECONOMIC VALUE OF BIODIVERSITY IN SRI LANKA. A CASE STUDY ON PHARMACEUTICAL PROSPECTING

SUMMARY

Sri Lanka is recognized as a "biodiversity hotspot" of global importance Conservation and use of biodiversity is necessary to achieve sustainable development

This study has reviewed socio-economics causes that depletes bioaversity the role of environmental economics in facilitating policy decision making to conserve biodiversity The study provides a simplified review of economic theory on value of biodiversity and techniques of valuation The study finally demonstrates the application of a valuation techniques to value the pharmaceutical prospecting value of bioaiversity of the Sinharaja forest The findings of the study are used to suggest policies to conserve biodiversity

There has been very few studies done to examine socio-economic causes that deplete biodiversity in Sr Lanka Not knowing the causes of depletion of biodiversity is a serious lapse to suggest effective policies to conserve biodiversity Since Sri Lanka has adopted a market economic system, it is proposed that market incentives and dis - incentives be used to encourage society to conserve biodiversity However prudent research should be done to identify Such incentives or dis-incentives

Failure to recognize the total economic value of biodiversity leads depletion of bioaiversity cue to human over-use Estimation and appropriation of total economic value of bioaiversity could reauce over-use of bioaiversity Policy aecision making on bioaiversity conservation primarily depends on deciaing on optimal land allocation between land use for conservation and development alternatives Environmental economics could facilitate policy decision making by providing monetary values of biodiversity which could be compared with alternative land uses This study has demonstrated the application of an economic valuation technique to value an option value of biodiversity viz. pharmaceutical prospecting value

The results shows annual pharmaceutical prospecting value of endemic woody plants (10 cm dbh) in the Sinharaja forest as 118 11 US$ per hectare Sensitivity analysis on policy variables viz. the appropriation rate (a), the royalty rate (r) and probability of invention of successful plant based pharmaceutical (p) shows that opportunity cost of land use under tea cultivation can be compensated if $a = 50\%$ and $r = 27\%$ under $p = 5$ in 10000 These are high values which may be difficult to achieve yet could be pursued Policies to increase the possibilities of appropriate pharmaceutical value of biodiversity is discussed. It is necessary to establish intellectual property rights for biodiversity Further research should be done to gather information on the availability of species Gathering information on indigenous knowledge on use of plants for medicines will be worthy Vertical integration in biodiversity prospecting i e developing indigenous meaicines could appropriate value of biodiversity in

the short-run This has the advantage of capturing growing markets for natural markets internationally and also using the existing possibility of patenting products

The study suggests, pharmaceutical prospecting value of biodiversity alone would not provide incentives to conservation and sustainable use of biodiversity Therefore policy to conserve and use biodiversity would have to focus on valuing and appropriating other benefits of biodiversity such as direct use values (sustainable use of non timber forest products, eco - tourism medicinal plants use), indirect use values (watershed protection, ecological protection nutrient cycling carbon sequestration), existence values etc, to provide incentives for biodiversity conservation

The estimated pharmaceutical prospecting value is an under-estimation because not all the endemic plant species in Sinharaja were taken in to account the availability of indigenous knowledge on plant use for medicines was not explicitly recognized The value is based on market value of currently marketed western pharmaceuticals only It does not recognize the value of indigenous medicines and the values of lives saved The value of pharmaceutical prospecting is only one component of the total economic value of Sinharaja As other studies have shown the total economic value of Sinharaja is much higher Policy decisions should be based on total economic value

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National decision making is partly guided by National Income (NI) accounts Current NI accounting neglects values of most environmental and natural resource use and the degradation of natural resource Bio-diversity is a natural resource, the values of its services are not immediately realized in the 'present market there by not included in NI Therefore

[1] bio-diversity need to be valued and
[2] integrated to national income accounts,

to guide rational policy decision making on conservation and use of bio-diversity to achieve sustainable development

1 2 National Context Strategy for the Preparation of a Biodiversity Action Plan for Sri Lanka

In order to abide by the commitment to the Biodiversity Convention (UN 1992) and on long-term national development interests, the Sri Lankan Government will be preparing a Biodiversity Conservation Action Plan As an initial step a Strategy to Prepare the Biodiversity Action Plan has been prepared (MTHEW A, 1995) The strategy outlines the data (information) and analysis that are required to support the preparation of the Biodiversity Conservation Action Plan

The SPBAP solicits proposals on techniques to value biodiversity in Sri Lanka and on methods to integrate the value of biodiversity to national income (Terms of Reference 6 of the SPBAP 1995) The specification of Terms of Reference 6 is as follows

[1] Develop techniques to value bio-diversity
[2] Value bio-diversity in Sri Lanka (by conducting case studies)
[3] Develop methods to integrate value of bio-diversity to NI
[4] Develop systems to ensure that local communities affected by conservation are benefited

Two studies were conducted to achieve above These are

[1] Pharmaceutical Prospecting Value of Biodiversity in Sri Lanka
[2] Integrating Forest Values to National Income Accounting in Sri Lanka

This study presents the first of the two studies

1 3 Significance of Valuing Biodiversity in Sri Lanka

Sri Lanka is persevering to achieve simultaneously, the development objectives of alleviating poverty and conserving the environment. Given the intricate mix of complementary and conflicting interdependencies between the two development objectives national policy decision making has become complicated National policy decisions, proposed development plans and projects are often subjected to controversial public debate Policy makers, and the public require scientific information to resolve these controversies amicably, such that pursuit to achieve national development is unhindered

Sri Lanka is bestowed with a rich environmental and natural resource base Biodiversity is one such resource that has vast potential economic value[1] If biodiversity is sustainably conserved and used it could contribute to sustainable development of the country Regrettably, there are powerful economic forces acting against its conservation (see section 2 2)

Figure 1 compares the biodiversity of Sri Lanka with other Asian countries It is observed that Sri Lanka has a very high biodiversity and also a very high human density per unit land area The increasing population pressure on limited land area has lead to rapid degradation of biodiversity which may continue if unabated Thus there is an imperative and impending need to take deliberate policy action to conserve and use at least the remaining biodiversity of Sri Lanka Knowing the economic value of biodiversity would enable the comparison of cost and benefits of biodiversity conservation with other land use alternatives and thereby facilitate rational decision making on policy options

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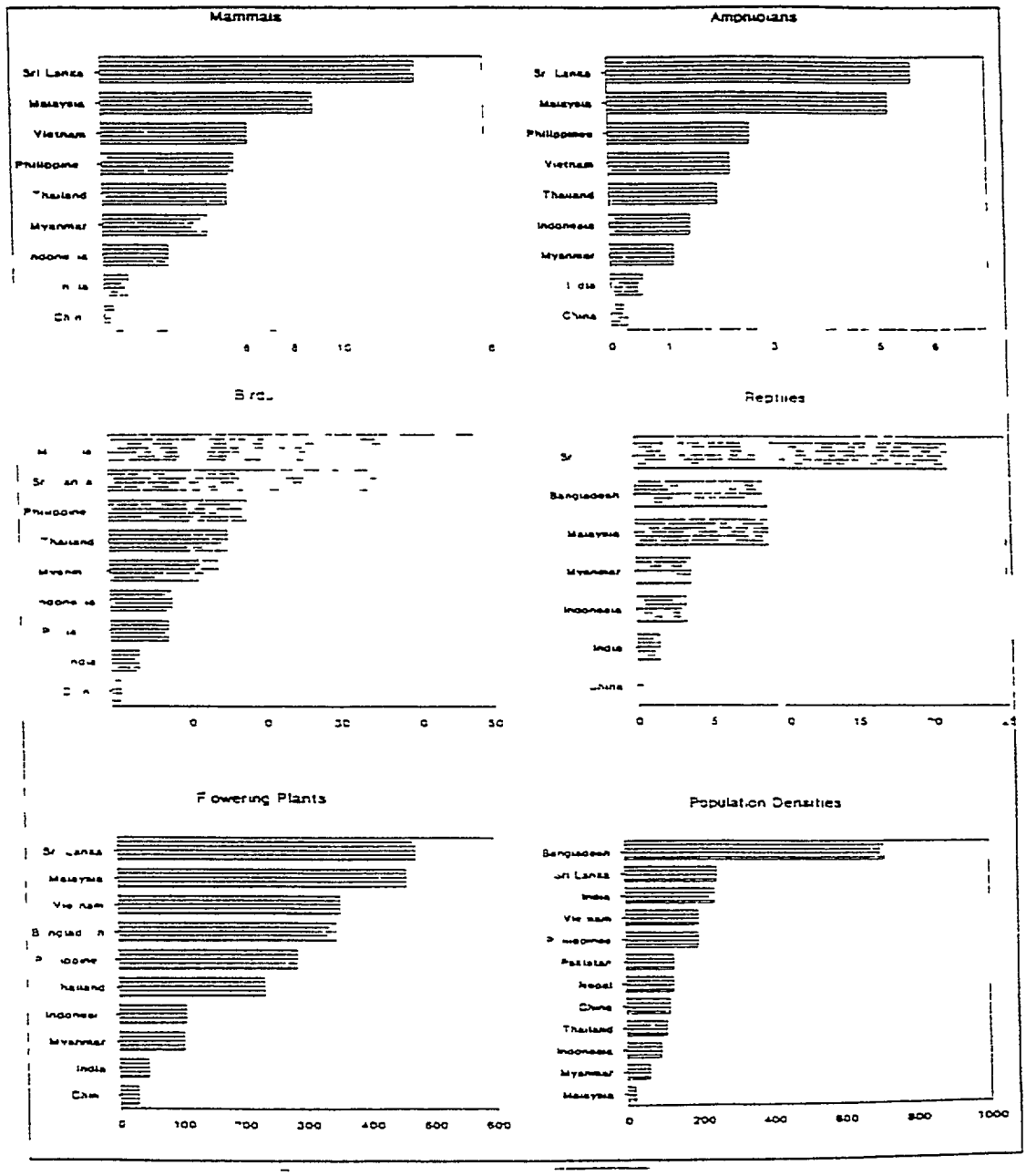
1 However it need to be recognized that biodiversity conservation could be a Pandora s box which when opened may uncover misery too ! To quote Nesiah (1995)
Biological pollution could be even more threatening than chemical or nuclear and chemical pollution
Preparedness to avert such disaster is required whilst focusing efforts on the conservation and use of biodiversity

Figure 1 Biodiversity of Sri Lanka in Comparison with other Asian Countries



Source National Resources of Sri Lanka Conditions and Trends

CHAPTER 2

SUSTAINABLE DEVELOPMENT AND BIODIVERSITY CONSERVATION

2 1 Sustainable Development

Development as commonly understood is a process of increasing the satisfaction of human beings of a nation The concept of development has undergone an evolution through addition of new operational attributes The evolution of the concept of development is summarized in table 1

Table 1 Evolution of the Concept of Sustainable Development

	Operational Attributes of Development
1950 s	Growth in national income (i e Material development)
1960 s	Growth in national income – Intra-generational equity – fairness in the distribution of national income (equitable development)
1970 s	Growth in national income – Intra generational equity in the distribution of national income – Improvement in the quality of life
1980 s	Growth in national income Intra-generational equity in the distribution of national income – Improvement in the quality of life – Safeguarding human rights women s rights children s rights and democracy (righteous development)
1990 s	Growth in national income – Intra-generational equity in the distribution of national income – Improvement in the quality of life – Safeguarding human rights – Environmental conservation to achieve inter generational equity in the distribution of benefits of development i e Sustainable development

2 The periods are only indicative and not empirically based The periods are authors judgement of the period during which the different development concepts were publicly made aware in Sri Lanka

In the decade of 1950 development was thought to be a process of growth in national income (i e the monetary value of commodities produced within the country in a given year) The basic presumption was that higher availability of commodities and its consumption increases satisfaction of a nation s society The value of commodities produced in a given year is measured by Gross Domestic Product (GDP) As shown in figure 2 the GDP of Sri Lanka has increased from Rs 13 812 to Rs 453,092 million during 1970 to 1993 (Annual Reports of Central Bank of Sri Lanka)

The experience of 1960's decade was that increased national income perse had not achieved development Although national income increased "rich were getting richer" and "the poor were getting poorer" resulting to discontent of the society As shown in figure 3 in Sri Lanka during 1973 to 1991 the top 10% income receivers had increased in come form 50% to 60% whilst the income of the bottom 10% of income receivers has dropped from 8% to 1% It was hence thought that development requires not only a growth in national income but also an equitable sharing of the national income among the population

