Chapter 2
Economic Systems and Ecosystems: Interlinkages, Co-evolution or Disparate Movement?

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2.1 Economic Systems and Ecosystems: How Do They Relate to Each Other?

In general parlance, an economic system is a fairly well-understood term, while ‘eco-systems’ is a somewhat esoteric one. An economic system refers to the production, distribution and consumption of goods and services in an economy and the network of societal arrangements and institutions governing them. Ecosystems are nature based categories. They have been defined as “a dynamic complex of plant, animal, and microorganism communities, and the non-living environment interacting as a functional unit.” In other words, the natural world as we understand it can be thought of as consisting of a range of ecosystems.[1] One would expect that the manner in which humankind organizes its economic activity or the ways in which it provides for its material provisioning should be based on these subdivisions of the natural landscape. This happens only in a very limited manner. For the most part economic systems and the buzz that surrounds them overshadows and supersedes substantially the role of nature. We specify below how this happens.

Economic systems are categorized, more often than not, with reference to the significant institutions through which their functions of providing for human con-

[1]The Millennium Assessment (MEA 2005) identified nine major ecosystem types among them forests, fresh water, marine, agricultural and drylands.

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sumption are performed. Broadly, three kinds of economic systems are distinguished between: traditional, centrally planned and market, respectively those where the central organizing institution is tradition, central government planning (or command) and the market. Given that a range of traditional and government institutions, market structures and social customs are inevitably associated with all economic activity, this means that each of the three economic systems referred to above focuses more on some aspects to the neglect of others. Moreover, there has occurred a gradual transition from systems based on tradition towards the other two, even as it may sometimes be claimed that all three continue to co-exist simultaneously.

Another perplexing fact is that market dominated economic systems capture a great deal of attention in the discipline, even though historically speaking, they have had a relatively short time span of existence. People were hunter-gatherers for 99.5% of human history, until the rise of agriculture began some 15,000 years ago, and markets became significant much later. Even so, production, consumption and distribution of goods and services, by markets of different kinds seem to occupy the attention of economists most of the time. This may be due to the oft-mentioned fact that whereas the rules designed by societies or by central fiat need norms and laws to be implemented, markets provide, "self-correcting" systems where the forces of demand and supply working through prices (whether of goods, services or factors of production) ensure course-correction. It was postulated that economic activity took place when factors of production entered into contracts in market situations.

The reality however is that some aspects of production, consumption and social welfare, in all economies, lie outside markets. In the main, ecosystems and the services they provide as a category belong here. For a large part of human history, when the scale of economic activity was localized and limited, these systems constituted the main focal point of economic activity. However, technological change and the ever increasing scale of production and consumption expanded the reach and operating capacity of human creativity. The organization of economic activity took place in ways far removed from the natural resource base. As the Millennium Assessment put it, this resulted in increased human well-being for large populations but also led to a lacuna in the formal understanding of the association between natural and economic systems.

2.1.1 Are Ecosystems an Intrusion into the Functioning of Economic Systems? or, Is It the Other Way Round?

Currently, a large part of the literature in the context of nature and society is about re-conceptualising the links between nature and economic systems and their significance under different situations. One way to look at the role of nature is as an intrusion into the economic space, with nature limiting the space through constraints imposed by ecosystems which in turn become binding on economic activity. This is the widely held understanding of ecological issues limiting economic activity. It is a variation of the traditional 'externality' argument in economics. In this mode of thinking, human well-being in the present is of the essence. Anything which limits an extension of the economic system to enable it to achieve higher levels of current human welfare is considered an intrusion.

A more in-depth awareness of the science behind ecosystem state and functioning results in nuances in this approach bringing in the role of irreversible as against reversible change in ecosystem states and of discontinuous changes in ecosystems. These impact economic welfare through their impact on the scale of economic activity. Witness the literature on the ecology of shallow lakes and the consequences for their economic management (Carpenter 2001; Scheffer 1997): *the deep economics of shallow lakes, as stated by an experienced practitioner of the art*.[2] Economic systems and ecosystems are treated as *interlinked entities* in this mode of analysis.

