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Developing Payment of Ecosystem Services Mechanisms for Sanjay Gandhi National Park- A Revenue Generating Model

A Collaborative Study

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Introduction to ecosystem services

The term 'ecosystem services' define the many different benefits that ecosystems provide to people (MA, 2005)[1]. Ecosystems can produce a diversity of services simultaneously. For example, a stand of trees can reduce air pollution, purify the water supply, reduce the likelihood of floods and help regulate the climate by capturing and storing carbon. It might also provide timber for buildings, a space for recreation and improve the aesthetic qualities of the landscape. Benefits to people span multiple aspects of human well-being, including basic biophysical security, materials for viable livelihoods (food, shelter, clothing, energy, etc., or resources from which to generate the income necessary to purchase them), freedom and choice, good health, and good social-cultural relations.

There are two-way interactions between people and the ecosystems that support them, flows of ecosystem services support human well-being but ecosystems in turn are influenced by the means by which people exploit their services. These human-ecosystem linkages occur at all scales: from the local to the global; in all places in the world, from the least to the most developed; and for all peoples, from the poorest to the wealthiest and the rural to the urban and industrialized. Differential levels of ecosystem exploitation and damage raise important issues of equity in terms of the distribution of benefits and losses in both space and time resulting from changing flows of ecosystem services. These issues can only be satisfactorily resolved by adopting a comprehensive approach to development that simultaneously considers ecological, social and economic outcomes, balancing the interests of all affected groups, as well as benefits achieved in the present relative to options available to future generations.

Evidence in recent decades of escalating human impacts on ecological systems worldwide raises concerns about the consequences of changes in all of the world's ecosystems for human well-being. Human well-being can be enhanced through sustainable uses of ecosystems, supported by appropriate instruments, institutions, organizations and technology. Creation of these through participation and transparency may contribute to people's freedoms and choices and to increased economic, social, and ecological security. Conversely, and more commonly, exploitation of ecosystems for narrow purposes and immediate gains tends to undermine ecosystem integrity, functioning and generation of a wide range of services.

We identify direct and indirect pathways between ecosystem change and human well-being, both positive and negative. Indirect effects are characterized by more complex webs of causation, involving social, economic, technology choice and political threads. Threshold points exist, beyond which rapid changes to ecosystems can occur with potentially detrimental outcomes for human well-being. Marginalised, poorly resourced and otherwise disadvantaged communities are generally the most vulnerable to adverse ecosystem change. Spirals, both positive and negative, can occur for any population, but the poor are more vulnerable.

Ecosystems and ecosystem services are constantly changing, driven by societal changes – demographic, economic, socio-political, technological and behavioural – which influence demand for goods and services and the ways we manage our natural resources. The impacts of human activities on ecosystems have increased rapidly in the last few decades. While many of these are beneficial to human well-being, for example increases in the efficiency of food production, there is growing evidence of adverse effects for many of the range of ecosystem services. Ecosystems and their services may be directly affected by conversion of natural habitats, pollution of air, land and water, over-exploitation of terrestrial, marine and freshwater resources, invasive species and climate change. From late 1947 (post Indian independence) onwards, emphasis in India was placed on maximising production of goods to meet human needs for food, fibre, timber, energy and water. While productivity increased, there was an initial decline in the delivery of a range of other ecosystem services, particularly those relating to biodiversity and air, water and soil quality.

Despite some improvements in environmental management, many ecosystem services are still far below their full potential – often as a consequence of long-term declines in habitat extent or condition, or both – and some continue to deteriorate, with a range of adverse impacts on human well-being. A growing population, urbanisation and industrialisation trends, compounded by the increasing impacts of climate change, mean that the future is likely to bring more challenges. India will remain an active trading nation, with substantial flows of biomass across its borders, generating a substantial ecological 'footprint' overseas while simultaneously being affected by social, economic and ecological changes elsewhere and within the country as well. This is, in fact, a global phenomenon, as observed by the Millennium Ecosystem Assessment (2005) and the UK National Ecosystem Assessment (UK NEA 2011)[2].

Types of ecosystem services

Ecosystem services are diverse in nature, relating to the many ways in which ecosystems support human health, wealth creation and life potential. They include, for example, production of ecosystem goods (such as seafood, wild game, forage, timber, biomass fuels, natural fibers, and many pharmaceuticals, industrial products, and their precursors, many of them important and familiar parts of the human economy) but also services maintaining ambient conditions and enriching the human experience (Holdren and Ehrlich 1974[3]; Ehrlich and Ehrlich 1981[4]).

The Millennium Ecosystem Assessment (2005) presented a consistent global classification of ecosystem services recognizing four qualitatively different categories:

1. Provisioning services, which relate to materials and energy extracted from ecosystems, such as food, timber, natural medicines and harnessing flows of energy;
2. Regulating services, spanning services such as purification of water, flood control, or regulation of air quality or the climate (particularly via carbon sequestration);
3. Cultural services, defining less material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and tourism, and aesthetic experiences; and finally
4. Supporting services, relating to processes within ecosystems, such as nutrient and water cycling, soil formation and habitat for wildlife, which are essential the functioning, resilience and capacity of ecosystems to produce all other services.

Examples of ecosystem services within each category are provided in Table 1 below. Note that some subsequent reclassifications of ecosystem services (for example TEEB, 2010[5]; Braat and de Groot, 2012[6]) redefine supporting services as functions, omitting them from valuation in to avoid 'double-counting' benefits. However, we explicitly retain supporting services in this analysis, recognising the necessity of integrating their vital underpinning roles into decision-making contexts to avert undermining the functioning and resilience of ecosystems, including their capacities to generate other services.