During the periods of 1970 s and 1980 s further attributes such as the necessity to achieve an acceptable quality of life (i e availability of basic facilities of education health/ sanitation shelter etc) the necessity to safeguard human rights of various sectors of the society (women children social minorities etc) were added as necessary attributes of development As shown in figure 4 the maternal and infant mortality has decreased substantially over the years In the 1930 s the maternal and infant mortality rates have been around 20/1000 and 25/1000 respectively and in 1990 s the maternal and infant mortality rates are about 2/1000 and 8/1000 respectively

In the 1990 s the concept of sustainable development emerged Environment is recognized as an integral resource that contributes to sustainable development This is because the environment s

[1] A source of supply of renewable (ex natural forests fisheries) and non-renewable (ex land mineral deposits biodiversity) resources

[2] A sink absorbing the wastes resulting from production and consumption of commodities (ex CO_2 Sequestration by forests)

[3] A source of supply of global support services (ex protection by ozone layer)

Figure 2. Growth of GDP in Sri Lanka

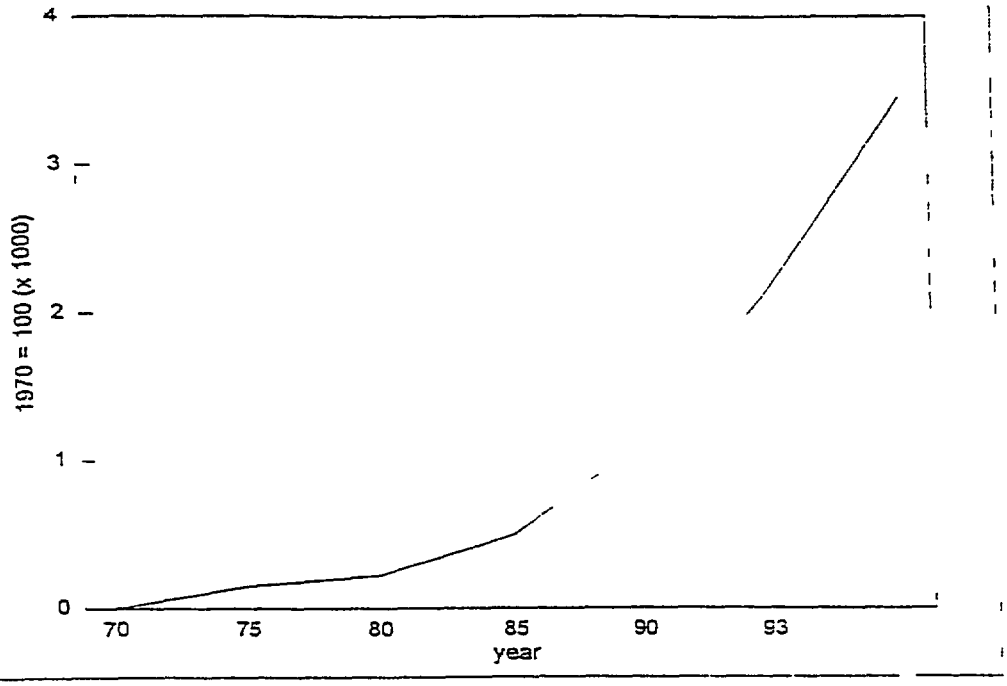


Figure 3 Income Distribution in Sri Lanka

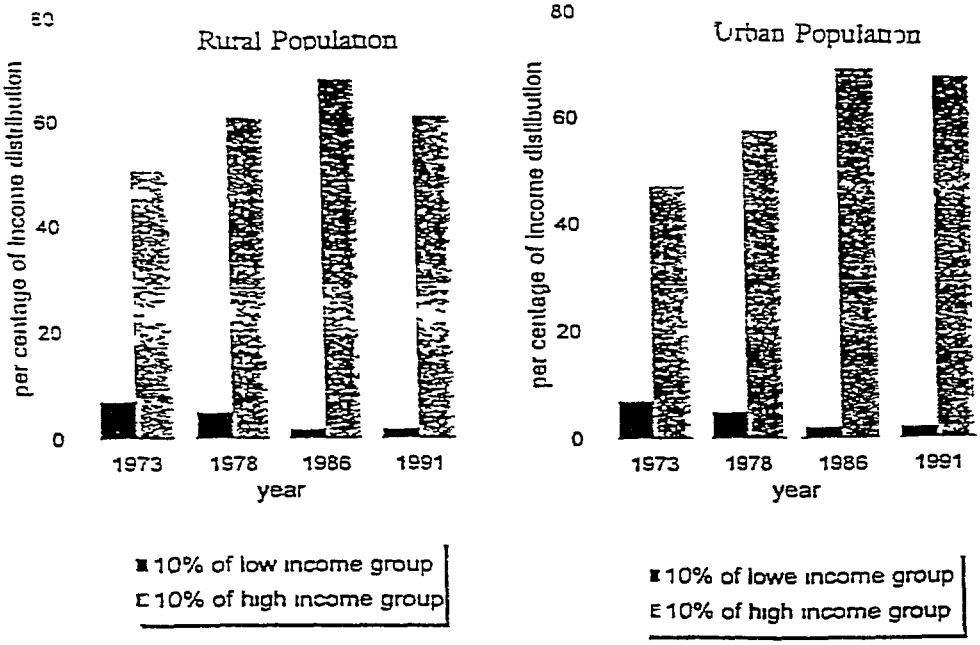


Figure 4 Maternal (MMR) and Infant (IMR) Mortality Rates in Sri Lanka

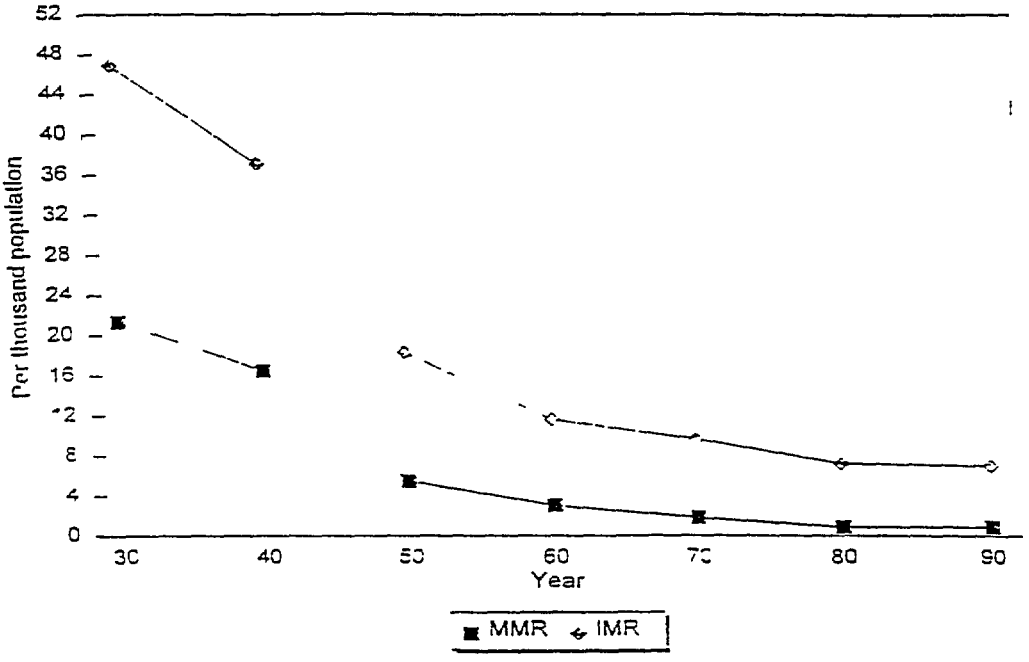
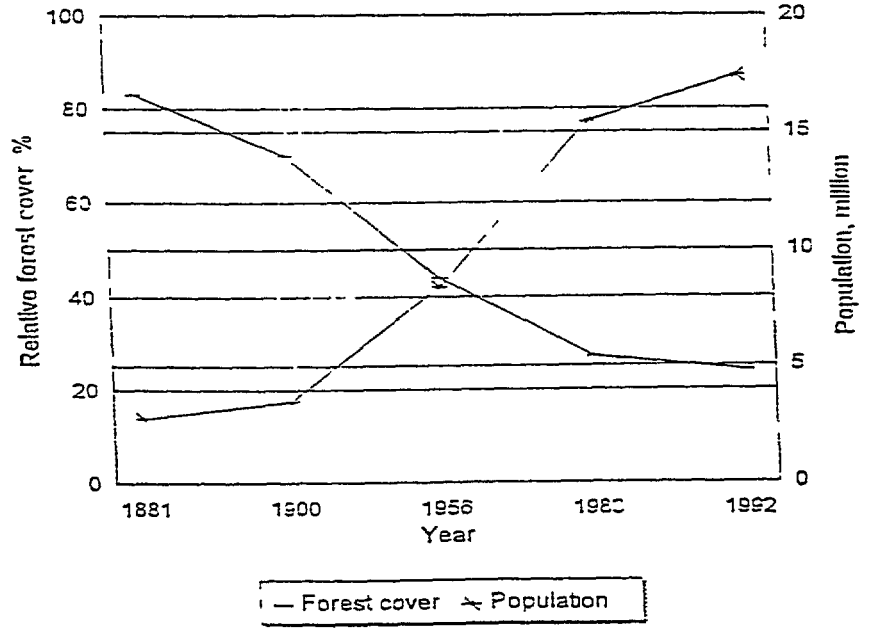


Figure 5 Trend in Forest Land Use in Sri Lanka



Past development activities has lead to rapid depletion of renewable and non-renewable resources This has also resulted to reduction of the ability of the environment to assimilate waste and has damaged global support services Thus looms the uncertainty whether past development trends could be sustained to the future A comprehensive description on natural resource use and trends in Sri Lanka is given in 'Natural Resources Conditions and Trends (NARESA, 1991) To consider few examples of natural resource use trend, the extent of forest had reduced from 84% to 20 4% of the land area during 1881 to 1993 (see figure 5) Vehicle registrations (a proxy of urban air pollution) has increased from 8000 to 10000 during 1970 to 1990 (see figure 6)

Sustainable development recognizes the human sentiment of wanting to take care of development needs of future generation [3] Thus sustainable development is most commonly defined as a process of development that

> best satisfies the present generation without compromising the opportunities for future generations to satisfy themselves "

From an economic point of view, sustainable development is where development has the following characteristics

[1] Economic growth (national income) increases or least is constant over time

[2] Economic growth is subject to least variance over time

[3] Economic growth if dropped could adjust rapidly to earlier growth rates

[4] The benefit of economic growth is equitably shared intra and inter generationally

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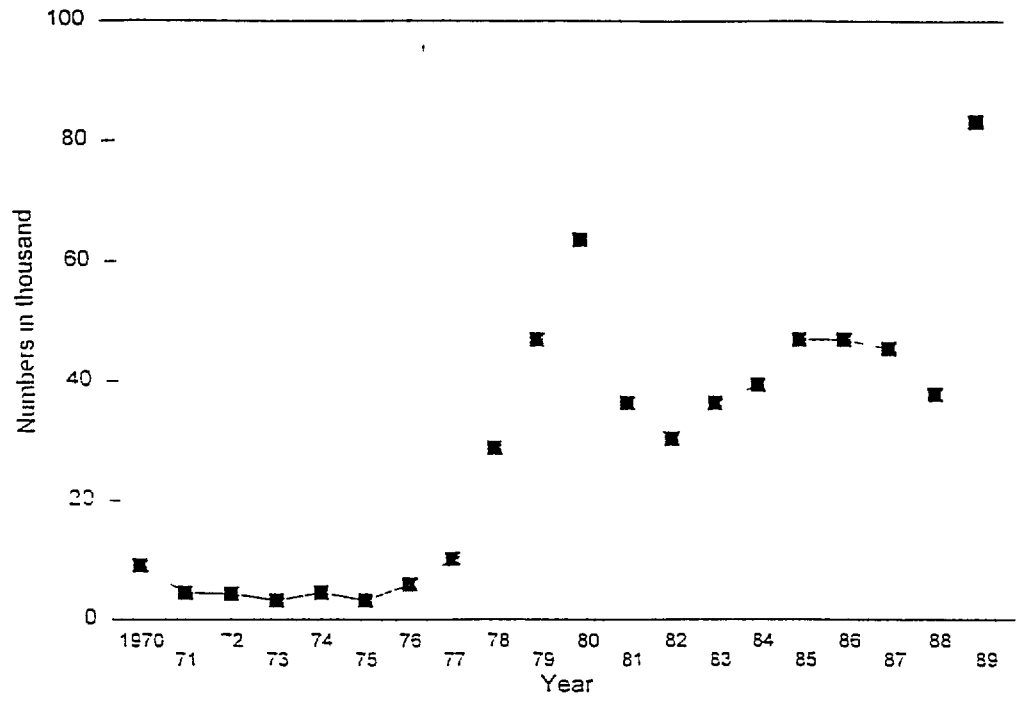
3 Sustainable development is not merely an economic concept Sustainable development is a comprehensive concept that involves the integration of economic social and ecological concepts Munasinghe and Shearer (1995) gives a comprehensive description on the concept of sustainable development a study conducted by Pathirana and Kotagama (1996) using an integrated index comprising of economic social and ecological variable concluded that although coastal resources in the Kalpitiya region in Sri Lanka was used at high economic efficiency the social and ecological sustainability was low