Alternative approaches, formulated under the rubric of 'ecological economics', have taken a position that the *economic system is a part of a larger ecosystem*, conceived of as the sum total of the physical world with the laws of thermo-dynamics governing it. This larger viewpoint generated perhaps a scientifically more correct view of the world (such as that of a 'space ship earth' perspective and so on). It ordained that the safe operating space within which humanity could function was determined by planetary boundaries of different kinds.[3]

But it had two deficiencies. The first emerged from the fact that it took a very macro, physical view of the earth, which must manage its whole environment and give content to the notion of optimal physical scale of the economy relative to the ecosystem by minimizing throughput and energy use. But the planetary ecosystem that it conceived of is made up of several smaller ecosystems and the limits imposed are not equally binding on all sub ecosystems and at all times and places. Secondly, it left out of its reckoning the social and individual motivations for human behavior. Behavioral sciences are not integrated into the calculus of such ecological thinking. The ecological critique of economics has a fairly long lineage but has not been able to impact mainstream economics due partly to "the separation of the natural and the social sciences".[4] An important component in any integration shall have to be via the factors determining human behavior. Also, the unwillingness of these earlier forays to consider explicitly power relations in society has also been commented on.[5]

[2]See Maler (1999).

[3]One recent exposition of this is to be found in Rockstorm et al. (2009).

[4]See Martinez-Alier (1991).

[5]See for example, Gale and M'Gonigle (2000).

2.1.2 Both as Complex Adaptive Systems

We maintain in this chapter that economic systems and ecosystems can both be viewed as complex adaptive systems. In economies as well as in nature, individual agents compete for resources, and interact with one another directly through competition, exploitation or beneficial association or co-operation. In this interaction in the competitive economy, the coordination role of prices and markets was understood right from the time of Smith (1776) and culminated in the contributions of Leon Walras (1877) and Alfred Marshall (1890). This coordination worked both to ensure co-operation and to resolve conflict over resources. Ecological systems at all levels are similar to economic systems with possibilities of competition, co-operation and conflict between individual agents in the system. Both are "composed of individual agents which adjust their behavior or their relative numbers, with consequences for the system as a whole, and these consequences can in turn affect individual behaviours".[6]

Another similarity is that individual and community (or social in the economic context) goals do not often converge: incentive mechanisms may be inadequate: or may not exist at all. Further, both kinds of systems may collapse if thresholds are breached. Though economic systems exist within the larger biosphere or ecosystem, they ignore ecological thresholds in particular. This is often because market incentives do not exist to enable individual agents to internalize such irreversibilities. If anything it is the somewhat lower level of development of market institutions that prevents economic systems from taking ecosystem based risk and uncertainty into account. In this chapter we shall discuss two directions which can be taken to correct for this underlying deficiency of economic systems in their interaction with ecosystems.

The first direction is one in which independently generated scientific knowledge is used in the framework of risk analysis and management to set limits on the domain of economic systems. We argue that the links between ecosystem functioning and economic activity need to be looked at through the lens of risk, determining thereby, a safe operating space for humanity.

The second is one where economic decision-making is strengthened by attempting to put a value on hitherto unvalued ecosystem services, in particular of the regulating, supporting and cultural kinds. The notion of linking ecosystems to human well-being through the services they provide for humans is one of the plausible ways of placing nature and its contributions in the policy domain.

We conclude the chapter by focusing on ethical issues at the core of the interlinking between economic systems and ecosystems. The value we place on the present as against the future, (more mundanely, the social rate of discount) is fundamentally a human decision and is an ethical one. Since the time frame within which change occurs in the two kinds of systems differs greatly, it becomes of the

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[6]See Arrow et al. in Barrett et al. edited (2014).

essence in determining the nature of the interaction. The economic system often drives the direction taken with a short-run perspective. It is here that the responsibility of humanity lies in adopting an informed and sufficiently long run perspective to ensure the continuance of a safe operating space.

2.2 Managing the Links Between Ecosystems and Economic Systems

2.2.1 Risk Analysis and Management

If nature is to be taken into account in the management of an economic system for development, the inherent uncertainties in the science of ecosystems should be known and factored in. We can then proceed with alternate frameworks of decision-making depending on the context for economic activity. Thus, where life-support services such as biodiversity or carbon sequestration are concerned, leaving decisions to the market will prove costly for long term economic growth. In others, such as recreational services and a range of provisioning services (food, fibre, fodder, fish) economic frameworks of analysis prove adequate where well-functioning markets exist, with built—in safe guards such as institutions to control perverse incentivisation so that basic principles provided by neoclassical economics are not violated. These include those such as the rate of regeneration not being lower than the rate of harvesting for renewable natural resources. However, here too, what is presumed is that the market for ecosystem services will function efficiently, at par with other product markets in terms of prices and costs in decision-making, with externalities fully accounted for. For instance, an assumption which is frequently violated in the real world is that of having no information asymmetry among agents. As Arrow et al. (2014) conclude, markets alone cannot create a society that is both just and sustainable.