Category	Examples of ecosystem services provided
Provisioning services i.e. products obtained from ecosystems	• Food e.g. crops, fruit, fish • Fibre and fuel e.g. timber, wool • Biochemicals, natural medicines and pharmaceuticals • Genetic resources: genes and genetic information used for animal/plant breeding and biotechnology • Ornamental resources e.g. shells, flowers
Regulating services i.e. benefits obtained from the regulation of ecosystem processes	• Air-quality maintenance: ecosystems contribute chemicals to and extract chemicals from the atmosphere • Climate regulation e.g. land cover can affect local temperature and precipitation; globally ecosystems affect greenhouse gas sequestration and emissions • Water regulation: ecosystems affect e.g. the timing and magnitude of runoff, flooding etc. • Erosion control: vegetative cover plays an important role in soil retention/prevention of land/asset erosion • Water purification/detoxification: ecosystems can be a source of water impurities but can also help to filter out/decompose organic waste • Natural hazard protection e.g. storms, floods, landslides • Bioremediation of waste i.e. removal of pollutants through storage, dilution, transformation and burial
Cultural services i.e. non-material benefits that people obtain through spiritual enrichment, cognitive development, recreation etc	• Spiritual and religious value: many religions attach spiritual and religious values to ecosystems • Inspiration for art, folklore, architecture etc • Social relations: ecosystems affect the types of social relations that are established e.g. fishing societies • Aesthetic values: many people find beauty in various aspects of ecosystems • Cultural heritage values: many societies place high value on the maintenance of important landscapes or species • Recreation and ecotourism
Supporting services, necessary for the production of all other ecosystem services	• Soil formation and retention • Nutrient cycling • Primary production • Water cycling • Production of atmospheric oxygen • Provision of habitat

Table 1: Examples of ecosystem services within each category (source: Defra 2007)

Provisioning services

Agro-ecosystems provide food for human consumption and, together with the associated ecosystems supporting marine and freshwater fisheries, underpin global food security. As of the year 2000, about 37 percent of Earth's land area had been converted for agricultural uses. About one-third of this area, or 11 percent of Earth's total land, is used for crops. The balance, roughly one-fourth of Earth's land area, is pastureland, which includes cultivated or wild forage crops for animals and open land used for grazing (FAO 2000)[7]. Plants and animals derived directly from marine and freshwater biodiversity provide a significant part of the human diet. Fisheries and aquaculture produced 110 million tonnes of food fish in 2006, a *per capita* supply of 16.7 kg (FAO 2009)[8]. Food in many parts of the more developed world is produced principally in intensively managed agro-ecosystems but, apart from areas devoted to wildlife conservation or recreation and those used for other production systems (e.g. forestry), most landscapes/seascapes are involved in food production to some extent. With dwindling marine fish stocks worldwide, aquaculture is considered the best means to increase fish production in order to feed an increasing human population. However, this activity, which has been growing rapidly and accounts now for half of the global fish production, is still very dependent on wild fish for seed and feed (FAO 2009) and thus on functioning natural ecosystems and biodiversity.

The provision of fuels and fibres – such as timber, cotton, jute, sisal, sugars and oils – has historically been a highly important ecosystem service. Natural systems provide a great diversity of materials used for construction and fuel, notably oils and wood that are derived directly from wild or cultivated plant species. Production of wood and non-wood forest products is the primary commercial function of 34% of the world's forests, while more than half of all forests are used for such production in combination with other functions, such as soil and water protection, biodiversity conservation and recreation. Yet only 3.8% of global forest cover corresponds to forest plantations, indicating that a substantial fraction of natural forests is used for productive uses (FAO 2006)[9]. Many other ecosystems in addition to forests, such as savannas, grasslands and marine and coastal systems, are important in delivering this service.

Genetic provisioning services cover both the genetics of agrobiodiversity and natural biodiversity. Agrobiodiversity includes the diversity of genetic resources in the traditional resources (wild types and the older domesticated landraces) together with modern cultivars. In crops, greater genetic diversity tends to improve production and resistance to pests and climate variation (Ewel 1986[10]; Altieri 1990[11]; Zhu et al. 2000[12]). In low-input systems especially, locally adapted varieties often produce higher yields or are more resistant to pests than varieties bred for high performance under optimal growing conditions (Joshi et al. 2001)[13]. Genetic resources sourced from wild ecosystems and plant and animal strains will become increasingly important in support of improved breeding programs (e.g. for crop plants, farm animals, fisheries and aquaculture) to include desirable traits for a wide range of objectives, such as increasing yield, resistance to disease, optimization of nutritional value, and adaptation to local environment and climate change. Biodiversity is of central importance as the primary resource for this service; genetic diversity is inevitably lost when biodiversity declines. All ecosystems are of potentially high importance for their genetic resources, whether realised and exploited or not.

Biochemicals, natural medicines and pharmaceuticals encompass a broad range of chemical attributes found within natural systems. Some substances are of high value, for example metabolites, pharmaceuticals, nutrients, crop protection chemicals, cosmetics and other natural products for industrial use (for example enzymes, gums, essential oils, resins, dyes, waxes), whilst others form the basis for biomimetics that may become increasingly important in nanotechnology applications as well as in wider contexts (Ninan 2009)[14]. Some of the best-characterized examples are pharmaceuticals, the value of which has been long recognized in indigenous knowledge and traditional medicine systems. It has been estimated that "of the top 150 prescription drugs used in the U.S., 118 originate from natural sources: 74% from plants, 18% from fungi, 5% from bacteria, and 3% from one vertebrate (snake species)" (ESA 2000)[15]. All ecosystems are potential storehouses of valuable biochemicals. Numerous examples can be cited from the oceans and shoreline, freshwater systems, forests, grasslands and agricultural land. Species-rich environments such as tropical forests have often been assumed to supply the majority of products.

Regulating services

Various processes within ecosystems contribute a diversity of services regulating the condition of the environment, and are consequently of high importance for human well-being. Where natural habitat is sparse, such as in urban areas, the presence of vegetation may be particularly significant in reducing air pollution and buffering noise, mitigating the "urban heat island‟ effect and reducing the impacts of climate change (Bolund and Hunhammar 1999[16]). Green areas, vegetation and trees in urban areas may also have direct health benefits, including in mental health (Nilsson et al. 2014[17]) as well as biophysical health, as for example in a study from New York correlating the presence of street trees with a significantly lower prevalence of early childhood asthma (Lovasi et al. 2008)[18]. Green area accessibility has also been linked to reduced mortality (Mitchell and Popham 2008)[19] and improved perception of general health (e.g. Maas et al 2006)[20].

The global climate is regulated by a natural "greenhouse effect" that keeps the surface of the planet at a temperature conducive to the development and maintenance of life. Numerous factors interact in the regulation of climate, including the reflection of solar radiation by clouds, dust and aerosols in the atmosphere. The principal greenhouse gas (CO_2) is absorbed by water and by vegetation (through photosynthesis), leading to storage in biomass and in soils as organic matter; storage of carbon in soils and biomass is a major regulator of climate. Other greenhouse gases, notably methane (CH_2) and oxides of nitrogen (NO_x), are regulated by soil microbes and potentially modified by moisture and redox potential. Organisms in the marine environment play a significant role in climate control through their regulation of carbon fluxes, by acting as a reserve or sink for CO_2 in living tissue, and by facilitating burial of carbon in sea bed sediments (Beaumont et al. 2007)[21]. The capacity of the marine environment to act as gas and climate regulator is very dependent on its biodiversity.