Figure 6 Trend in Vehicle Use In Sri Lanka



Some have argued that sustainable development could be achieved even through the total conversion of the environment and natural resources to man-made capital This however is refutable, on the following reasons

[1] Natural capital and man-made capital are not perfect substitutes in supplying particularly global support services

[2] Although man-made capital can be rebuilt if destroyed, natural capital can not be rebuilt if destroved The destruction of natural capital is irreversible

[3] Man-made capital lacks diversity whilst natural capital possesses diversity that enables to withstand shocks of change (i e resilience)

Thus conservation of the environment is an imperative to achieve sustainable development Environmental and natural resources are gifts of nature i e non-producible by human beings One such environmental resource is biodiversity It's conservation and use is necessary due to the following reasons (Munasinghe 1993)

[1] Biodiversity supports food fiber medicinal and other current production systems and indirect products such as recreation

[2] Biodiversity could provide resilience for the future production systems

[3] Some of the functions (such as ecological function) of biodiversity cannot be substituted by man made capital

[4] Biodiversity contributes to development and sustenance of culture

2 2 Role of Conservation and Use of Biodiversity in Sustainable Development

Biodiversity refers to the variety of biological beings (plants and animals) on earth There are broadly three levels of biodiversity, genetic variation within species, the variety of species within a habitat and the variety of habitats in the world Biodiversity could be natural as found in natural habitats or artificial as found in artificial habitats that human beings have created

An example of rich natural biodiversity in Sri Lanka is the Sinharaja forests and the Knuckles forest The Sinharaja forest covers a land area of 11 187 hectares in the wet zone of Sri Lanka About 51 3% of the woody plants of 10 cm dbh found in Sinharaja are endemic (Forest Department National Conservation Review Data Base) The Knuckles forest is located in the center of Sri Lanka within the dry intermediate and wet zones It has several diverse habitats There are 24 endemic plant species 14 bird 3 fish, 1 amphibian 1 reptile endemic species in the Knuckles forest (Knuckles Management Plan, 1993)

An example of rich artificial biodiversity is the Kandyan home gardens A typical Kandyan home garden is at least one generation old and is about 0 4 ha There are on the average 46 plant species per home garden (Perera and Rajapakse 1991) A study conducted by Batagalla and Kotagama (1996) confirms above species richness of Kandyan home gardens

Biodiversity is a scarce resource that could be used to satisfy human beings Thus biodiversity has an economic value (see section 3 1 for details on meaning of economic value) Biodiversity as a resource is different to a biological resource (genes/ species/ habitat) Biodiversity as a resource is the difference in the generation of economic value between a diverse range of genes/species/habitat and less diverse range of genes/ species/ habitat Hence the economic value of biodiversity is not the total economic value generated by a biological resource The economic value of biodiversity is the difference in total economic value of a habitat (a biological resource) that is diverse and less diverse Thus to estimate the economic value of biodiversity it is necessary to estimate the total economic value of biological resources [4] The components of total economic value of biological resources are portrayed in table 2

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4 Based on this interpretation of the economic value of biodiversity it could be said that most studies conducted thus far has estimated the economic value of biological resources and not the economic value of biodiversity However if the base biological resource is considered to have zero economic value then the economic value of a biological resource is equal to economic value of biodiversity

Table 2 Components of Total Economic Value of Biological Resources

Total Economic Value (TEV)				
Use Values (personal consumption of commodities)			Non-use values (non-personal consumption of commodities)	
Present use values		Future use values		
Direct use values	Indirect use values	Optional use values	Bequest values	Existence values
Value generated form direct consumption of commodities	Value generated from indirect consumption of commodities	Value generated from maintaining options for either direct or indirect consumption of commodities in future	Value generated from conserving for consumption opportunities for future human generations	Value generated from preserving existence of biological resources for their own sake
Food Fibre Timber Fuel-wood Medicines Recreation etc	Maintenance of ecological systems Nutrient recycling Carbon sequestration Watershed protection etc	Use of chemical as future pharmaceuticals Use of genes in increasing future agricultural productivity	Preserving unique habitats species etc	Preserving endangered habitats species etc

Economic value is derived from human utility (satisfaction) generation in the use of scarce resources/ commodities Biodiversity is a scarce resource Human satisfaction can be generated through either personal or non-personal use of biodiversity In personal use of biodiversity individuals gain satisfaction by meeting individualistic/ selfish desires In non-personal use of biodiversity is not used by individuals instead individuals derive satisfaction on the feeling that it will be available for use by other individuals, particularly of the next generation

Personal use of biodiversity could take three forms, viz direct use, indirect use, and option use Direct and indirect use occurs at present and option use may occur in future Direct use refers to the direct consumption of products of biodiversity either destructively or non-destructively Examples of destructive use of biodiversity are harvest of timber and some non-timber forest products such as food, fibre, medicines etc from forests[5] The value of timber harvest in 1995 has been Rs 521 million from natural forests and forest plantations (De Silva and Kotagama, 1996) Around 500 plant species are believed to be used medicinally in Sri Lanka (MTHEWA 1993) Villagers in the periphery of the Knuckles forest range use 48 forest plant types for food, medicines, roping material etc, deriving a value of Rs 4095 00 per ha per year (Gunatilake et al 1993) Similarly, villagers in the periphery of the Sinharaja forest derive a value of Rs 575 00 by harvesting non-timber forest products (Gunatilake et al, 1993)

Non-destructive use of biodiversity is exemplified by enjoying the scenery of diverse nature, use of biodiversity for education, photography, eco-tourism etc In 1993, 13 273 Sri Lankans and 963 foreigners have visited Sinharaja forest, for above purposes On entrance fees this would have earned approximately Rs 200 000, i e about Rs 18/ha/year (Steel, 1996) Similarly the value derived form the Horton Plains and Yala wild life sanctuaries are Rs 1150/ha/year and Rs 250/ha/vear, respectively (Steel, 1996) Kariyawasam (1992) has estimated the recreational value of Sinharaja forest to Sri Lankans as Rs 394 000 00 and the value per visit as Rs 1 50 based on a travel cost study A study done by (Gunawardene, Edirisinghe and Kotagama, 1995) has estimated the willingness to pay for recreational benefits of Hikkaduwa marine sanctuary of Sri Lankans and foreigners as Rs 222/year and 358/ year, respectively

Indirect uses of biodiversity is through the maintenance of ecological functions For example the maintenance of food chains, regulation of pests in cultivated crops through natural predators and the mere maintenance of nature as a primary resilient life support system etc, Further habitat conservation of biodiversity could indirectly contribute to preservation of watershed functions of water and soil conservation and Co_2 sequestration [6] Very few economic studies have been done to estimate these values, mainly because of the inadequacy

5 Not all non timber forest harvests are destructive Non timber forest products may be non-destructively and sustainable harvested too

6 The relationship of biodiversity with watershed (soil and water protection) is not clear A mono-cropped plantation forest may be able to function effectively as a forest with high biodiversity

of bio-scientific information De Silva and Kotagama (1995) have estimated the watershed value (agro-hydrological and domestic water) of forests in Sri Lanka as Rs 3555 million. It has been estimated (Bandaratilake, 1991 quoted in Knuckles Management Plan, 1994) that the run off/ rainfall ratio in the Kaluganga catchment of the Knuckles forest range has increased from 0 5 to 0 65 between 1960 to 1969, during which Knuckles forest was cleared for cardamom cultivation It has also been recorded that 'A' horizon of the soil has reduced form 30-35 cm in natural forest to 15-25 cm in cardamom cultivated areas Also the moisture holding capacity has dropped from 50-60% in natural forests to 15-25% in cardamom cultivated areas (Knuckles Management Plan, 1994) De Silva and Kotagama (1997) have estimated the Co_2 sequestration and Carbon sink value of natural forests in Sri Lanka as Rs 90 87 thousand per hectare per year

An important indirect use of biodiversity is its influence on moral and cultural values of society Traditional Sri Lankan culture have had intimate relations with nature Many customs norms and institutions that guide human behavior had links to nature The expression of human feelings too were expressed in relation to natural phenomena [7] Culture sustenance is considered as a necessity for sustainable development Whether the study of the influence of biodiversity on human culture is within the domain of economics is arguable Culture is a strong factor that influences human preferences thus economic values

Option use of biodiversity refers to the satisfaction gained through opting to conserve diversity with the hope that in future it could be used directly or indirectly Conserved biodiversity could probably be used as a source of genetic material in crop or livestock improvement or in extracting chemicals for pharmaceutical purposes Contingent valuation studies have estimated the option value of Sinharaja (Abeygunawardene, 1992) as Rs 54 70/year and Rs 204 50/year for peripheral communities in Sinharaja and Urban communities in Sri Lanka, respectively Gunawardene, Edirisinghe and Kotagama (1995) also using contingent valuation have estimated the option value of Hikkaduwa Marine sanctuary as Rs 106 62/ year of Sri Lankans and Rs 145 00/ year of foreigners

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7 Such as strong love been expressed in sinhala as *gahai velai wage* (like the wine entangled on a tree) and the opposite strong hate expresses as *navai mugativavi wage* (like the snake and mongoose)

The common understanding of the value of biodiversity is based on its option values, i e the potential to produce pharmaceuticals using plant based chemicals and potential to improve crop[8] and livestock production using genetic materials of wild cultivars The economics of these aspects haves not been studied in Sri Lanka[9] Hence a case study was done to estimate the option value of pharmaceutical in the Sinharaja forest The findings are reported in chapter 4

Non-personal use of biodiversity could take two forms, viz, bequest use and existence use Bequest use is where people gain satisfaction on the knowledge that biodiversity would exist to be used by future generations Existence use is where people gain satisfaction on the knowledge that biodiversity exists for its own sake-- for the sake of the ecosystem Sri Lanka have had a culture that has greatly apprec ated existence values Around 300 BC, Arahat Mahinda s sermon to the king Devanampiyatissa is believed to have mentioned

> "the birds and beasts have equal right to this land and the king was only the custodian of them"

Using contingent valuation Abeygunawardene (1992) and Gunawardene and Kotagama (1995) have estimated bequest and existence values of Sinharaja forest and Hikkaduwa marine sanctuary The bequest value of Sinharaja has been estimated as Rs 72 30/ year of peripheral communities and Rs 271 20 /year of Urban communities and the existence value has been estimated as Rs 41 30/ vear of peripheral communities and Rs 171 60/ year of urban communities in Sri Lanka The bequest value of Hikkaduwa marine sanctuary has been estimated as Rs 270 93/ vear of Sri Lankan and Rs 496 50/ year of foreigners and the existence value as Rs 83 56/ year of Sri Lankans and Rs 133 00/ vear of foreigners

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8 At present the profitability of the production of rice is dropping A main reason is the increasing cost of labor A large portion of labor (and also energy) is spent in the preparation of land seasonally If paddy could be improved such that ratoon harvest could be obtained it would immensely beneficial Such possibilities exists by using wild strains of paddy such as *uru wee* (Personal Communications Dr Gerry Jayawardene Director of the Horticulture Institute Department of Agriculture)

9 A study on the value of genetic up grading in paddy in Sri Lanka through a use of local genetic material is being done at the Post graduate Institute of Agriculture University of Peradeniya

Which of above values of biodiversity are important to a society would depend on its stage of development and the cultural association with environment Generally poor developing countries, under the present economic context, would value more the direct uses that give immediate benefits, whilst affluent developed countries would value the existence of biodiversity

2 3 Causes of Loss of Biodiversity

Of the flowering plants known in Sri Lanka 14 3% are considered threatened of extinction It is also believed that 13 orchid species have been extinct (Steel 1996) Of snakes known to have existed in 1950 least 10% are not recorded currently Of the more visible animals, within a century the elephant population has dropped from about 10 000 to 3 000

Sri Lanka have had 311 known paddy varieties (Perera, 1995) of which most are extinct It is believed that the genetic diversity of plantation crops too have drastically dropped [10]