It is, therefore, useful to adopt a ***risk analysis and management approach*** to prioritize amongst the ecosystem services which are instrumental to sustainable economic development, in particular when faced with the reality of tipping points and non-linearity in natural processes. Both the probability of and hence likely exposure to the occurrence of a change in an ecosystem service, and the economic system's ability to cope with these changes would determine the risks to social welfare (including change in physical or/and monetary values of economic assets, lives) and the need for foresight in planning for risk management. This is an important input into planning for investments in a manner conducive with acceptable levels of risk. For instance, a region well equipped with storm shelters and early warning systems may suffer low consequences, although it may fall in a high probability zone for cyclonic activity. Thus, an understanding of risks can result in appropriate planning, such that a location which is in a high-risk zone by mere biophysical parameterization, is transformed into a location in an acceptable risk zone for the community with judicious planning and investment.

An ecosystems approach towards economic decision-making has to focus on much beyond the biophysical as it seeks to accommodate the uncertainties of available knowledge, to minimize risks to ecosystems and communities dependent on these ecosystems. We consider two illustrations here that have relevance to the South Asian region, one in terms of rural areas where increasingly stress on water resources is being felt, partly due to climate change; and the other arising from pressures of fast paced urbanization.

Consider that climate change can lead to movement of species, leading to disruptions of ecosystem services such as water purification, pollination of crops or preservation of soils (Oppenheimer et al. 2014). Climate change adds to the stress caused by destruction of forested areas, acquisition of land for industrial activity and pollution of rivers, which in themselves have led to adverse impacts on biodiversity in many parts of South Asia. At the extreme, there is a risk of extinction of biodiversity. The resulting vulnerability is to the entire human and social systems as the loss in ecosystem services plays out in terms of challenges to food security, malnutrition and other such emergent risks that arise from the complex interactions of the socio-ecological and biological system. The implications for managing the risks arising from this vulnerability would be twofold:

(a) reduce the risk of biodiversity loss through non-market mechanisms such as use of a precautionary principle
(b) reduce the exposure and vulnerability of human systems through better management of land and water resources by using a range of policy instruments: market mechanisms such as efficient pricing of water to reflect its scarcity value and taxing water pollution; non market mechanisms such as protecting watersheds through legislation and community participation.

Fast paced urbanization has combined with the development of coastal areas in many parts of deltaic south Asia. These areas have become vulnerable to a host of stresses induced by sea level rise, coastal erosion, storm surges, flooding and saline intrusion (Oppenheimer et al. 2014). Climate change constitutes a threat multiplier, exacerbating the existing stresses in these areas and compounding of risks may take place as an initial risk leads to another cumulatively.

A risk management approach could comprise of:

(a) reducing impacts through adaptation strategies, building appropriate infrastructure (including through the creation of market based incentives)
(b) non market mechanisms such as investment by the public sector in projects that have high costs and low returns in the short run but high returns if all externalities are internalized (e.g. building storm shelters)
(c) managing the potential threats of displacement and conflicts among communities (those receiving populations and those displaced) through participatory and collective action among stakeholders. Thus, the impacts of extreme events can be managed, and is dependent on the economic options that are exercised to manage the risks (IPCC 2012, SREX).

These two illustrations highlight that (a) risks vary spatially and temporally and (b) effective risk management will to a large extent depend on the choices that are made based on value judgements about these risks depending on how different losses and damages are valued and ranked by society.

2.2.2 Risk Levels and Risk Management

Risk levels can be graded in terms of the probability of an adverse occurrence and the consequences of this occurrence. The extent of risk, whether high or low, will depend on the extent of exposure and vulnerability that the dynamic nature of the relationship between economic growth and the ecological system leads to. To quote from the IPCC glossary: risk is "the potential for consequences where something of human value (including humans themselves) is at stake and where the outcome is uncertain." In other words,

"Risk = (Probability of events or trends) × Consequences"

In the context of global warming for instance, the risks that may result from warming are graded from undetectable to very high, for various consequences in the recent IPCC report (IPCC, AR5, SPM WGII). Figure 2.1 presents how the risk level posed to human or natural ecosystem changes with the likely degree of warming (temperature changes discussed here are relative to 1986–2005). Current understanding is that the additional risk posed by warming at 1 °C to unique and threatened ecosystems has severe consequences, and can become very high at 2 °C warming. This includes the Arctic sea ice systems and coral reefs. However, the risks in terms of global aggregate economic impacts are moderate till 2 °C temperature rise, while risks from large scale singular events which comprise of