Natural hazards include extreme and/or episodic events that may pose a high level of threat to life, health or property. Living organisms can form and create barriers or buffers to natural hazards. For example, forests (including mangroves), coral reefs, seagrasses, kelp forests, wetlands and dunes can mitigate the effects of some natural hazards such as coastal storms (Wells et al. 2006)[22], hurricanes (Costanza et al. 2006)[23], tsunamis (Kathiresan and Rajendran 2005)[24], avalanches (Gruber and Bartelt 2007)[25], wild fires (Guenni et al. 2005)[26] and landslides (Sidle et al. 2006)[27]. Wind breaks from managed woodlands, hedges or natural forests can play significant roles in protecting crops and habitations against both violent storms and general damage from exposure to high winds.

Water regulation, as defined by the Millennium Ecosystem Assessment (2005), relates to regulation of hydrology including extremes such as floods and droughts as well as the timing and duration of water flows. Flooding is a problem in a wide range of ecosystems, including steep deforested catchments, flat alluvial plains and urban ecosystems with constrained water flows; ecosystems naturally ameliorate catchment-borne floods (Bradshaw et al. 2007)[28]. Coastal wetlands are known to play a major part in defence against tidal flooding. Ecosystems also buffer flows to reduce extremes of drought, and this flow buffering has importance for hydrological variability to which many species and traditional land and water use practices are adapted.

Green cover on land plays a significant role in erosion regulation. In coastal environments, marine flora and fauna can play a valuable role in the defence of coastal regions, and dampen and prevent the impact of tidal surges, storms and floods. This disturbance alleviation service is provided mainly by a diverse range of species which bind and stabilize sediments and create natural sea defences, for example salt marshes, mangrove forests, kelp forests and sea grass beds (Rönnbäck et al. 2007)[29].

In some estimates, over 75% of the world's crop plants, as well as many plants that are source species for pharmaceuticals, rely on pollination by animal vectors (Nabhan and Buchman 1997)[30]. Bees are the dominant taxon providing crop pollination services, but birds, bats, moths, flies and other insects can also be important. Richards (2001)[31] reviewed well-documented cases where low fruit or seed set by crop species, and the resulting reduction in crop yields, has been attributed to the impoverishment of pollinator diversity. Increasing evidence indicates that conserving wild pollinators in habitats adjacent to agriculture improves both the level and the stability of pollination services, leading to increased yields and income (Klein et al. 2003)[32].

Pests and diseases are regulated in ecosystems through the actions of predators and parasites as well as by the defence mechanisms of their prey. Natural control of plant pests is provided by generalist and specialist predators and parasitoids, including birds, bats, spiders, beetles, mantises, flies and wasps, as well as entomopathogenic fungi (Way and Heong 1994[33]; Naylor and Ehrlich 1997[34]; Zhang et al. 2007[35]). In the short term, this process suppresses pest damage and improves yields, while in the long term it maintains an ecological equilibrium that prevents herbivorous insects from reaching pest status (Zhang et al. 2007, Heong et al. 2007[36]). A diverse soil community will not only help prevent losses due to soil-borne pests and diseases but also promote other key biological functions of the soil, including improving soil nutrient availability for plants (Wall and Virginia 2000)[37].

Cultural services

Cultural services refer to the aesthetic, recreational (including tourism potential), spiritual, psychological and other benefits that humans obtain from contact with ecosystems, including the role of ecosystems in the formation of communities (such as villages shaped by landscape features, or cropping or fishing communities organising themselves around common resources). Although all societies value the spiritual and aesthetic services that ecosystems provide, the manifestation of this value is highly culturally relative and may be reduced in many (but not all) affluent, stable and democratic societies. Nevertheless, biodiversity plays an important role in fostering a sense of place in most societies and has considerable intrinsic cultural value. Natural landscapes also provide humans with recreational and exercise opportunities, provided by the biodiversity and geodiversity of which they comprise. Diverse cultural, intellectual and spiritual traditions contribute to a wide range of less tangible but nonetheless crucial aspects of human well-being. Walking and playing sports in green space is not only a good form of physical exercise but also lets people relax as well as a socialise, also with a significant role in combatting social isolation. The role that green space, as well as 'blue space' (proximity to water), plays in maintaining mental and physical health is increasingly being recognized, despite difficulties of measurement, for example by increasingly common prescriptions of 'green exercise' by medical professionals.

Cultural and recreational activities in the environment are the source of much economic revenue through tourism and sport. Substantial intellectual development, both artistic and scientific, is influenced directly or indirectly by interaction with and inspiration from the natural environment. Ecosystems and biodiversity play an important role for many kinds of tourism which in turn provides considerable economic benefits and is a vital source of income for many countries. In 2008, global earnings from tourism summed up to US$ 944 billion (UNWTO 2009)[38]. Cultural tourism and ecotourism can also educate people about the importance of biological diversity.

Language, knowledge and the natural environment have been intimately related throughout human history. Biodiversity, ecosystems and natural landscapes have been the source of inspiration for much of our art, culture and increasingly for science.

In many parts of the world, natural features such as specific forests, caves or mountains are considered sacred or have a religious meaning. Nature is a common element of all major religions and traditional knowledge, and associated customs are important for creating a sense of belonging.

Supporting services

Supporting services, as described above, are a distinct category recognising processes within ecosystems maintaining their integrity, functioning and capacities to provide all other provisioning, regulating and cultural services.

Soil formation occurs through a number of physical, chemical and biological processes, governed by the nature of the parent materials, biological processes, topography and climate. The progressive accumulation of organic materials is characteristic of the development of most soils, and depends on the activity of a wide range of microbes, plants and associated organisms (Lavelle and Spain 2001)[39] and is also particularly relevant as a process underpinning the climate regulating service

Soil quality is also underpinned by nutrient cycling, which occurs in all ecosystems and is strongly linked to productivity. Local recycling of water, in which evaporation and condensation processes maintain water in tight local cycles retaining it within ecosystems, is another example.