The loss of biodiversity arises when the rate of extinction of species far exceeds the rate of creation The physical causes of biodiversity loss are habitat loss degradation and fragmentation, destructive exploitation of resources introduction of species alien to habitats, pollution and global climate change Underlying some of these physical causes of loss of biodiversity are socio-economic causes The economic causes of biodiversity losses are development pressure due to population increase, market failures (property rights, externalities, uncertainty and irreversibility, market imperfections), policy intervention failure (ineffective positive interventions and unintentional negative interventions through fiscal, monetary, land policy etc,) and political failure (inherent weaknesses in political systems and lack of political will, etc,) The economic causes of biodiversity loss is elaborated below

10 Personal communications with the Coconut Research Institute Research Board

2.3 1 Economic development

Though sustainable development is desired, in practice little has been achieved in terms of investments to avert and rectify environmental degradation (Pilapitiya, 1996) Over-consumption, population growth, expansion of infrastructure and mono-cropped areas are some of the direct economic development related causes of loss of biodiversity Indirectly factors such as inequities in the distribution of wealth could too lead to loss of biodiversity (Flint, 1991)

Mass scale loss of biodiversity in the wet zone occurred clearly due to mono-crop plantation cultivation of coffee tea rubber and coconut etc by colonial governments Since gaining independence in 1948 further forest areas were rapidly cleared for the expansion of irrigated paddy cultivation in the dry zone and hydro power generation About 50% of the loss of natural forest since independence was due to these large scale development projects The Mahaweli development project alone lead to the clearance of about 200,000 ha of natural forest, displacing about 20% of the elephant population (NARESA, 1991) As a result of the development activities the forest cover has decreased from 84% of the land area in 1881 to 23 9% in 1992

The impact on biodiversity in terms of loss of species in natural habitats due to development activities of the past will never be known The threat of future survival of species will become greater as their habitats diminish and gets fragmented The forest cover in the wet intermediate and montane zones, which is more important in terms of biodiversity and environmental services contributes only 15 9% to the total forest cover (NARESA 1991) Because of dense human population the loss of biodiversity is greatest in the wet zone where endemism is highest (FSMP, 1995) However, recent studies show that the rate of natural forest depletion (clear felling) has stabilized (Wategodakumbura and Kotagama 1995) Nevertheless, selective illegal over-harvesting of natural forest timber and non-timber forest products, for domestic or export may further cause the loss of biodiversity in the future too [11]

11 Personal communications Mr Sunil Liyanage Forest Department Sri Lanka

2 3 2 Market failure

The market is the most widely used (including Sri Lanka)economics system Whilst the market system is efficient in allocating many resources it clearly fails in the allocation of biodiversity resource The market fails in the allocation of biodiversity due to imperfections in the market, lack of non-attenuated property rights, prevalence of externalities, public goods, and inability of the market to derive true preferences of society intra and inter-generational The market is unable to reveal and appropriate the total economic value of biodiversity Hence, Sri Lankan society continues to take economic decisions based on under-valuation of biodiversity

Nanayakkara (1995) has studied the 'Intellectual Property Rights (IPR)' in Relation to biodiversity conservation It reveals that the present Sri Lankan patent regulations as heavily biased towards industrial patenting and does not provide for defining property rights on biodiversity It has recommended that property rights of biodiversity to be vested on the state Outside (international) access to genetic resources to be provided on valid prospecting agreement However definition of detailed property rights would be worthy is questionable Property rights would be worthy and effective only if markets develop for biodiversity prospecting The international evidences suggest that effective biodiversity prospecting markets may not develop (Simpson et al 1996) Nevertheless on the principle of 'precautionary management of resources' developing property rights on biodiversity should be a national priority

2 3 3 Policy failure

When markets fail to achieve socially desired allocation of resources governments may through economic policy intervene to correct market failures These policies could take the form of direct market regulations such as price fixing of inputs and commodities, setting aside resource use (conservation areas) and allocating quotas for production and indirect market regulations through fiscal (government income and expenditure) and monetary (regulation of money markets) controls

The government institutions may be inefficient in the management of resources due to internalities and private goals, redundant and rising costs, derived externalities and

distributional inequities (Wolf Jr 1979)

Government ownership of land (80% of the land in Sri Lanka) may lead to undue pressure on the privately owned marketable land for construction and agriculture leading to rapid loss of biodiversity in such lands In a recent study (Batagalla and Kotagama, 1996) it was found that nearly 90% of the land under Kandyan Forest Gardens have been privately owned *(sinnakara)* for least two generations These lands are the first to be used to construct houses due to high security of tenure Also it was found that land fragmentation and thus reduction in the land holding size lead to reduced diversity of species

In 1965 lands in the Knuckles forest range was alienated to private entrepreneurs to cultivate cardamom with the aim of earning foreign exchange This lead to rapid illegal cultivation of cardamom which has destroyed the biodiversity of the forest The number of trees in the natural forests of Knuckles has been 7, 21 and 67 in the top, middle and low lavers, respectively This has changed to 9, 4 and 4 in the top, middle and bottom layers respectivelv in cardamom cultivated areas

Other than above cursory observation there has not been deliberate research on examining the impact of economic policy on biodiversity Policy changes could have more environmental impacts than several projects[12], since policies effect the whole nation many economic sectors and all individual decisions made on resource use

Fiscal policies - taxes and subsidies - though implemented to achieve certain desired social objectives may lead to unintended loss of biodiversity Subsidies given for mono-cropped agriculture may lead to clearing of forests (as may be the case around Sinharaja forest in the cultivation of tea) or biodiversity rich home gardens (as may be the case of Kandyan Forest Gardens) etc These issues are being currently researched (Battagala and Kotagama 1996) The effect of monetary policy (regulation of domestic money markets and exchange rates) on biodiversity has not been studied in Sri Lanka

12 Projects are investment activities that are clearly identified in terms geographical temporal administrative boundaries etc Environmental impact assessments should be done for specified projects in Sri Lanka

Political failure

l systems are expected to represent society's preferences and allocate resource he market fails However, the political system too could fail This is due to short orizons of political planning, encouraged by short periodic electoral systems and ie to electoral divisions of contiguous natural resource bases and politicians g to competitively satisfy her/his constituency The economic management of ersity requires a long term planning horizon and preferably a national plan ce electoral activity These issues have not been given the due importance despite ource use decisions are very clearly and dominantly taken by the political system Lanka Given the rapid changes that are occurring in the sphere of political s in Sri Lanka socio-economists may want to investigate the impact on ersity of such change

gh not 'scientifically proved' and is tautological, it is fact that weak law ement in natural resource use issues is due to - in common persons jargon - al interference' This would have lead to increased rates of agricultural chment and timber cutting etc In Sinharaja only 66% of the forest remains forests rest has been encroached (Bavnard and Fernando 1988) [13]

nservation of biodiversity is an up-hill climbing task', given the present political nic system, in which the individual, the nation and the present generation is The costs of biodiversity conservation is private, national and borne by present tion as foregone development opportunities but some of the benefits of ersity conservation is public, international and are promised for the future Since nkan society has opted the market economic system and the global inclinations are wards the persistence of the market economic system it would be best to address ilures of the market that were mentioned above to conserve biodiversity nmental economics provides a framework to address conservation of biodiversity arket economic system

13 Whether people should be totally kept away from forest for biodiversity conservation is a contentscious issue

2 4 Role of Environmental Economics in Conservation of Biodiversity

2 4 1 Market failure and role of environmental valuation

Economics is a scientific study of human behavior, of how choices are made in the allocation of scarce resources to best satiate human desires Economic theory provides an analytical frame work to examine and guide decisions on how best to allocate resources at micro levels of individual decision making and macro level of national policy making

Among the various economic systems that are adopted following are the two most prominent systems

(1) Centrally planned (command and control or communist) system The prominent feature of this system is that a central planning organization decides on resource allocation

(2) Free market (Capitalist system) The market coordinates "wishes and abilities of individuals" on consumption (demand) and production (supply) through deciding prices The relative prices decides on resource allocation

There are theoretical and practical pros and cons of the desirability of the systems Therefore many countries including Sri Lanka has adopted a mix of the two economic systems The current trend however is more inclined to adopting the market economic system

The market economic system presumes that individual values make up societal values Values of resources are not intrinsic and that value arise due to human desire to consume Thus the value for the environment arise because people desire to consume it The consumption of the environment could direct such as to convert it to other productive forms (wet land habitat used for housing and other purposes) or to use physical products that are provided naturally (fishing in natural water bodies), to use it

for amenity value of the present generation (recreation of sight seeing, swimming boating etc) or to opt to "not physically use" with the expectation of using in future (as expectations of discoveries that would benefit humankind on use of genetic resources contained in the natural environment) or opt to "not physical use" the environment for nationalistic and altruistic reasons etc , of preserving the environment for future generations

If property is defined and enforced, if perfect competition prevails [14] then the market would allocate resources efficiently, under prevailing distribution of income Efficiency is meant as a situation where resources are allocated to "best" satisfy human desires under conditions mentioned above

Despite the strength of the market system in efficient allocation of resources it has weakness internal to the system too that leads to the failure of the market These failures arise in following situations

(1) Barriers to perfectly competitive markets (such as in the case of economies of scale allowing for monopolies)

(2) Deficiencies in property rights either in defining rights or in the enforcement of rights (as the case for environmental resource such as clean air)

(3) Prevalence of public goods, i e commodities of which consumption by one individual does not reduce the amount of commodity available to another individual, (such as the enjoyment of scenic beauty)

(4) Externality when production or consumption of one person effects another and is not compensated for the benefit or the cost (such as the upstream pollution of water bodies effecting downstream uses)

(5) Missing preferences and equity

(a) Inter-generational equity Market does not represent the wishes of the poor The market works on the wishes and purchasing power

14 i e large number of buyers and sellers homogenous products free mobility of resources technology and information free entry and exit to the industry etc prevails in the market

(income) of the existing distribution of income Thus the efficiency in resource allocation may not 'best' satisfy the society on aspirations of equity (fairness) of resource allocation

(b) international equity Market does not represents the preferences of the unborn (future) generations Hence market may not allocate sufficient resources to meet needs of future generations

The market fails (due to reasons given above) in allocating most environmental resources due to its inability to price environmental resources Environmental economics offers techniques to value environmental resources within the frame work of the market economic system The valuing of benefits of environmental conservation or cost of environmental degradation in monetary term provides an objective quantitative comparable indicator, that could give guidance to policy makers to make rational decisions to efficiently allocate environmental resources

2 4 2 Economics strategy for biodiversity conservation

The conservation and use of biodiversity involves the implementation of several activities that ought to be cyclically linked These activities are identified in figure 7 Biodiversity could be conserved and used only if owners and contributors to the conservation and use of biodiversity are compensated equivalent to foregone opportunity costs and the compensations are equitably shared

For sustainable use of biodiversity it is initially required that the society through intellectual deliberation and awareness creation understand what is biodiversity and why it should be conserved [15] The outcome would be the society being convinced that biodiversity has an economic value in use and thereby need to be sustainably used The activities there on ought to be pragmatic