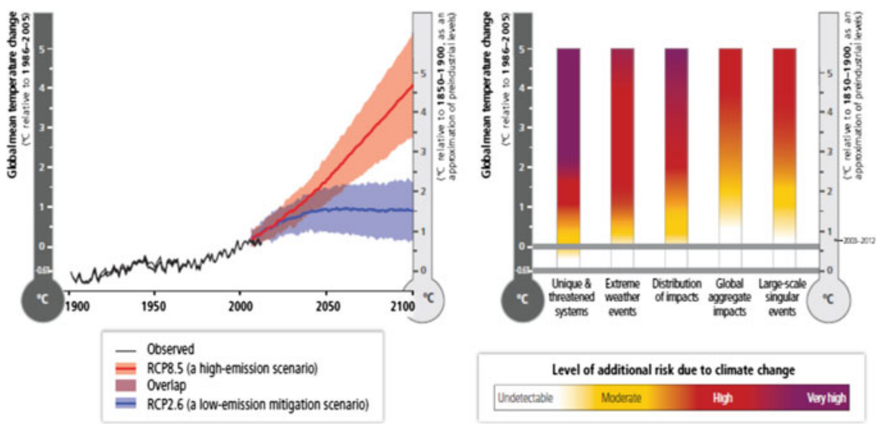

Fig. 2.1 Key risks across sectors and regions. *Source* Assessment Box SPM1. Fig. 1 (IPCC WG II, AR5, SPM, 2014). http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/ar5_wgII_spm_en.pdf

irreversibilites of ecosystems are moderate between 1 and 2 °C, and rise disproportionately to become high risk as temperature increases from 1 to 2 °C. This would include large irreversible sea level rise due to loss of ice-sheet.

To understand the linkages across risks, the adverse occurrences in the natural world and their consequences, the risk to unique and threatened ecosystems, and global distributional impacts is further elaborated upon.

Risks to species can be represented in terms of the maximum speeds at which species can move across landscapes compared with speeds at which temperatures are projected to move across landscapes (Fig. 2.2). The white bar indicates the lower bound, median and upper bound of maximum speeds at which species can move across landscapes (compared with speeds at which temperatures are projected to move across landscapes). The left vertical axis measures speeds of movement, while the right vertical axis represents climate velocities for increasing temperatures. Horizontal lines show climate velocities for global land area averages (or for large flat regions) under alternative scenarios of warming for the future at 2.6, 4.5,

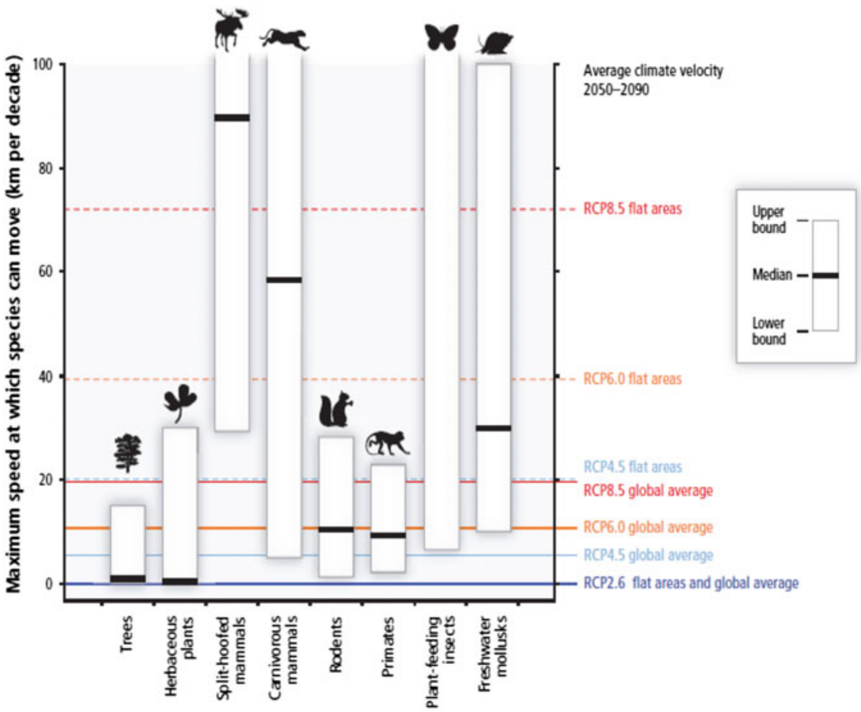

Fig. 2.2 Maximum speeds at which species can move across landscapes compared with speeds at which temperatures are projected to move across landscapes. *Source* IPCC, AR5, WG II, SPM: Fig. 5. http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/ar5_wgII_spm_en.pdf

and so on futures (namely RCPs or representative concentration pathways). Species with maximum speeds that are below these lines, are unlikely to be able to move to overcome global warming without human intervention, and thereby likely to face extinction. Thus, primates are at risk and unlikely to survive at global warming corresponding to scenarios of 4.5 whereas plant feeding insects are not at risk for any of the scenarios shown.