Habitat for wildlife is a discrete ecosystem service, applying not just to scarce species and other organisms of particular concern (some of which may therefore be represented as cultural services) but also to the characteristic and functional ecosystems shaped by heterogeneous spatial conditions, supporting both resident and migratory plants, animals, fungi and microorganisms and the genetic diversity within each species and group of organisms, interacting as functional whole units. Ecosystems that exhibit particularly high levels of biodiversity (biodiversity hotspots) with exceptional concentrations of endemic species are undergoing dramatic habitat loss. “As many as 44% of all species of vascular plants and 35% of all species in four vertebrate groups are confined to 25 hotspots comprising only 1.4% of the land surface of the Earth” (Myers et al. 2000)[40]. In addition to the overall importance of these ‘hotspots’ in maintaining genetic diversity, this service is of particular and immediate importance in preserving the gene-pool of most of our commercial crops and livestock species. Biodiversity and geodiversity are not explicit services, but underpin the production of harvested and cultivated products, economic and livelihood resources, and contributions to a wide range of benefits realised predominantly through provisioning, regulating and supporting services.

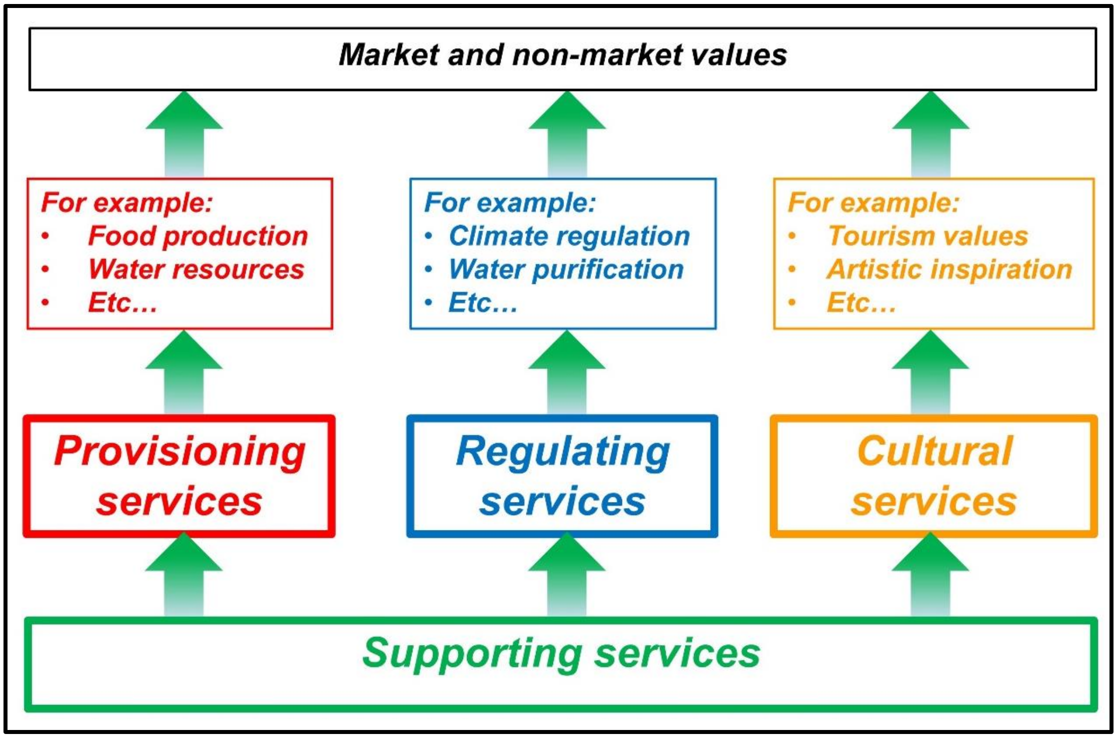


Figure 1: How ecosystem services are interconnected and contribute to flows of benefits of diverse market and non-market value to society

Systemic interconnections between ecosystem services

Understanding ecosystem systems as a fundamentally systemically interconnected whole is essential if they are to be managed sustainably. For example, ecosystems play important roles in the global hydrological cycle, contributing to water provision (quantity, defined as total water yield), regulation (timing, the seasonal distribution of flows) and purification (quality, including biological purity as well as sediment load) (Dudley and Stolton 2003[41]; Bruijnzeel 2004[42]; Brauman et al. 2007[43]). Vegetation, particularly forests, significantly influences the quantity of water circulating in a watershed. It is commonly assumed that forests generate rainfall and, in comparison with pasture and agriculture, promote higher rates of evapotranspiration and greater aerodynamic roughness, leading to increased atmospheric humidity and moisture convergence, and thus to higher probabilities of cloud formation and rainfall generation. Vegetation, microbes, and soils remove pollutants from overland flow and from groundwater through various means, including: physically trapping water and sediments; adhering to contaminants; reducing water speed to enhance infiltration; biochemical transformation of nutrients; absorbing water and nutrients from the root zone; stabilizing eroding banks; and diluting contaminated water (Brauman et al. 2007). Water reaches freshwater stores (lakes, rivers, aquifers) by a variety of routes, including direct precipitation, surface and subsurface flows, and human intervention. In all cases, the water quality is altered by the addition and removal of organisms and substances. Ecosystems therefore play a major role in determining water quality, but in so doing also simultaneously generate a wider range of other regulating, provisioning and cultural benefits.

How have ecosystems changed?

The structure of the world's ecosystems changed more rapidly in the second half of the twentieth century than at any time in recorded human history, and virtually all of Earth's ecosystems have now been significantly transformed through human actions (Millennium Ecosystem Assessment, 2005). The most significant change in the structure of ecosystems has been the transformation of approximately one quarter (24%) of Earth's terrestrial surface to cultivated systems. More land was converted to cropland in the 30 years after 1950 than in the 150 years between 1700 and 1850. Between 1960 and 2000, reservoir storage capacity quadrupled; consequently, the amount of water stored behind large dams is estimated to be three to six times the amount held by natural river channels. Approximately 35% of mangroves were lost globally in the last two decades. Roughly 20% of the world's coral reefs were lost and an additional 20% degraded in the last several decades of the twentieth century.

Although the most rapid changes in ecosystems are now taking place in developing countries, industrialised countries historically experienced comparable rates of change as they liquidated their natural resources for short-term economic gain. The ecosystems and biomes that have been most significantly altered globally by human activity include marine and freshwater ecosystems, temperate broadleaf forests, temperate grasslands, Mediterranean forests, and tropical dry forests.