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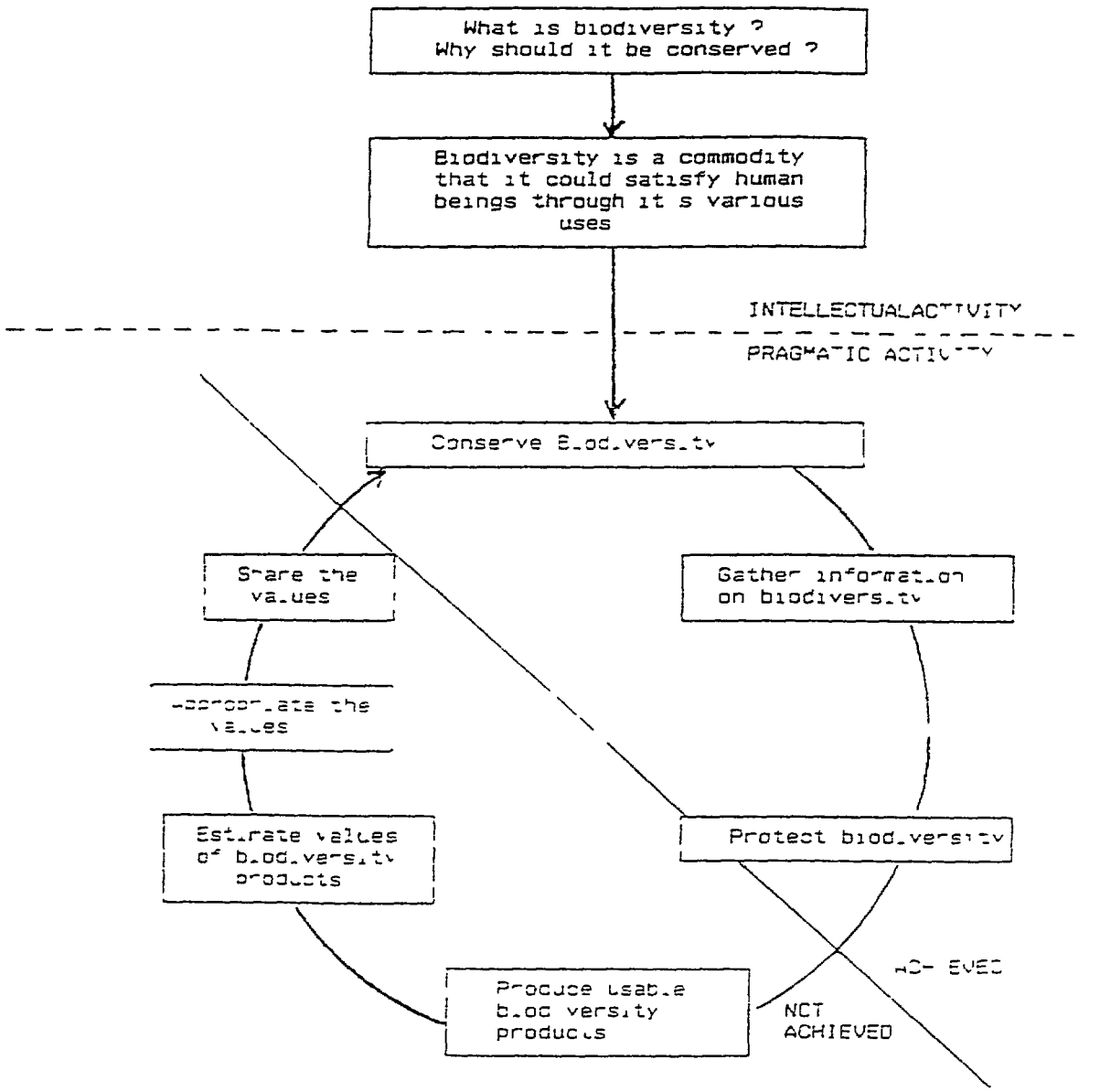
15 There isn t yet a precise understanding of what is biodiversity The absence of precise definition and measure of biodiversity hinders effective management The difference between biological resources and biodiversity remains ambiguous The ethical objective of preserving all existing biodiversity is often mixed up with anthropocentric economic objective of conserving what is of value to human beings

Figure 7 Strategy Cycle for Biodiversity Conservation and Use



It is first required to have information on bio diversity This information could be collected through research/sample surveys of fauna and flora [16] Upon having information on existing biodiversity decisions could be made on optimal extent on localities etc, to be conserved [17] Conserved biodiversity requires to be used The production of some biodiversity uses, such as genetic improvement of agricultural production possibilities would require the application of bio technology [18] Next the values of the products need to be known Since the markets do not value some of biodiversity uses (indirect use, option use, bequest use existence use) values may have to be estimated[19] These values then have to be appropriated[20] The appropriated values have to be finally shared among the custodians and those who contribute to generate use values of biodiversity [21]

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16 Information on biodiversity would help in its conservation through priority setting of habitats to be conserved and also in expediting the use of biodiversity Information gathering is intellectually stimulating and brings personal glory thus has its internalized incentive In the contrary biodiversity conservation implementation is more a public activity with most benefits external to those involved Both activities research and implementation compete for the same limited resources In the past interests and investments have beenmore on research and information gathering and rather less on implementation of bio diversity conservation

17 It need to be recognized that decisions on biodiversity conservation (ex selection habitats and extent) should be not based solely on ecological criteria but should also recognize socio economic criteria Some such socio-economic criteria are to conside the possibility of maximizing complementary benefits appropriating use values in the shortest possible time the eminence or threat, comparative advantages likelihood of success etc An approach of conserving extent of safe minimum is most appropriate

18 Although biodiversity is most found in poor countries biotechnology is most found in rich countries Therefore cooperation between rich and poor countries is required This requires processes of biodiplomacy

19 To quote the Strategy for Biodiversity Action Plan of Sri Lanka It would be useful if some quantified economic value could be placed on the components of biodiversity not only of those components that are (directly) used but also the opportunity cos of conserving biodiversity Such an economic valuation is a longstanding conundrum but one that deserves to be attempted however difficult the task and however imperfect the result achieved

20 Biodiversity prospecting refers to the process of appropriating commercial values of biodiversity products The most known example of biodiversity prospecting is between the Costa Rica s National Biodiversity Institute (INBio) and the US based pharmaceutical firm Merck & Co Ltd The agreement between the two parties was financing an initial research budget of US $ 1 135 000 (for 2 years) and that royalties would be paid to INBio of any invention of a commercial produc INBio to contribute 50% of the royalty to the government national park fund for the conservation of those

21 The highest biodiversity is found internationally and nationally among the poor nations and poor people Tropical forests that cover 7% of the earths surface contains 50% of all species However biotechnology is available in the rich countries This suggests the need for cooperation between rich and poor countries which would allow the use of biodiversity What is equally important is the sharing of the value of biodiversity Currently developing country germplasm adds US $ 50 billion/ year Developing country germplasm adds US $ 32 billion/year to the pharmaceutical industry in USA It has been estimated that medicines derived on indigenous knowledge accounts for US $ 43 000 million of which less than 0 001% goes to indigenous people

Sustainable use of biodiversity requires

[1] The completion of the cycle of activities,

[2] The benefits of biodiversity conservation and use are larger than the costs of biodiversity conservation and use, and the benefits and costs are equitably shared

Policies should be implemented to ensure that the cycle is effectively completed However at present what has been at least moderately achieved is the formal gathering of biodiversity information and the development and implementation of some strategies for conservation of mostly natural habitats Policies and strategies for biodiversity utilization has not been adequately addressed at the national level (Kotagama 1996)

For sustainable use of biodiversity it is necessary that the benefits of use are larger than costs of conservation Biodiversity conservation is a land use economic policy issue [22] The benefit of biodiversity conservation is the ability derive satisfaction through use of biodiversity directly indirectly etc The cost of biodiversity conservation is the value of development opportunities foregone on land (marine too) The opportunity cost of land would be dependent on the stage of development of the country, on macro-economic variables (fiscal policies), welfare policies, institutional strengths (property rights) etc, There are numerous land use options viz, preservation, conservation and conversion These all have a role in ensuring sustainable development Large number of biodiversity benefits which are not normally exchanged in market are generally ignored in decision making, on land use Undervaluation of these welfare enhancing services introduce distortion to efficient resources allocation Therefore any decision made on land use option must be based on the total economic value i e both marketed and non marketed benefits

22 See Pinnalanda and Kotagama (1994) on application of multi objective (conservation and agricultural) linear programming analysis on land use allocation in the Knuckles forest region

CHAPTER 3

REVIEW OF ECONOMIC THEORY VALUE OF BIODIVERSITY AND METHODS OF ESTIMATION

3 1 The Meaning of Economic Value

It is unfortunate that even economist do not agree on what is economic value Robinson (u d) an eminent economist on reviewing the meaning of economic value has concluded

> Value will not help It has no operational content It is just a word'

While such bold conclusions based on conceptual gymnastics is warranted to stretch the borders of knowledge, such may not be useful in meeting with pragmatic needs Both, economist as well as ecologists would agree on the existence of value of biodiversity They may disagree whether it could be valued and should be valued, whose values to consider if it should be valued what ought to be the unit of value etc Some of these issues are discussed below

Why Value? Valuation of biodiversity is fundamental to the effective implementation of convention on biodiversity conservation (Brown and Moran 1994) Knowing the value of biodiversity could facilitate policy decision making on conservation and use of biodiversity (such as in deciding land use for biodiversity conservation by comparing cost and benefits of alternatives land uses providing economic incentives/ dis-incentives, enacting laws etc), in prioritizing and allocating national investments for conservation and to bargain with international community to appropriate values of biodiversity etc

Whose Values? There are two discourses on the issue of whose values should be considered in the valuation of biodiversity These two are the anthropocentric and eco-centric discourses

The anthropocentric discourse which is based on western Christian ethic and market economics, considers biodiversity as a resource for human use Hence value arises on human preferences to use the resource and on the scarcity of the resource The market economic system, is able to aggregate individual preferences on resource use to derive social values - referred to as market prices Economic value is thus a relationship among people and between people and resources

An economist estimating value of biodiversity in a market economic context, is not giving her/his personal value but is deriving the values given by the society on biodiversity An economist in positive (objective) analysis is essentially 'holding a mirror to the society" If society is confused, ignorant (of the value of biodiversity) or even selfish (thus destroying biodiversity) an economic study that identifies these characteristics through low economic values should not be blamed! The economic value of biodiversity is not intrinsic, absolute or permanent It is derived, relative and dynamic It depends on dynamic relationship among people and biodiversity

The eco-centric view of value is based on the thinking that biodiversity has an intrinsic value of itself Biodiversity has it own right of existence as much as human beings do Human beings are only one component of biodiversity Every person has an legitimate right in democratic society to claim that biodiversity has its own right of existence The fact is that such preferences are forced to be revealed through the economic system If society has strong eco-centric values, society may opt not to give high values to destructive use of biodiversity

Unit of Value Money has been globally accepted as the unit of measuring value Money as unit of measurement of value enables the conversion of different forms of goods, services resources to a common comparable denominator This facilitates comparison of alternatives and thereby facilitates better decision making

Total and Marginal Value Total value refers to the total satisfaction gained in the consumption of a commodity Marginal value refers to the satisfaction gained per unit increase in the consumption of the commodity Given all other commodities consumed is kept constant, the increased consumption of a commodity will increase total value will increase at an increasing rate, then increase at a decreasing rate, reach a maximum and then

reduce Corresponding to the change in total value the marginal value will increase and then decrease This obvious law of nature can be understood by considering the consumption of any good (say rice) by any person (say your self) Air as a commodity is consumed in breathing to maintain life Thus air must have a high total value Air however has a low market value Air for breathing is rarely priced Market values are based on marginal values (the value of an additional unit) and not on total values Decisions on the quantity to consume of a commodity is based on marginal values In the market in purching a commodity a price has to be paid, i e a marginal value given up in terms of consuming some other commodity Hence a person will always equate the price (marginal value given up) to the marginal value gained in deciding the quantity of a commodity to be purchased If the price is lower than the marginal value gained more will be purchased and vise versa Air for breathing although has a high total value has a zero marginal value (a zero market price/ value) Biodiversity similarly althougn has a high total value could have a low marginal value Where marginal value is low more of it is used The purpose of economic analysis is analyzing decision making on conservation and use of biodiversity Hence the relevant concept of value is marginal value

3 2 The Concept of Total Economic Value

The value of biodiversity resource is expressed in terms of Total Economic Value (TEV) The components of TEV in relation to Sri Lanka were described in section 2 2 To briefly reiterate, TEV is comprised of Use Values (UV) and Non-Use Values (NUV) UV are Direct Use Values (DUV), Indirect Use Values (IUV) and Option Values (OV) NUV are Bequest Values (BV) and Existence Values (EV) In an Equational form TEV of biodiversity resource (say X Sinharaja habitat) can be expressed as follows

$$TEV_x = UV_x - NUV_x = (DUV_x - IUV_x - OV_x) + (BV_x + XV_x)$$

3 3 Economic Value of Biodiversity

The value of biodiversity is the difference between TEV generated by a highly diverse (say TEV_h) and a less diverse (TEV_l) biological system (gene, species, habitat), i e value of biodiversity = TEV_h - TEV_l Though this definition is conceptually correct it's practical application is difficult One would have to decide a base case (a less diverse system) to estimate values of diverse system Valuation of biodiversity without a base case may not be useful in policy decision making, where comparison is required However due to inability to accept such a base practically what is estimated as the value of biodiversity is the value of biological resources in a given habitat [23]

3 4 Techniques of Biodiversity Valuation

Valuation techniques(VT) that could value biodiversity are broadly classified as objective and subjective techniques Objective techniques initially estimates the "physical linkage" between the changes of biodiversity and the change (damage function) of marketed commodities The level of damage is subsequently valued using market prices of those commodities

The subjective valuation techniques can be classified as revealed preference and stated preference techniques Revealed preference techniques presumes that the value of biodiversity is include in the price paid for a marketed asset Therefore the price of an asset is decomposed (through econometric techniques) to estimate the value of the biodiversity The stated preference techniques directly elicit (by survey techniques) the value of the biodiversity from individuals The principle upon which each VT is based, the steps of conducting the valuation the advantages and disadvantages of using each techniques is briefly explained next A possible application is also mentioned