Risk levels are impacted by factors that mitigate the probability of an adverse event's occurrence and or its consequences. For instance human intervention can influence the consequences of economic activity on the ecosystems. Consumption patterns, population and the availability of new technology, mediate this link between exposure levels of a system to a hazard, and its vulnerability.

Thus, economic policy instruments can become crucial in regulating and determining the extent of intrusion that occurs into natural systems, due to economic activity. However, as the very grouping of risks in Fig. 2.1 indicates, decision-making on the appropriate tools and instruments involves much more than a mere aggregation of the monetized damages arising from the threats posed by climate change. Rather it calls for a reasoned balancing of the overlaps and trade-offs among these risks, and the designing of interventions that are dependent on the scale, context and level of risk.

The argument can be elaborated upon, linking Figs. 2.1 and 2.2. Since climate change impacts crop production in different parts of the world differentially for the same global temperature change, the distributional impacts when aggregated may not be considered to be too high till a 2 °C warming level is breached. However, some ecosystems (for instance coral reefs) are already under risk, as are some unique ecosystems and cultures associated with them. The risk to these increases to a high level even with a 1 °C rise in temperature. Standard economic valuation techniques can provide a limited measure of the values that maybe lost due to extinction, given the current state of the art of these techniques. In recognition of these limitations, newer techniques such as non probabilistic methodologies and use of multi criteria analysis have been encouraged to supplement such measures in decision-making as to whether a 2 °C change in temperature would be acceptable or not in such circumstances.

A recognition of the interdependence between distributional impacts, species adaptive capacity and ecosystem well being, throws up the difficulty of using only estimates of aggregative economic damages for managing the threats. Risk management would include the use of a range of instruments that encompass the traditional, market and non-market societal values.

2.3 The Role of Valuation

The notion of value to humans is another significant way in which ecosystems have been linked to economic systems. This approach is rooted in economic science and is based on the assumption that services provided by ecosystems are anthropocentric in nature. As relative value is of the essence in making choices in economic theory, valuation is extended as a principle for factoring in ecosystem services.

It follows then that the role of monetary valuation of the services provided by ecosystems comes into its own as a guiding principle when trade-offs between different ecosystem services or with other goods and services is of the essence. On the other hand, risk analysis and management approaches are relevant when thresholds in ecosystem states are significant. Even after such thresholds have been factored in, there exist a range of ecosystem services for which tradeoffs are relevant.

2.3.1 Valuation of Ecosystem Services

It can be argued that ecosystems, through the services they provide, are of value to humans. Relative value, which leads to choice or trade-offs between services is often of the essence here. In other words, more availability of one service means less of the other. A choice has to be made. This choice does not become apparent if markets do not exist for both kinds of services. Typically, provisioning services from ecosystems have been privileged at the expense of regulating services because the former enter the metric of market valuation, while the latter do not. Although there are reasonable estimates of the value of many provisioning services—where markets are most well-developed—there are few reliable estimates of the value of most cultural services and all regulating services. The literature has, of course, thrown up a slew of methods for valuation of ecosystem services, including non market valuation. A discussion of these methods and their application to valuing ecosystem services can be found in Freeman (2003), and Pagiola et al. (2004). In recent years, the literature on valuation of ecosystem services has proliferated in particular with cases studies in different parts of the world using both revealed preference and stated preference methods.[7]

However, several aspects of the contribution made by ecosystem services to present and future human well-being are still largely not accounted for, among them the following:

- The effect which regulating services have on the distribution and supply of the provisioning and cultural services.

[7]See, among others, Haque et al. (2011).

- The exact nature of the links between the state of an ecosystem (such as forests) and the ecological services accruing there-from e.g. increasing forest cover may sometimes lead to decreases in water flows and flood regulation benefits may be lower than commonly assumed.
- The existence of ecological trade-offs and the disservices such as pathogens and pests which may accrue from some ecosystems.
- The future option values of some kinds of ecosystems.

Irrespective of reservations with respect to its accuracy and relevance, valuation of ecosystem services has found favour with policy makers, mainly because it fits into the economic money-metric. Such valuation, however incomplete or partial, is then used in the application of some methods for decision-making. A benefit-cost framework (BCA) is the most often used: more recent frameworks recommended are multi-criteria, deliberative methods or participatory methods. Decision makers almost always have a preference for relationships derived from empirical investigation which (provided they are expressed transparently)are more useful than those obtained only through deliberation[8] and BCA gets privileged on this count. This may result in ill-conceived analysis with erroneous policy implications, in particular when inputs from other approaches are not incorporated in decision-making.