Within marine systems, the world's demand for food and animal feed over the last 50 years has resulted in fishing pressure so strong that the biomass of both targeted species and those as "bycatch" has been reduced in much of the world to one tenth of the levels prior to the onset of industrial-scale fishing. Freshwater ecosystems have been modified through the creation of dams and through the withdrawal of water for human use. The construction of dams and other structures along rivers has moderately or strongly affected flows in 60% of the large river systems in the world. Within terrestrial ecosystems, more than two-thirds of the area of 2 of the world's 14 major terrestrial biomes (temperate grasslands and Mediterranean forests) and more than half of the area of 4 other biomes (tropical dry forests, temperate broadleaf forests, tropical grassland, and flooded grasslands) had been converted (primarily to agriculture) by 1990 (Millennium Ecosystem Assessment 2005)

Degradation of ecosystems

The Millennium Ecosystem Assessment (2005) also found that approximately 60% of global ecosystem services are being degraded or used unsustainably. Technological advances and changing social dynamics are the most important factors that have contributed to ecosystem degradation and associated risks: and they may be equated with the five major indirect drivers of ecosystem degradation identified by the Millennium Ecosystem Assessment. These factors are changes in: (1) population; (2) economic activity (which increased nearly sevenfold between 1950 and 2000); (3) socio-political factors; (4) cultural factors; and (5) technological changes. These factors do not all directly degrade ecosystems, but tend to operate more diffusely by amplifying and promoting the direct drivers of ecosystem degradation (such as landscape conversion, over-fishing, pollution and other factors).

Throughout the twentieth century, growing global human populations have substantially elevated demands for provisioning ecosystem services such as food, water and timber, often increasing disproportionately quicker due to factors such as industrialisation, urbanisation and increasing affluence, though generally slower than overall economic growth. This trend is still accelerating, with many provisioning services used at unsustainable rates. Humans have also substantially altered regulating services such as disease and climate regulation by modifying the ecosystems providing these services. In the case of waste processing, technological means have been innovated to supplement natural limitations on purification processes, though modifications such as the simplified hydrology resulting from construction of large dams can increase prevalence of waterborne diseases through the proliferation of vector organisms such as water snails and mosquitoes. Although the use of cultural services has continued to grow, the capability of ecosystems to provide cultural benefits has been significantly diminished in the past century due to declining ecosystem extent and quality.

Global gains in the supply of food, water, timber and other provisioning services were often achieved in past centuries despite local resource depletion and local restrictions on resource use by shifting production and harvest to new underexploited regions, sometimes considerable distances away. These options, however, are diminishing as resources become fully exploited, and the ethics of resource appropriation come under closer scrutiny.

A vital consideration in all natural resource use and management is the systemically interconnected nature of all ecosystem services. Modification of an ecosystem to exploit or alter any one ecosystem service generally results in changes to all other interconnected ecosystem services. Positive synergies are possible where actions to conserve or enhance the productive basis of the system, such as improved catchment protection yielding improved water quality and quantity, fishery and other wildlife enhancement, and aesthetic and tourism and other values, with net beneficial distributional outcomes for the diverse beneficiaries of all these services. However, the prevalent trend remains one of narrow exploitation of one or a few services – typically marketable provisioning services such as food or timber production – overlooking systemic ramifications and as often inadvertently degrading the properties of the productive system and the many benefits it provides to a range of stakeholders.

Valuation of ecosystem services

Some ecosystem services, such as timber, fishes and non-timber forest products (NTFPs), are traded in markets. However, many ecosystem services, like fresh and clean air, environmental flows of water, scenic landscapes, climate stability, etc., are not traded, so lack market values. These ecosystems are nevertheless of substantial value though lacking a monetary expression. The division of ecosystem services into four qualitatively differing categories by the Millennium Ecosystem Assessment inherently recognises the diverse value systems by which these services are appreciated and realised. The valuation of ecosystem services is an emerging area of policy appraisal, subject to considerable debate and method evolution about the extent to which the full range of costs and benefits of marginal changes in service provision can be quantified. A common method used to compare differing, often incommensurable values on a common basis is to find means to represent the societal significance of these services in financial terms, albeit that the values themselves (such as significance for spiritual, aesthetic and community cohesion) are beyond the market. These are often based on 'expressed preferences' (what people say they are will to pay or be paid) to obtain or to forego an ecosystem service. For example, surveys may determine a downstream community's preferences regarding their willingness-to-pay (WTP) for improved services, and how much an upstream community may be willing-to-accept (WTA) with regards to changing their livelihood activities to affect ecosystem services within a river basin. This kind of trading between service 'providers' and 'users', can form a basis for markets known as 'payment for ecosystem services' (PES) arrangements. Many such market mechanisms are in operation around the world, but there is need in many developing countries for a deeper understanding of PES both in terms of payment mechanism and supporting institutional arrangement (Sangkapitux et al., 2009)[44].

Given the inherent complexity of nature, a number of different dimensions of nature-based value can be discerned and evaluated in various ways. The values provided by natural resources are often considered within the framework of Total Economic Value (TEV). This framework can be adapted to value ecosystem services. TEV refers to the total gain in wellbeing from a policy measured by the net sum of 'use values' (from actual or potential exploitation) and 'non-use values' (inherent values and those available for future generations). WTP/WTA refers to the monetary measure of the value of obtaining/forgoing environmental (or other) gain or avoiding/allowing a loss.