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23 Nevertheless there are economic studies that have even considered the genetic differences between species to guide policy decision making on what species to preserve (Weitzman 1993)

3 4 1 Objective Valuation Techniques

3 4 1 1 Productivity change

Principle

Where a change in biodiversity, effects a change in the production of a marketable commodity, the value of biodiversity is estimated by the market value of the change in quantity of the commodity

Method

The method consists of two steps as follows

(1) Estimating the relationship between the change in biodiversity and the change in quantity of marketable commodity

(2) Estimating monetary value The change in the quantity of the commodity is multiplied by the market price of the commodity

Advantages

(1) If data are available, the method is analytically simple

(2) Due to the pure scientific base on the estimation of damage function and close relation to market it is intelligible, and it appeals to pure scientists who do not receive knowledge on economics and other social sciences

Disadvantages

(1) Data on damage function are not readily available Even if available may be

site specific Estimation of damage functions could be expensive in terms of time and resources required Estimating damage function could have technical problems of isolating the cause and effect from other extraneous factors and of accounting for natural change that occur

(2) Market prices use for valuation may be distorted (doest not represent true social values)

(3) Only use value of biodiversity could be estimated

Possible Application

Ornamental fish are sold to foreign and local markets on a explicit market price Coral reefs are breeding grounds and living habitat for many types of fish The ornamental fish industry in Sri Lanka is largely dependent on coral reef habitats The coral reefs are being depleted rapidly due to various economic activities ranging from direct extraction to produce lime and due to coastal pollution etc An example is the coral reef in the Hexade marine sanctuary

The value of biodiversity of a coral reef could be estimated if the technical relationship between loss of coral reef biodiversity and loss of ornamental fishery is established

3 4 1 2 Preventive cost and replacement cost

Principle

The value biodiversity is estimated by estimating the cost people incur to prevent change on biodiversity or the expenditure people would incur to replace the changed biodiversity to its initial state

Method

Two methods could be used

(1) Estimate the actual cost people incur to prevent or restore change in biodiversity

(2) Estimate the preventive or restoration costs based on opinion of technical experts

Advantages

(1) Does not require sophisticated methods of analysis

(2) Due to the clear intuitive principle the preventive or restoration cost estimates may readily be acceptable by those with no knowledge in economics

Disadvantages

(1) The preventive cost technique assumes that people are aware of change in biodiversity and would take preventive action

(2) The technique is biased on values of the rich who could afford preventive cost

(3) The technique assumes that the benefit from preventive cost is solely the prevention of damage due to loss of biodiversity, whereas the expenditure could give other benefits too

(4) Replacement cost assumes that the original biodiversity could be fully restored This may not be technically possible

(5) The methods will recognize values only of those people who are attempting to avert the damage due to loss of biodiversity by being on-site It may not recognize the values of those people who have totally moved from the site of the damage in anticipation of it

Possible application

Elephants are a endangered species The elephant population is dwindling rapidly due to habitat destruction There are many attempts to prevent further reduction in the elephant population Those attempts take different forms viz, investing on electrical fences, driving elephant to better habitat etc The cost of these investment done to prevent the extinction of elephants may be considered as the value society (willingness to pay) gives to conserving elephants Also it is found that farmers in the Handapanagala have change the crops cultivated to crops that elephant do not consume The cost of this change (though may be low) is an prevention of damage to crops by elephants

3 4 1 3 Human capital

Principle

Where biodiversity effects the health of people, the value of productivity lost (or gained), medical treatment cost (or saving) and in the case of death the present value of lost (or saved) productivity of the person is considered as the value of the biodiversity

Method

The application of the human capital approach is similar to that of productivity loss (gain) approach It requires to established the link between biodiversity and the effect on human health and the number of persons effected is quantified the loss (or gain) of working days and the wages earned are known to estimate the value biodiversity

Advantages

(1) The analytical method is simple
(2) Intelligible to policy makers

Disadvantages

(1) The labor markets (wage) and health care markets (price of health care) may be distorted

(2) To consider the value of unemployed and poor as zero could be an inequitable proposition

(3) Psychological costs of suffering and long term chronic conditions of illness will not be valued

(4) Valuing human life monetarily may be ethically objected

Possible application

In situation where degradation of biodiversity leads to an increase of disease causing insect / organism The value of biodiversity can be estimated in terms of loss of human capital The value of medicinal plants used directly in producing medicines can be valued interms of value of expensive substitute medicines or values of lives saved

3 4 1 4 Hedonic value

Of the two hedonic techniques of valuation viz, Property value and Wage differential techniques only the property value method is relevant in valuing biodiversity

Principle

In the absence of a market for biodiversity the value of it is obtained from prices of surrogates of property values Thus it is presumed that the property value encompass a value of biodiversity Further that the value of biodiversity could be decomposed if all other factors determining property value are known

Method

Data is collected on the value of property in varying biodiversity habitats and the factors

effecting the property value Through regressing the property value with the factors determine those along with biodiversity variables the value of biodiversity is estimated

Advantages

(1) Could estimate TEV

Disadvantages

(1) Needs a large data base
(2) Needs use of statistical techniques viz regression Problems with use of regression technique are therefore associated with the technique
(3) Biodiversity as a variable may not be accurately quantifiable as required for regression
(4) Markets for property and may be distorted due to government intervention
(5) People may not be aware of the biodiversity quality difference
(6) Not so intelligible to technical scientists and policy makers

Possible application

Divers landscapes fauna and flora make-up beautiful sceneries Land site that face beautiful sceneries fetch high price than otherwise Tourist hotel demands such sites resulting to increased property value Data on property values thus could be used estimate value of divers habitat

3 4 1 5 Travel cost

Principle

The value people place on biodiversity is estimated based on the cost of traveling to a site and the value of productive time that is lost, in visiting the site

Method

The area surrounding the concerned site is divided in to equi distance concentric circles/zones Visitation rates for each of the zones are calculated The visitation rates are regressed on travel costs and other socio-economic variables for each zone to derive demand curves for each zone Consumer surplus (value) is estimated from the demand curves

Advantages

(1) Total economic value of biodiversity may be estimated

Disadvantages

(1) High data requirement

(2) Analytical procedure is complicated Problems with use of regressions arises

(3) Considering the value of productive time may be erroneous if travel is undertaken during leisure or by unemployed people

(4) Travel itself may be part of the pleasure of visiting sites Hence people may spend high travel cost for the pleasure of travel rather than gain pleasure form visiting the site

(5) A trip may be to multiple sites In such situations decomposing the travel cost to a single site may difficult

(6) The value of biodiversity estimated by travel cost does not consider the total value of the environment It ignores the option and existence value It also ignores the benefits derived from the site to those who do not visit the site such as those living close to it

(7) Access to sites may be artificially controlled i e restricted market

(8) Travel costs to urban amenities may be small and travel too could be part of the pleasure Most urban amenities would be used spend leisure during non

productive times

Possible application

Sri Lanka has several habitat that are conserved for biodiversity, such as Yala national park, Horton plains Bundala etc These are visited for recreation and other purposes by many foreigners and locals Their travel cost data could be used to estimate the value of these habitat

3 4 2 Subjective Environmental Valuation Techniques

3 4 2 1 Contingent valuation

Principle

People are directly asked the willingness to pay for the conservation of biodiversity or the willingness to accept compensation for the loss benefits of biodiversity, assuming that people are aware of the implications of change in biodiversity on human welfare

Method

Sample surveys are conducted to elicits peoples valuation on willingness to pay or accept Different techniques are used (open ended questioning bidding games etc) to elicit responses

Advantage

(1) The technique is able to estimate total economic value of biodiversity
(2) The only applicable technique for valuing biodiversity components that do not have even an indirect market

Disadvantages

(1) The technique is of hypothetical nature Thus its results may not be readily accepted by technical scientists and policy makers

(2) The technique has the possibility (which could be corrected) of estimating biased values

(3) The technique requires that people are aware of the environmental problem and its likely impact

(4) The technique does not constrain the demand for a good environment on income Hence estimated values may be unrealistic

Possible application

With appropriately designed experiment the method can be applied to value species or habitats in terms of willingness to pay for their conservation

3 4 3 Multi-criteria analysis

Principle Where monetary valuation is impossible or unacceptable multi criteria analysis could be done to present trade offs between two physical variables, one representing the environment For example one could be a measure of biodiversity and the other the quantity of electricity generated through different options of generating electricity

3 5 Criteria to Assess the Potential to Apply Environmental Valuation Techniques

The criteria that could be considered in assessing the applicability of EVT's are briefly discussed below

3 5 1 Data requirement

There are two types of data that could be used viz, primary and secondary data Collection

of primary data is generally expensive It requires more trained personal and time Subjective EVT's require primary data whilst objective EVT is require secondary data Objective EVT require reliable data on damage functions, which if not available would require considerable technical expertise and experimentation to generate damage function However since damage functions are technical, it is believed that once estimated those could used in most circumstances

3 5 2 Congruence with free market

The major assumption on which EVT's are based is that the value of the environment as been derived from aggregation of individual values/preferences Price in a perfectly competitive market gives social value of resources based on individual preferences Most EVT s (except contingent valuation technique) depend indirectly on a market price of a commodity that is effected by environmental change Hence the 'degree of perfectness of the market" of the considered commodity determines the degree of accuracy of valuation

3 5 3 Ability to estimate the total economic value of the environment

The value of the environment is composed of broadly of use values and non use values Use values generally are more tangible (fisheries production) and measurable, whilst non use values are not (preserving species for the future generation) Objective EVT's are mostly unable to value non-use values of the environment whilst subjective EVT s are able, to value both use and non-use values of the environment

3 5 4 Analytical requirement

The sophistication of statistical/econometrics techniques required for the application of objective EVT s is less than that required for subjective EVT s

3 5 5 Ethical/ Cultural acceptability

Techniques such as the human capital approach may not be ethically acceptable, because it values human life Those techniques that indirectly depend on markets prices, thereby

derives values based on the existing property rights and income distribution may not be acceptable

3 5 6 Intelligibility to policy makers

Techniques that could be intuitively understood and seem plausible may be better accepted by policy maker and technical scientists in case they do not have an adequate understanding of economics

CHAPTER 4

PHARMACEUTICAL PROSPECTING VALUE OF BIODIVERSITY IN SRI LANKA

4 1 Role of Pharmaceutical Prospecting in Biodiversity Conservation

Potential to use biodiversity to produce pharmaceuticals has long been realized Around 119 pure chemical substances extracted from about 90 species of higher plants are used for medicinal purposes throughout the world The World Health Organization has listed over 21000 plant names (including synonyms) that have reported medicinal use around the world (World Conservation Monitoring Center, 1992) In the 19th century, prior to the advent of the pharmaceutical industry, medicinal preparations were derived directly from nature mostly from plants Often a mix of plant parts were processed (grinding boiling etc) and consumed The use of such medicines still continue all over the world and particularly in Sri Lanka The isolation of active ingredient/s (i e specific chemical/s that is effective in curing a disease) and mass production of pharmaceutical is recent, and has lead to the pharmaceutical industry The growth of the pharmaceutical industry has been of cyclical nature (Findeisen and Laird, 1991, Aylward, 1993) During the past 20-30 years very few major new pharmaceutical have been developed from plant sources (Aylward 1993)

In the recent years new technological developments in screening plant chemicals have rekindled the interest of the pharmaceutical industry in searching disease curing chemicals in plants In addition knowledge over the rich sources of plant chemical diversity found in the tropical rain forest may have also added to the interest to explore the potential of plants in pharmaceutical applications (Aylward, 1993)

Conservation of biodiversity is an opportunity cost in terms of alternative development opportunities foregone on land use (such as conversion of natural forests to agricultural use,

n = Number of pharmaceutical developed from plants species [40 in USA]

H = Extent of land under biodiversity conservation [1 billion hectares the approximate area of tropical forests]

According to estimates by Pearce and Moran (1994) pharmaceutical prospecting value of a hectare of land on biodiversity conservation is 20 US $ per hectare per year (Rs 400 per acre per year)

Estimates on pharmaceutical prospecting values of Moist Tropical Mexican forest made by Adger Brown Cervigni and Moran (1995) using the Pearce and Moran (1994) model are 1 6 and 90 US $/ha/yr for low, central and high estimates Assumption of this study has been (a) 5000 species is the lower estimate of the number of species in moist tropical forests in Mexico (b) Forest area 9 7 million ha , (c) Probability of success is 0 0005, (d) Royalty rate is 5% (e) Low estimate a = 0 1 Vi/n = US $ O 39 million / yr (f) Central estimate a = 0 5 Vi/n = US $ 1 billion / yr high estimate a = 1 Vi/n = US $ 7 billion / yr