In India, for instance, the understanding of the economic value of forest ecosystem goods and services in India is majorly impacted by various considerations depending on the scale at which the services are considered and the stakeholders' perceptions can vary significantly. On one hand, there is substantial mineral wealth below the ground in many forested regions of the country, for instance in states such as Orissa, Madhya Pradesh, Chattisgarh and Jharkhand. On the other, the forests themselves are of high and substantial ecological value, including biodiversity and habitat, and the sustenance of flows in rain-fed rivers which originate here and therefore support water related economic activities such as agriculture, downstream pastures, and inland navigation. Which of these should be given precedence? In this context, Mukhopadhyaya and Kadekodi (2012) provide an analysis of how a misplaced use of benefit-cost analysis with an under-valuation of forest ecosystem services can provide misleading pointers in favour of mining.

There is also a significant population of forest dwellers many of whom are critically dependent on these forests for both economic and socio-cultural reasons. The fact that large numbers of forest peoples (i.e. both forest inhabitants and forest adjacent communities) reside in states with poverty levels well above the national average, implies that decision-making based on the monetized values of ecosystem services would be erroneous in terms of its impact on sustainability of livelihoods of the poor. As per the methodology recommended by the Planning Commission Expert Group on Poverty (2009), the poverty level in states with a high number of forest dwellers is substantially higher. Concerns regarding the above issues have proved difficult to address in terms of quantitative approaches to deriving values. In

[8]See, for instance the discussion in Lele and Srinivasan (2013).

fact issues of marginalization and giving voice to diverse stakeholders, has led to the development of literature on the relevant language of valuation (Martinez-Alier et al. 2010) and on alternative approaches for assessing ecosystem services (Puroshothaman et al. 2013). At another level, recognition of the need to take "a middle of the road" approach have led to the refinement of methodology towards 'disaggregated benefit-cost approaches' as well (Lele and Srinivasan 2013).

Ecosystem services and their interdependencies have been assessed at macro scales as well. Climate change has forced recognition of the contribution ecosystem services make to economic growth at a macro level as increasingly evidenced by an upsurge in academic modelling exercises computing costs imposed by climate change in aggregate terms of loss in GDP (Stern 2007; IPCC 2014). At a macro scale, for instance, ADB and IFPRI (2009) estimate that for Asia, the annual spending for coping with adverse agricultural impacts of climate change between 2010 and 2050 lies in the range of $4.2–$5 billion. At the sectoral level, agriculture has received attention in costing and valuation studies on climate change. Dasgupta et al. (2013a) estimate that India could experience a decline of up to 18% in foodgrain production between 2030 and 2050. Kumar and Parikh (2001) estimated that a 2.0 °C rise in temperature and 7% increase in precipitation would lead to about 8.4% loss in net revenue in agriculture in India.

In other words, in a range of issues the determination of trade-offs, opportunity costs and benefits provides the metric for arriving at the value of different ecosystem services. However, whereas valuation has a role to play when trade-offs exist, it needs to be used in a very careful and context specific manner. Decision criteria that emerge from CBA or cost minimizing approaches are in themselves a reflection of the privileged position given to individual rationality, the dominant value underlying most of economic analysis. We need to further ask, whether this dominant value is also the correct one in analyzing the relation between ecosystems and the economic system. Could it be that the social constructivist position which assumes that an individual is 'socially constructed' may be a better starting point for analyzing the relationship between ecosystems and economic systems?

Further, and more importantly, in the valuation paradigm, we value ecosystem services as items (e.g. provisioning, regulating), with additive or non-additive properties, whereas they can be viewed only partly as items as they are also intrinsic outputs of ecosystem structures. Vatn (2009) illustrates this aptly with reference to Wilson's definition of biodiversity.[9] This definition captures two different traditions of defining biodiversity, firstly as a set of species and secondly as a system feature.

Does valuation capture both? Very unlikely; hence the limits of this approach in examining the relationship of economic and ecosystems and the imperative to bring

[9]Wilson (2001) defines biodiversity as "The variety of organisms considered at all levels, from genetic variants belonging to the same species through arrays of species, to arrays of genera, families, and still higher taxonomic levels; includes the variety of ecosystems, which comprise both the communities of organisms with particular habitats and the physical conditions under which they live" (p. 377).

in an analysis of system structures, and likelihoods of changes in them through a reliance on risk analysis and management.