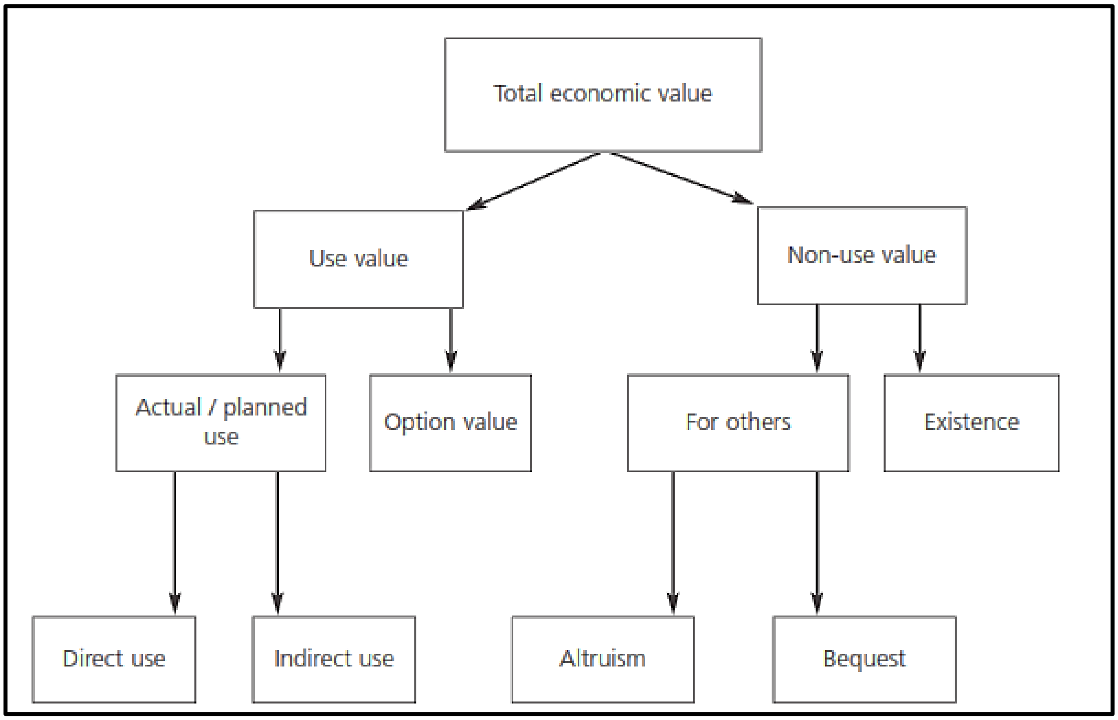


Figure 2: Total Economic Value Framework (Defra 2007)

Use value:

Direct use value*:*

This is where individuals make actual or planned use of an ecosystem service. This can be in the form of consumptive use which refers to the use of resources extracted from the ecosystem (e.g. food, timber) and non-consumptive use, which is the use of the services without extracting any elements from the ecosystem (e.g. recreation, landscape amenity). These activities can be traded on a market (e.g. timber) or can be non-marketable such as where there is no formal market on which they are traded (e.g. recreation or the inspiration people find in directly experiencing nature).

Indirect use value:

This is where individuals benefit from ecosystem services supported by a resource rather than directly using it. These ecosystem services are often not noticed by people until they are damaged or lost, yet they are very important. These services include key global life-support functions, such as the regulation of the chemical composition of the atmosphere and oceans, and climate regulation; water regulation; pollution filtering; soil retention and provision; nutrient cycling; waste decomposition; and pollination. Measuring indirect use values is often significantly more challenging than measuring direct use values. Changes in the quality or quantity of a service being provided are often difficult to measure or are poorly understood.

Option value

This is the value that people place on having the option to use a resource in the future even if they are not current users. These future uses may be either direct or indirect. An example would be a national park where people who have no specific intention to visit it may still be willing to pay something in order to keep that option open in the future. In the context of ecosystems and their services, option value describes the value placed on maintaining ecosystems and their component species and habitats for possible future uses, some of which may not yet be known. Option value can also be thought of as a form of insurance, e.g. a wide species mix in a particular habitat can provide an insurance function: as conditions change, different species may fulfil key ecological roles.

Non-use value

This is also known as passive use and is derived simply from the knowledge that the natural environment is maintained. There are three main components:

- Bequest value: where individuals attach value from the fact that the ecosystem resource will be passed on to future generations.
- Altruistic value: where individuals attach values to the availability of the ecosystem resource to others in the current generation.
- Existence value: derived from the existence of an ecosystem resource, even though an individual has no actual or planned use of it. For example, people are willing to pay for the preservation of whales, through donations, even if they know that they may never actually see a whale.

Non-use value is relatively challenging to capture since individuals find it difficult to 'put a price' on such values as they are rarely asked to do so. However, in some circumstances, non-use value may be more important than use value. For example, a study on the value of Natura 2000 sites in Scotland found that 99% of the overall value of such sites was non-use. (Jacob 2004)[45].

Chapter 2: Payments for Ecosystem Services – Concepts and Principles

Introduction

In essence, a 'payments for ecosystem services' (PES) scheme is a market-based instrument in which a market, or markets, is/are established between ecosystem service 'providers' and 'purchasers'. We are familiar with paying for the provisioning service of food produced by a farmer, and the associated trading, taxation, regulation and other arrangements that make this possible, as well as the public supply of water for which consumer charges are re-circulated to water service providers. Trading between service 'providers' and 'users' is also the essence of markets established for other ecosystem services. In 2010, the OECD (2010)[46] estimated that thousands of such PES arrangements had been established globally and at a range of scales from the highly local to the international, addressing a range of services including, for example, water supply, water quality protection, recreation, climate regulation and biodiversity protection.

Payments for ecosystem services (PES) is a voluntary transaction for an environmental service (or a land use likely to secure that service), purchased by at least one environmental service buyer from at least one environmental service provider, if and only if the environmental service provider meets the conditions of the contract and secures the environmental service provision (Wunder, 2005)[47]. The basic idea behind PES is that those who provide ecosystem services – like any service – should be paid for doing so. PES therefore provides an opportunity to put a price on previously un-priced ecosystem services like climate regulation, water quality and flood regulation, and the provision of habitat for wildlife. In so doing, a PES market brings these formerly overlooked services into the wider economy.

Neoclassical economics argues that if those responsible for managing provision of ecosystem services also benefit directly from them, the market should be able to protect and sustain these services (e.g. provisioning services, such as food and fibre; Engel et al., 2008)[48]. However, when benefits mainly accrue to others in society (e.g. downstream flood protection), markets often fail to reward service managers (e.g. upstream farmers or foresters). Conversely, some land uses and management activities provide benefits for landowners and managers at a particular location and time, at the expense of wider society. In response to this "social dilemma" (as it is characterised by Muradian et al., 2013)[49], the concept of PES is gaining increasing attention as a way to pay for, or at the very least to make visible, the societal benefits of sustainable land management (Braat and de Groot, 2008)[50].

In an influential paper, Ferraro and Kiss (2002)[51] argued that "direct" payments for biodiversity conservation were more effective and efficient than integrated conservation and development projects (ICDPs) and called for their adoption as policy tools to conserve ecosystems. Since then, the application of PES has boomed (Pattanayak *et al.* 2010)[52]. The natural environment delivers critical services that support human well-being (MEA, 2005[53]; TEEB, 2010[54]), yet these services are often forgotten or neglected in policy and land use decision-making (Scott et al., 2013)[55]. Worldwide, these services (e.g. food, water, protection from extreme weather, medicines and the health and cultural benefits people derive from nature) are estimated to be worth more than the global gross domestic product (Costanza et al. 1997)[56]. When ecosystems become degraded, the cost of restoration can be prohibitive, and restored ecosystems are often in poor imitations of the original ecosystem (Crouzeilles et al., 2016)[57]. Evidence shows that the sustainable management and protection of natural capital and ecosystem services are the most cost-effective way to sustain their benefits to human wellbeing (Ekins et al., 2003)[58].