Kumari (1995) using the Pearce and Moran (1994) model has estimated the pharmaceutical prospecting values of Peninsular Malaysia Table 3 gives the values estimated for protected areas

Table 3 Pharmaceutical Prospecting Value of Bio Diversity in Peninsular Malaysia (US $/ ha/ Yr)

Appropriation Rate	Low (V/n)	Medium (V/n)	High (V/n)
100%	38 73	99 30	695 11
50%	19 36	49 56	347 55
10%	3 87	9 93	69 51

Note (V/n) = $ 390 million (low) $ 1000 million (medium) and $ 7000 million (high)
H = 711472 ha N = 2826, P = 5/10000 r = 5%

Above estimates are average values and not marginal values of land under biodiversity conservation It is the marginal value that is used in the decision making on the optimal extent of land allocation for biodiversity conservation and would be paid by interested prospectors to conserves of biodiversity (in a perfectly competitive market)

Simpson et al (1995) have estimated the 'upper bound' marginal value of a hectare of land for 18 world biodiversity 'hot spots' The value estimated for Southwestern Sri Lanka is US $ 16 84/ ha This is the second highest value next to Western Ecuador (US $ 20 65/ ha)

These studies suggest that the pharmaceutical prospecting value (average or marginal) as very low (though it could have a high variance) Thus the possibility of pharmaceutical prospecting to provide incentives (financing)for biodiversity conservation is low

4 4 Pharmaceutical Prospecting Value of Biodiversity in Sri Lanka

4 4 1 Method of analysis

This study estimated the pharmaceutical prospecting value of plant biodiversity in Sinharaja by using the Pearce and Moran (1994) model It was slightly modified to enable the calculation of average as well as marginal values of land area under biodiversity conservation

$$TV_{rp}(L) = \{ Np \quad p \quad r \quad a \quad V/n \} \text{ per annum} \quad (1)$$

It is assumed in Pearce and Moran (1994) model that the species-area relationship is linear However, the theory of island biogeography (Simpson et al, 1996 quoting MacArthur and Wilson 1967) have suggested an exponential relationship between habitat area and richness of species, viz

$$n_i = \lambda_i A_i^z \qquad (2)$$

Where the notations are,

- n_i = Number of species of a particular taxon
- λ_i = Constant that measures the species richness potential of an area The value for South Western forest in Sri Lanka is 61 46 (Simpson et al, 1995)
- A_i = Size of an area
- z = Falls between 0 15 and 0 35 or on the average 0 25 The average value is used in this study

By using equations (1) and (2) the following model can be obtained

$$TV_{mb} = \{ \lambda_i A_i^z \quad p \quad r \quad a \quad V_i/n \} \text{ per annum} \qquad (3)$$

Number of endemic species is obtained by introducing the proportion of endemic plant species to total plant species (e/n_i) to the equation (3) thus deriving equation (4) Only endemic plants are considered in the valuation because endemic plants are the plants that are economically scarce (not being found in other countries) Although non-endemic plants may have pharmaceutical values, Sri Lanka will not be able to fully appropriate such values with other countries selling the plant in the market

$$TV_{mb} = \{ \lambda_i A_i^z \quad e n_i \quad p \quad r \quad r \quad V_i n \} \text{ per annum} \quad (4)$$

$$AV_{mp} = \{ \lambda_i A_i^z \quad e/n_i \quad p \quad r \quad r \quad V_i/n \} / A_i \text{ per annum} \qquad (5)$$

$$MV_{mb} = \lambda_i \quad e/n_i \quad p \quad r \quad r \quad V_i/n \quad z \quad A^{z-1} \text{ per annum} \quad (6)$$

- AV_{mb} = Average value of land area under biodiversity conservation
- MV_{mp} = Marginal value of land area under biodiversity conservation

AV_{mp} was calculated using available national data on species diversity in Sinharaja, extent of Sinharaja and using average values of international data on probability of invention of successful plant based pharmaceutical the royalty rates, the appropriation rate Sensitivity analysis was done in order to examine the variation of pharmaceutical value for different

values of policy variables (nationally controllable variables), royalty rates and appropriation rate etc Sensitivity analysis was also done where information was uncertain, ex, species number in Sinharaja

AV_{mp} is considered as the pharmaceutical prospecting value of biodiversity on the assumption of a monopoly market for endemic biodiversity The monopoly is due to natural reasons of plant endemicity

4 4 2 Selection of location

The Sinharaja Man And Biosphere (MAB) reserve was selected for the case study since it has been studied extensively and data on species diversity was readily available The Sinharaja - low land evergreen rain forests - covers 11187 hectare of undisturbed and logged forest scrub and fern land It was declared as International Man and Biosphere Reserve by UNESCO in 1978, then a National wilderness Area in 1980 under the National Wilderness Area Act No 3 of 1980 and subsequently a World Heritage Site in 1989 (Forest Department Undated)
The value of Sinharaja is well known as a "store house of great biological wealth" It is described as a "rich treasure trove of nature with great diversity of habitats and a vast repository of Sri Lanka s endemic species"

4 4 3 Data collection

Primary data were collected by direct interviews The following institutions provided the data Ministry of Agriculture Land and Forestry (Forestry division), Ministry of Transport Environment and Women Affaire (Environment division), Environmental Foundation Limited Ceylon Institute of Scientific and Industrial Research Registry of Patent and Trade mark, Bandaranayake Memorial Ayurvedic Research Institute Faculty of Science (Botany Department) and Faculty of Medicine of the University of Peradeniya

Data used in research studies in other countries, were collected on review of literature Probability of invention of plant based pharmaceutical, the royalty rate, the appropriation rate and the average annual value of plant based pharmaceutical so far developed were collected from international literature These s and related issues were discussed with Sri Lankan researchers administrators and policy makers

4 4 4 Analysis

4 4 4 1 Relationship of plant species diversity and pharmaceutical prospecting value

A study on floral and faunal species diversity in several forests in Sri Lanka has been done by the National Conservation Review (NCR) Project of the Forests Department This study has identified only woody plant (10 cm dbh) species diversity (table 4) Pharmaceutical prospecting is however not limited to woody plants only In fact it is generally believed, based on use of plants for indigenous medicines that bushy plants do have equal or more potential on pharmaceutical prospecting Lower order plant types too have pharmaceutical prospecting potential

Table 4 Woody Plant Species Diversity in the Sinharaja Forest

Families	Genera	Species	Species			
			Unique	Endemn	Threatened	
					Nation	World
194	198	337	28	173	31	11

Source NCR data base of Forest Department

Data given in table 4 shows that 51 3 % woody plant species are endemic, 31 and 11 are threatened nationally and globally, respectively Gunatilake and Gunatilake (1996) reported that the total angiosperm flora of the Sinharaja reserve including all woody and non woody life forms in both primary and secondary vegetational elements could be estimated to be around 700 species based on several floristic surveys and herbarium collections Inclusion of lower vascular taxa such as pteridophyte, brayophytes microfungi and lichens may increase this to 1000 or even more As explained earlier (see section 5) another possibility to predict the number of species in a habitat is to use the theory of island biogeography (MacArthur and Wilson, 1967, Simpson et al, 1996) Thus the pharmaceutical prospecting value was estimated on the different sources of data on species diversity in Sinharaja and are given in table 5

Table 5 Pharmaceutical Prospecting Value with Variation of Species Diversity

Number of plant spp	Source	Proportion of endemic spp in Sinharaja	Pharmaceutical value US $/yr/ha
337	NCR data base	51 3%	62 97
632	Based on Island biogeography equation	51 3%	118 11
700	Gunatilake and Gunatilake (1996)	50 0%	127 49
1000	Gunatilake and Gunatilake (1996)	50 0%	182 13

Note x_1=61 46, z=0 25, e^{z}/n_1=0 513, p = 5 in 10000 V n = 1 63 billion r = 0 05, a = 0 1 A_1= 11187 ha

The results indicate that the pharmaceutical prospecting value as increases with increased information on species availability Therefore research studies to identify species diversity are needed in order to justify it's conservation However the increased average value per species is very low (US $ 0 18/ha/yr) requiring prudence of such research

4 4 4.2 Relationship between probability of invention of successful plant based pharmaceutical and pharmaceutical prospecting value

In the past few years, new technological development, including advances in chemical screening technologies have increased probability of invention of plant based pharmaceutical Ceylon Institute of Scientific and Industrial Research (CISIR), Medical Research Institute

and Bandaranayake Memorial Ayurvedic Research Institute are the main institutions that are involved with initial steps of pharmaceutical prospecting activities The view of all interviewed experts regarding probability of invention of successful plant based pharmaceutical were similar All of them expressed that " technological advances in Sri Lanka are not sufficient to develop successful plant based pharmaceuticals" However extensive research has been carried out in Sri Lanka examining potential to 'harness natural products' for development (Gunatilake, 1986) Over 800 species of plants have been screamed for various classes of biodiversity important phyto constituents such as alkaloids, steroids terpenoids and flavonids The studies have identified 17 plant species which have potential commercial pharmaceutical use

Balance Poganv and Forstner (1992) has reported that over the past 30 years, 90 % of new commercially pharmaceutical originated from 10 countries- the US, Japan and eight European countries The whole process of research, production and marketing of pharmaceutical products is immensely expensive and also developing countries may not have comparative advantage in investing in such industry (Simpson, 1996) However, this does not preclude Sri Lanka in undertaking some of the process within the country to retain value addition from pharmaceutical prospecting A distinction need to be made between pharmaceuticals used in western medicine and in indigenous medicine Generally western pharmaceutical are based on a single active ingredient while indigenous medicines are based on interaction of several active ingredients The focus of this study is on western pharmaceuticals

Since it is reasonable to assume that Sri Lanka at present do not have adequate capacity to invent plant based pharmaceuticals, the probability of inventing plant based pharmaceuticals on international experiences is considered in this study Principe (1991) has estimated that the probability of any given plant species giving rise to a successful pharmaceutical a between 1 in 1000 and 1 in 10000 Table 6 shows sensitivity analysis of pharmaceutical prospecting value with different probability of invention of successful plant based pharmaceutical

Table 6 Pharmaceutical Prospecting Value with Variations in Probability of Invention of Pharmaceutical

Probability of invention	Pharmaceutical value US $/ha/yr
1 in 1000 (0 001)	236 22
1 in 10000 (0 0001)	23 62
5 in 10000 (0 0005)	118 11

Note x_1=61 46 z=0 25, e/n_1=0 513, r= 5% a= 0 1 V/n = 1 63 US $ billion A_1=11187 ha

The experiences and knowledge of people who live in contact with plant and animal species is extremely important to improve the probability of invention of successful plant based pharmaceuticals This is because these communities have had hundreds of years of 'trial and error experimentation on usefulness of plants as medicines This indigenous knowledge can be used to indicate which species has high potential for pharmaceutical prospecting With the use of indigenous knowledge, research need not be done randomly at great cost Therefor forest habitats that have more records of indigenous use may fetch higher pharmaceutical prospecting value Hence in the pharmaceutical prospecting valuation a weight should be given to the degree of availability of indigenous knowledge The estimates given in table 6 shows that a small change in probability of invention could make a large change in the pharmaceutical prospecting value Hence recording indigenous knowledge on plant use may be worthy

4 4 4 3 Relationship between pharmaceutical prospecting value and patent right

Patentability and it s rights (of earning royalty) are discussed by Intellectual Property Right (IPR) Acts and related laws in a country Nanayakkara (1995) has studied Sri Lankan IPR in relation to biodiversity conservation

In Sri Lanka, the present code of IPR Act is found in Act No 52 of 1979 and No 30 of 1980 This code clearly mentions that plant and animal species can not be patented The

implication being lack of incentives to search and discover species

However, newly invented pharmaceuticals can be patented The registers of the last 15 years maintained by Registry of Patent and Trade Marks were searched It was found Sri Lanka does not have any patent for pharmaceuticals Therefore a royalty rate for plant based pharmaceuticals developed in Sri Lanka is not currently available It is reasonable thus to use the international average royalty rates

According to Pearce and Moran (1994) the existing royalty agreements involves royalty rates of 5 - 20 % for pharmaceutical development Table 7 shows sensitivity analysis of pharmaceutical prospecting value with different royalty rates The pharmaceutical prospecting value is very sensitive to the royalty rate This suggest that royalty rate is a strong policy variable that could be used to appropriate value of biodiversity

Table 7 Pharmaceutical Prospecting Value with Variation in Royalty Rate

The Royalty Rates	Pharmaceutical Value US $/ha/yr
5%	118 11
10%	236 22
15%	354 33
20%	472 44

Note λ_1=61 46, z=0 25, e/n=0 513 p= 5 in 10000 a= 0 1, V/n=US $ 1 63 billion, A_1= 11187 ha