2.3.2 Can Valuation Play a Role in Risk Management Approaches?

The role that economic valuation can play in building ecological sustainability, can also be visualised in terms of its contributions towards decision-making that reduces vulnerability to risks and increases resilience of both human and natural systems. In recent years, there has increasingly been a consensus emerging that risk is the resultant of complex interactions among ecological and socioeconomic systems, and that the social construction of risk should be through the concept of vulnerability (IPCC 2012; Oppenheimer et al. 2014). Vulnerability and resilience increasingly require conceptualisation in terms of risks and we look at this issue in the South Asian context.

Rural-urban spaces are being re-defined in the South Asian context, where rapid urbanisation is projected and new types of land-use and economic activity are emerging in what were more traditionally defined spaces for such economic activity (Dasgupta et al. 2014). Similarly, the role of small scale technology in adaptation for alleviating climate change and the importance of the value of knowledge embedded in specific members of rural communities is increasingly recognised, for instance in the water sector such as rain water harvesting, irrigation, improved efficiency and water allocation rights (Hatcho et al. 2010; Rivera-Ferre et al. 2013; Ngoundo et al. 2007). Most of the recent revival in agricultural growth rates in India is being attributed to the growth in coarse cereals with renewed focus on dryland agriculture, rather than the contribution of intensive irrigation based dominant cereals such as rice and wheat. In this context, there is an increasing recognition of moving towards a risk minimization approach, with or without valuation, recognising the uncertainties of ecosystems, and in particular with regard to climate change and climate variability. India's drought prone areas programme, watershed development programmes are in the nature of welfare enhancement that is linked to recognition of trying to ensure thresholds levels of well being that minimise risk for the farmers concerned. Once we place risk minimisation at the centre of policy making, economic valuation can help in *identifying the damages or losses from risks and the costs of adopting strategies to reduce the risks.* Potentially large, irreparable losses or damages to the ecosystem pose severe risks, and may call for varied policy approaches primarily invoking the precautionary principle towards managing risks.

However, what is more widespread is the losses of ecosystem services which are often small, slow in their progress, and considered to be marginal and therefore tend to be neglected in economic decision-making. The impacts are ignored till these reach a magnitude which constitutes a severe risk or threat such as near complete loss of a water body such as a lake which has been dying gradually due to dumping of solid waste; or the accumulation of suspended particulate matter in a city from industrial pollution.

Economic valuation has been used extensively in *evaluating the impacts of such small perturbations,* those which are often slowly evolving over time and lead to gradual loss of ecosystem services. A range of valuation techniques have been used, focused primarily on monetizing values for both marketed and non-marketed or partially marketed ecosystem services. In the context of South Asia in particular, a large number of these studies have been motivated by the importance of natural resources in contributing to the livelihoods of communities dependent on them, and a recognition of the need to thereby conserve and nurture them, quite distinct from an international perspective such as the one on transboundary sharing of water resources or of the consequences of global warming. These studies span a range of sectors and find that values of ecosystem services are significant for sustaining livelihoods and should be accounted for in economic decision-making. A range of techniques have been used in valuing ecosystem services in the region—namely, Bangladesh, Pakistan, Nepal, India, and Sri Lanka (Dasgupta 2009; Haque et al. 2011); forests and common property resources (Chopra and Dasgupta 2008; Khan 2011), mangroves (Adhikari et al. 2010; Das 2011), wetlands and rivers (Alam 2008; Alam and Marinova 2003; Dasgupta et al. 2013b; Dehlavi and Adil 2011), floods (ADB 2011), pollution reduction (Adhikari 2012; Dasgupta 2004; Bogahawatte and Janaranjana 2011; Murty et al. 2011) and in specific contexts of distributional implications (Jacoby et al. 2011).

An international initiative, TEEB (The Economics of Ecosystems and Biodiversity) has put together the estimates based on different case studies in eleven different biomes (such as oceans, coral reefs, coastal wetlands etc.) for about 22 ecosystem services. It is clear that not all services are quantifiable and the estimates vary greatly across biomes. Figure 2.3 provides a sample from these estimates.

In some situations, risk management strategies offer win-win solutions and are pursued with zeal because these address a range of developmental goals, while concomitantly reducing stress on natural resources, such as reducing over harvesting of NTFPs or over grazing if alternative livelihood options open up. Examples of such management strategies include poverty alleviation or good governance. Examples of situations of synergies include the use of abatement technology that reduces local pollution and increases the availability of resources (clean air, safe drinking water) for immediate consumption, increasingly being termed as co-benefits in the literature.