Further aspects of payment of ecosystem services

The novelty of PES arises from its focus on the 'beneficiary pays principle', as opposed to the 'polluter pays principle'.

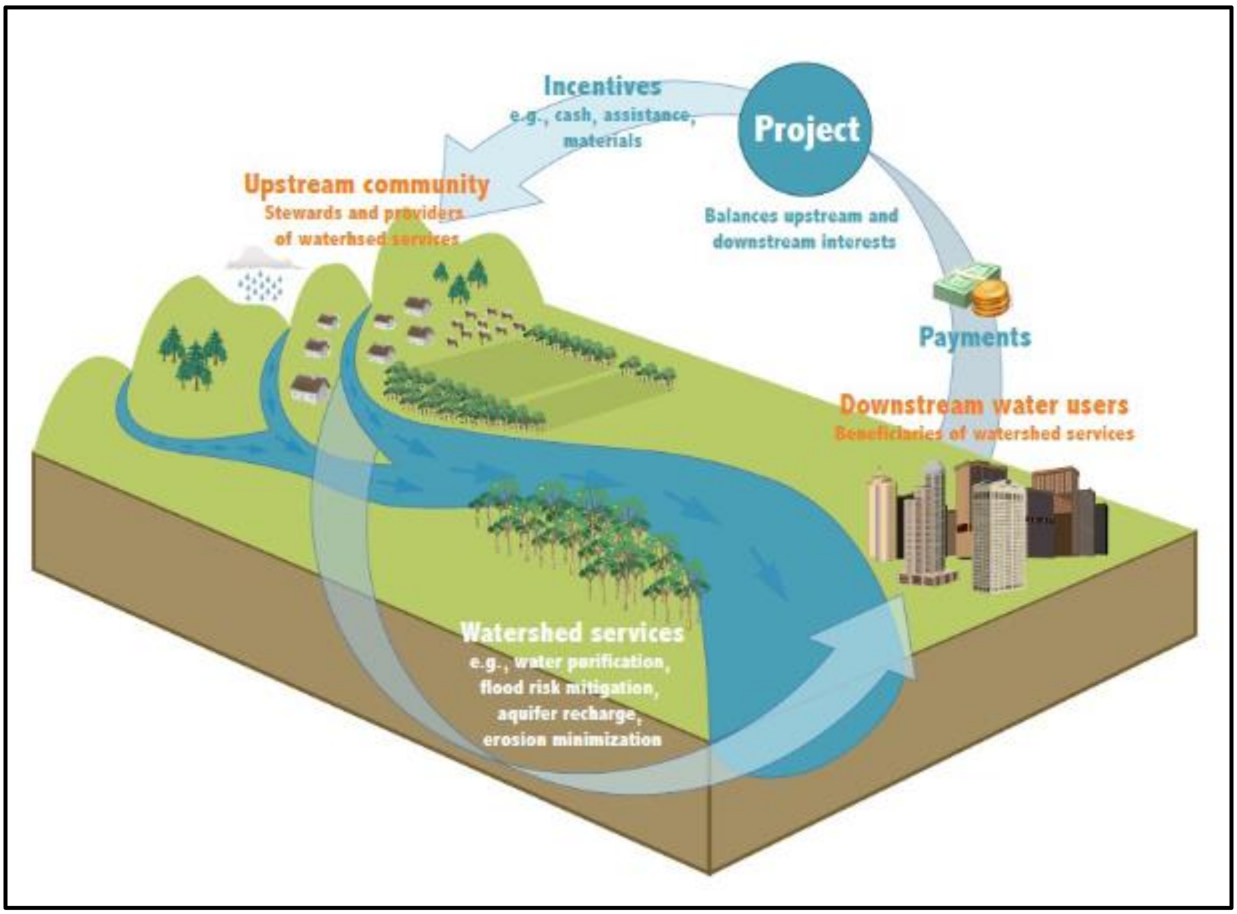


Figure 3: Concept of Payment of Ecosystem Services (Source: Bennett et al. 2013)[59]

The dominant theory for PES is based on the assumption that the undersupply of ecosystem services is the result of market failures, and therefore valuing and paying for such services will help to solve these environmental externalities (Engel *et al.* 2008). It is also argued that where providers of ecosystem services are poor landholders or disadvantaged communities, such payments can contribute to poverty alleviation (Pagiola *et al.* 2005)[60]. The possibilities of “win-win” scenarios are part of the reasons why PES have become so attractive, particularly among conservation practitioners and policy-makers in developing countries. PES offers monetary incentives to individuals or communities to voluntarily adopt behaviours that are not legally obliged, or where legislation is ineffective or impossible to implement, and which improve the provision of well-defined and quantifiable ecosystem services that it would otherwise have been economically unviable to provide (Muradian et al., 2013). However, it is important to recognise that where land or resource managers may be subject to regulation, PES should not be seen as a substitute for enforcement as a means to limit impacts on ecosystem service provision. In addition, some ecosystem service management may be neither required by legislation nor subject to PES, but may be self-beneficial, as for example in the case of reducing water usage in many applications which provides a benefit to users through direct cost savings. Many land or resource managers may also seek to protect or enhance ecosystem service provision electively in their role as custodians. Therefore, although PES provides means to increase the supply of an ecosystem service, or services, PES schemes must be carefully designed so as not to undermine existing stewardship arrangements on the part of land or other resource managers.

In a PES transaction, the beneficiary from the ecosystem service makes a payment or provides another form of reward to the land owner or person who has the rights to use the ecosystem (land or freshwater, marine), as a reward for managing the ecosystem a way that secures an ecosystem service. This payment or reward should be conditional upon the delivery of the service. In practise it may be difficult to fulfil all the conditions of PES, but it may not be necessary or appropriate to do so in some cases. For example, ‘payment by results’ related to monitored ecosystem service outcomes, that also tend to be notoriously volatile, is in practice rare, with most PES schemes based instead of land uses or other measures agreed as likely to result in protection or enhancement of the desired service(s). As shown in Fig 5, an intermediary governance structure is an important feature of PES mechanisms.