However, the possibilities of biodiversity value appropriation is clearly dependent on a strong IPR system Genetic resources and indigenous knowledge are not sufficiently protected by existing IPR system in Sri Lanka All interviewed experts emphasized the need of strong IPR system to protect biodiversity and indigenous knowledge to appropriate value of biodiversity

4 4 4 4 Relationship between pharmaceutical prospecting value and the coefficient of rent capture (The appropriation rate)

The potential pay-off from "very highly profitable - blockbuster" pharmaceutical provide compelling argument for the identification and preservation of species rich ecosystems (Pearce and Moran, 1994) Although Sri Lanka is very rich in biodiversity, as discussed earlier, it has not been able to develop novel pharmaceuticals due to lack of technology Sri Lanka as a third world developing country, could presently engage in lower steps of pharmaceutical prospecting process of supplying raw materials (plant specimens) Whilst developed countries are involved in research production and marketing of activities of pharmaceutical prospecting process

In such circumstances the possibility for Sri Lanka to capture the potential economic benefits of biodiversity conservation is weak Ability to capture these potential economic values from invention depends on the IPR system and capabilities of the institution to appropriate value The poor institutional capability to appropriate values are well exemplified by the alleged rampant smuggling of ornamental fish species and various other fauna and flora fro Sri Lanka

Ruitenbeck (1989) suggest that rent capture is likely to be as low as 10 % in low income developing countries Table 8 shows the sensitivity analysis of the pharmaceutical prospecting value with different appropriation rates

Table 8 **Pharmaceutical Prospecting Value with Variations in Appropriation rate**

The appropriation rates	Pharmaceutical value US $/ha/yr
100%	1181 1
50%	590 6
10%	118 11
5%	59 06
1%	11 81

Note x_1=61 46 z=0.25 e/n_1=0 515 p= 5 in 10000 r= 5% Vm= US $ 1 65 billion A =11187 ha.

4 4 4 5 Relationship between annual value of a plant based pharmaceutical and pharmaceutical prospecting value

The value of pharmaceuticals could be considered in terms of the market value of pharmaceuticals or the value of lives saved Since value of lives saved may not be appropriated by the market the market value of pharmaceutical is used in this study The annual market value of a pharmaceutical have been estimated on a wide range Pearce and Moran (1994) has used a range of 0 39 to 7 billion US $ and Aylward (1993) has used 1 63 US $ (Table 9)

Table 9 Average Annual Value of Pharmaceuticals (in 1990 Dollars)

Annual value of a plant based pharmaceutical (US)	$ 390 million
Multiplier extending US data to OECD	3
Annual value of plant based pharmaceutical (OECD)	$ 1 17 billion
Multiplier extending data to world	1 4
Annual value of plant based pharmaceutical (world)	$ 1 63 billion

Source Pearce and Puroshothaman 1992 Aylward 1993

The price of the pharmaceutical reflects, of course, many more inputs than the cost of plant source materials The raw material value is usually only a very small proportion of the over all retail price of the pharmaceutical which includes factors such as research, production marketing, taxes etc Therefore estimate based on retail values of pharmaceuticals necessarily represent upper bounds on the raw materials values In that respect the pharmaceutical price grossly overstate the value of the plants and habitat The royalty rate and appropriation rates are assumed to bring down the market value of pharmaceuticals to the value of plant at host countries Equally market price could understate true willingness to pay for pharmaceutical there will be individuals who are willing to pay more than market price for pharmaceuticals

Table 10 gives the estimate of the pharmaceutical prospecting values based on above estimate of value of plant based pharmaceutical It is clearly observed that the pharmaceutical prospecting value is very sensitive to the value of plant based

pharmaceuticals The available estimate range widely as mentioned earlier and their availability is untested

Table 10 The Relationship Between Market Value of Pharmaceuticals and Pharmaceutical Prospecting Value

Market value of pharmaceuticals (Billion US $)	Pharmaceutical prospecting value (US $/ ha/Yr)
0 39	0 028
1 63	118 11
7 00	507 22

4 4 4 6 Cross sensitivity analysis on pharmaceutical prospecting value

Table 11 to 13 shows the variation of the average annual pharmaceutical value (US $) in the Sinharaja forest with the variation of the royalty rate and the appropriation rate with different probability of invention of successful plant based pharmaceutical

Table 11 Sensitivity analysis of Pharmaceutical Prospecting Value US$ Royalty Rates by Appropriation Rates given p = 1 in 1000

Appropriation rates	Royalty rates			
	5%	10%	15%	20%
100%	2361.27	4722.55	7083.83	9445.10
90%	2125.41	4250.29	6375.44	8500.59
80%	1889.02	3778.04	5667.06	7556.08
70%	1652.89	3305.78	4958.64	6611.57
60%	1416.76	2833.52	4250.29	5667.06
50%	1180.63	2361.27	3541.91	4722.55
40%	944.51	1889.02	2833.53	3778.04
30%	708.38	1416.76	2125.14	2823.53
20%	472 25	944.51	1416.76	1889 02
10%	236 12	472 25	708.38	944 51
1%	23 61	47 22	70 83	94 45

Note x_1=61 46, z=0 25, e'n=0 513, p = 1 in 1000 V/n = 1 63 billion, A_1= 11187 ha

Table 12 Sensitivity analysis of Pharmaceutical Prospecting Value US$ Royalty Rates by Appropriation Rates given p = 1 in 10000

Appropriation rate	Royalty Rates			
	5%	10%	15%	20%
100%	236 17	472 25	708.83	944.51
90%	212 51	425 02	637.54	850.05
80%	118 90	377 08	566.70	755.60
70%	165 20	330 57	495 86	661.15
60%	141 67	283 35	425 02	566 70
50%	11 81	236 12	345 19	472 25
40%	94 45	188 19	283 35	377 80
30%	70 82	141 67	212 51	283 35
20%	47 22	94 45	141 67	189 90
10%	23 61	47 25	708 38	9+ 45
1%	2 36	4 72	70 83	9 44

Note λ_1=61 46, z=0 25 e'n=0 513 p = 1 in 10000 V/n = 1 63 billion A_1= 11187 ha

Table 13 Sensitivity Analysis of Pharmaceutical Prospecting Value US$ Appropriation Rates by Royalty Rates given p = 5 in 10000

Appropriation rates	Royalty rates			
	5%	10%	15%	20%
100%	1181.63	2361.27	3541.91	4722.55
90%	1062 57	2125.41	3137.72	4250.29
80%	944.51	1889.02	2833.53	3778.04
70%	826 84	1652.89	2479.34	3305.78
60%	708.38	1416.76	2125 41	2833.53
50%	590 31	1180.63	1770.95	2361.77
40%	472 25	944.51	1416.70	1889.02
30%	354 19	708.38	1662.57	1416.76
20%	236 12	4720.25	708.38	944.51
10%	118 11	236 12	354 19	472 25
1%	11 81	23 61	35 41	47 22

Note λ =61 46 z=0 25 e/n_i=0 513 p = 5 in 10000, V/n = 1 63 billion A_i= 11187 ha

If the next best alternative of land use is cultivation of tea in the adjacent land of Sinharaja, opportunity cost of biodiversity conservation is approximately 30500 00 Rs (595 US $) per hectare per annum (Central Bank Report, 1995)

As hypothesized, pharmaceutical value that could be appropriated by biodiversity conservation must be higher than opportunity cost in order to provide incentives for conservation As shown in tables 11 to 13 the opportunity cost of land use under tea

cultivation can be compensated on combination of appropriation rates and royalty rat
indicated by hatched areas These appropriation and royalty rates are high values which m
be difficult to achieve However, the pharmaceutical prospecting value is only one value c
biodiversity conservation If the other values of TEV of biodiversity conservation ar
considered it may economically justify conservation of biodiversity The possibilities t
increase the value of pharmaceutical prospecting is briefly proposed in table 14 T
principle is to increase pharmaceutical prospecting values and decrease appropriating cost
alternative land use Separate studies need to be undertaken on each possibility proposed

Table 14 Policy Matrix for Sustainable Conservation and Use of Biodiversity

Policy Variable	Implication of change of variable	Policy Prescription
A Increasing the benefits of biodiversity use 1 N_R = Number of plant species at risk of extinction	Higher the value of NR higher would be the value of biodiversity use	Identify biodiversity (habitats species) under eminent threat of extinction of large numbers of plant animals for conservation
2 p = Probability of inventing drugs from a plant	Higher the value of p higher would be the benefits of biodiversity use	Invest on education and research on biotechnology Liase with developed countries on research Gather indigenous knowledge on use of biodiversity to support biotechnological research
3 r = Rate of royalty	Higher the value of r higher would be the benefits of biodiversity use	International negotiations establish intellectual property rights Estimate total economic value of biodiversity for royalty payments
4 a = Probability of appropriating values	Higher the value of a higher would be the benefits of biodiversity use	Address local and global market failure of biodiversity value appropriation particularly intellectual property rights on biodiversity and smuggling of biodiversity Address Local market failure due to open access insecure land tenure high uncertainty and transaction costs Address issues on local intellectual property rights on indigenous conservation and knowledge Develop effective biodiversity prospecting Link international aid to biodiversity values (GEF)

5 V = Market value one of the following 1 Market value of trade in medicinal plants 2 Market value of plant based drugs 3 Value of avoided deaths by use of plant based drugs	Higher the value of V higher would be the benefits of biodiversity use	Adopt environmental valuation techniques to estimate total economic value of biodiversity
6 N = Number of drugs based on plant species	Higher the value of n lower would be the benefit of biodiversity	Regulate supply depending on elasticities of supply and demand for biodiversity

Policy Variable	Implication of change of variable	Policy Prescription
7 H = Extent of land under biodiversity conservation	Higher the value of H lower the value of use of biodiversity	Minimize the area under conservation Select representative sample areas Consider other forms of conservation exsitu home gardens gene freezing etc
B Reducing the Opportunity Cost of Biodiversity conservation 1 Land use	land most suitable for agricultural productivity etc would increase the opportunity cost of land	Do scientifically rational land use planning Select areas that give complementary benefits such as watershed protection potential for eco tourism Select only restricted sample areas for conservation where biodiversity is very high high endemism highly threatened habitats or unique and likelihood of conservation is high
2 Economic policy distortions	Economic policy favoring forest land clearing will increase the opportunity cost of land	Remove economic policy distortions supporting clearing of forests supporting mono cropping
3 Institutional local		Establish property rights to avert open access to land
4 Institutional International		Compensate local population on opportunity cost of land on biodiversity conservation through international transfer of funds on bufferzone management activities etc

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Failure to recognize and appropriate TEV biodiversity leads depletion of biological resources Estimation and appropriation of the TEV of biodiversity is necessary for efficient conservation and use of biodiversity This study has demonstrated an economic techniques for valuing one optional use of biodiversity, viz pharmaceutical prospecting value

The results shows annual pharmaceutical prospecting value of endemic the woody plants (10 cm dbh) in the Sinharaja forest as 118 11 US $ per hectare This is an under-estimation of pharmaceutical value because not all the endemic plant species in Sinharaja were taken in to account the availability of indigenous knowledge on plant use for medicines was not explicitly recognized The value is based on market value of currently marketed western pharmaceuticals only It does not recognize that value of indigenous medicines and the values of lives saved The value of pharmaceutical prospecting is only one component of the total economic value of Sinharaja As other studies have shown the total economic value of Sinharaja is much higher Policy decision should be based on the total economic value

Sensitivity analysis on policy variables viz the appropriation rate, the royalty rate and invention of successful plant based pharmaceuticals shows that opportunity cost of land use under tea cultivation can be covered only if a = 50% and r = 27% under 5 in 10000 probability of invention of successful plant based pharmaceuticals These are high values which may be difficult to achieve, yet could be pursued The policy possibilities were summarized in table 14 The immediate need would be to establish IPR for biodiversity on a "precautionary principle" of biodiversity conservation Further research should be done to gather information on the availability of species It would be more worthy to gather information on indigenous knowledge on use of plants for medicines

The study suggests, pharmaceutical prospecting value of biodiversity alone would not provide an incentives to conservation and sustainable use of biodiversity Therefore policy on biodiversity would have to focus on valuing and appropriating other benefits of biodiversity such as direct use values (sustainable use of non timber forest products, ecotourism, medicinal plant use), indirect use values (watershed protection, ecological protection nutrient cycling) existence values etc to provide incentives for biodiversity

conservation Vertical integration in biodiversity prospecting i e developing indigenous medicines may be an alternative of appropriating value of biodiversity in the short-run This has the advantage of capturing growing markets for natural markets internationally and also using the existing patenting possibility

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