There are also situations where the trade-offs are much sharper and economic valuation contributes by helping decision-makers internalize the environmental externalities. Here, informed and often tough choices are to be made such as the extent to which one should invest in climate resilient infrastructure given the uncertainties of the future. Economic valuation has been and continues to be an important contribution to decision-making.

	Open oceans	Coral reefs	Coastal systems	Coastal wetlands	Inland wetlands	Lakes and rivers	Tropical forests	Temperate and boreal forests	Woodlands	Grasslands
TOTAL	84	1195478	79580	215349	44597	13488	23222	4863	1950	3091
PROVISIONING SERVICES	22	20892	7549	8289	9709	5776	9384	1736	862	715
Food	22	3752	7517	2600	2090	196	1204	1204	203	82
Freshwater supply				4240	5189	5580	875	455		602
Raw materials		16792	32	1414	2430		3723	54	659	31
Genetic resources							1799			
Medicinal resources				35			1782	23		
Ornamental resources		348								
REGULATING SERVICES	62	33640	30451	135361	23018	4978	7135	456	1088	2067
Influence on air quality							957			
Climate regulation	55			4677	351		761	376	387	1661
Moderation of extreme events		33556		9729	4430		340			
Regulation of water flows					9369		36	3		
Waste treatment/water purification		77		120200	4280	4978	665	77	701	358
Erosion prevention				755			3211			47
Nutrient cycling and maintenance of soil fertility			30451		4588		1067			
Pollination							99			
Biological control	7	7								
HABITAT SERVICES	0	56137	164	68795	3471	0	5277	2575	0	298
Lifecycle maintenance			164	59645	917					
Gene pool protection		56137		9150	2554		5277	2575		298
CULTURAL SERVICES	0	1084809	41416	2904	8399	2733	1426	96	0	11
Aesthetic information		27317			3906					
Opportunities for recreation and tourism		1057492	41416	2904	3700	2733	1426	96		11
Inspiration for culture, art and design					793					

Fig. 2.3 TEEB estimates of the maximum value of 20 ecosystem services in 11 biomes (in 2007 dollars per hectare per year). *Note* Not all services were valued. *Source* Kumar (2010)

However and increasingly, the inadequacies of economic valuations in managing risks have led to demands for multi metric approaches, where some values are quantified, of which some are monetised, while a large quantum of values are qualitative in nature. These include the valuation of socio-cultural aspects of ecosystem services (Vihervaara et al. 2010; Martín-López et al. 2012; De Groot et al. 2010), and constitute a recognition of the fact that institutions within which values are articulated are themselves not ideologically neutral (Gómez-Baggethun et al. 2010). Hence, there is scope for better decision-making through complimentary processes of non-monetized valuation (Chan et al. 2012a, b). A recognition that is most important is that economic criteria can by themselves prove inadequate, and real time decision-making requires inputs from multiple disciplines. It is known that equity matters, with people showing distinct aversion to risk, and to inequality (Dietz and Atkinson 2010).

However, the challenge lies in articulating this in a meaningful manner in policies, that recognize that the socioeconomic and ecological systems are complex adaptive systems that are interdependent. For instance, it is important to integrate policy interventions that lead a social system to retain desired attributes or get back to a desired state after adverse perturbations. This would be a marker of increased resilience and robustness (Arrow et al. 2014).

2.4 Concluding Remarks: The Role of Ethical Considerations

We have argued in the preceding sections that ecosystems and economic systems are best perceived as complex adaptive systems, coevolving in different but interlinked ways. Two ways of designing policy with respect to these linkages are considered: the risk and management approach and the valuation approach. We argue that the two approaches can be used in different contexts and also complement each other in some. However, underlying both is an ethical concern with services and well-being in the future, both of humans and non-human species.

How we value the welfare of future generations and non-human species are the core questions which determine the stance we take as individuals, communities and governments. In economic decision making, in a limited manner, the social rate of discount reflects this value (Dasgupta 2008) and it is now accepted that lower rates of discount are to be applied to investments in natural resources which yield ecosystem services. In a manner of speaking a new norm has been created in the realm of knowledge for policy. Norms and values are created very slowly but they also stay ensconced for long. Some literature exists on how humans think beyond self interest in varying situations. Hodgson and Geoffrey (2012) for instance, holds that the interplay of self-interest and moral impulses has the potential to lead to changes in preferences and behaviour. When this happens, we will be able to move towards a rights-based approach to the sharing of some of our threatened resources and to a more stable co-evolution of economic systems and ecosystems. Meanwhile, we will need to depend on second best instruments such as risk analysis and management and valuation to move towards a balance in the relationships between ecosystems and economic systems as they co-evolve, moving, at times, in disparate trajectories.

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