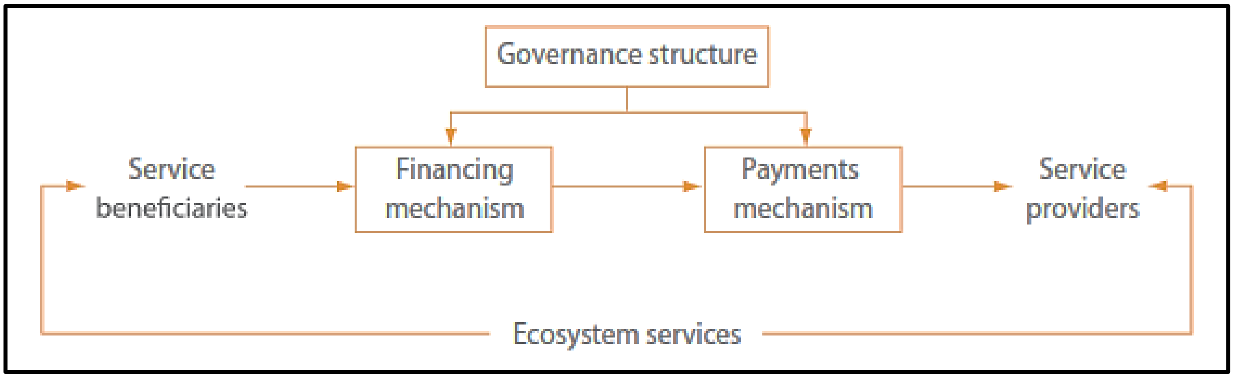


Figure 4: PES Flowchart. Source: Pagiola and Platais (2005)[61].

Types of PES scheme

According to Greiber (2011)[62] there are different types of PES schemes, namely:

a) Private schemes: direct payments by service beneficiaries to service providers, in which both providers and beneficiaries are private entities (individuals, groups of individuals, private companies); the government can participate only as an intermediary.

b) Public schemes: based on fiscal instruments (such as taxes or subsidies), relies on user fees, a government-driven system is established in which the public entity can play either as a provider or as a beneficiary.

c) Trading schemes: Government- and market- driven. It is based on a cap (aggregate maximum amount) for pollution or conversion of ecosystems, or extraction of natural resources and the allocation of permits (for pollution, conversion or extraction) which divide allowable overall total among users).

In the past decade, PES schemes have represented a growing trend in conservation policy, developing rapidly in both developed and developing countries around the world (Wunder et al., 2008)[63], mainly around three groups of environmental services:

(1) water quality and quantity, often including soil conservation measures in order to control erosion and sediment loads in rivers and reservoirs and to reduce the risk of land slides and flooding;
(2) carbon sequestration (and in some cases protection of carbon storage) to respond to demand from the voluntary and regulatory greenhouse gas emissions markets; and
(3) biodiversity conservation, by sponsoring the conservation of areas of important biodiversity (in buffer zones of protected areas, biological corridors or even in remnant patches of native vegetation in productive farms) and protecting agricultural biodiversity.

PES is a form of market-based instrument, sometimes referred to as a 'market for ecosystem services', since it is basically a new type of subsidy. However, unlike traditional subsidies that are financed by taxpayers at large, payments can be financed directly and voluntarily by the beneficiaries (users) of the ecosystem services PES help maintain. However, in essence, some subsidy schemes (such as agri-environment payments) are a form of PES, in which governments route tax revenues to resource managers on behalf of wider populations of public beneficiaries.

PES schemes are also applied at different scales, ranging from micro-watersheds to entire watersheds that may cut across state, provincial or national boundaries. WWF is exploring the possibility of a trans-boundary scheme for the Danube River. In Costa Rica, a country-wide program has been implemented since 1997, with a government agency in charge of this program as a representative of its beneficiaries. All landowners who produce one of the ecosystem services listed in the law are potential participants of the program. In other places, small-scale programs have been developed to solve specific problems such as water provision (Echaverria et al., 2004)[64]: water consumers in a locality pay landowners upstream to protect watersheds.

Scale of PES schemes

PES schemes can be developed at a range of spatial scales, including:

- **International**: examples include Reducing Emissions from Deforestation and Degradation (REDD+) whereby developing countries that are willing and able to reduce emissions from deforestation and degradation are paid by developed countries for doing so.
- **National**: for example the UK's Environmental Stewardship programme, a government-financed scheme in which about £400 million a year is paid to farmers and land managers on behalf of the public in return for more environmentally-sensitive farming.
- **Catchment**: for example, downstream water users paying for appropriate watershed management on upstream land. These schemes tend to be private-financed, for example where a water utility pays upland land managers on behalf of its customers to implement certain measures designed to stabilise or improve water quality.
- **Local / neighbourhood**: for example, a scheme whereby residents collectively fund a warden or environmental organisation to manage local green space for biodiversity, landscape and recreational value.

How PES works in practice

A system of payments for ecosystem (or environmental) services (PES) has a very simple logic: to increase the income of economic activities compatible with conservation, in order to encourage the sustainable use of natural resources, while at the same time penalizing 'predatory activities' (exploitation of benefits without investment). In an ideal system, the polluter or user must pay so that the protector or provider receives. Thus, there is an incentive to conserve the goods and services freely provided by the natural environment that are of interest, direct or indirect, to human beings. Hence, a PES is a self-interest system based on the economic assumption that agents tend to change their behaviour and attitudes according to incentives or penalties, in order to maximize their profits or utility, as far as those who benefit from the externalities provided by conservation are willing to pay (Wunder, 2005). Furthermore, PES should also be aimed at reducing poverty; how that could be implemented has been the subject of heated discussion (Ferraro, Hanauer & Sims 2011[65]; Rolón *et al*. 2011[66]). For a PES scheme to work, it must represent a win for both buyers and sellers. PES may be positive from a buyer's perspective if the payments are less than those associated with any alternative means of securing the desired service. For example, it may be less expensive for a water utility to pay land owners for improved catchment management than to pay for additional water treatment of more polluted water (Everard, 2013[67]). PES schemes may be positive from a seller's perspective if the level of payment received at least covers the value of any returns foregone as a result of implementing the agreed interventions. For example, a farmer may be willing to create ponds for enhanced water storage if the payments received at least cover the costs of doing so, including the costs associated with any lost agricultural production.

Take, for example, a change in farm management to focus on the provision of a greater range of ecosystem service benefits, for example through wetland restoration on existing cropland:

- the minimum PES payment would be generally expected to at least cover any (private) return forgone by the farmer as a result of reduced agricultural production;
- the *theoretical* maximum payment would be the cumulative value of additional ecosystem service benefits which would accrue to the buyer(s) (which might include flood risk attenuation, fresh water supply, habitat for wildlife, etc., depending on the services the buyer(s) wished to purchase); however, many of these benefits are hard to quantify, and many are 'produced' by the same types of management intervention; so
- in practice, the level at which PES payments are set would reflect supply and demand for particular ecosystem services and would be at a consensually-agreed intermediate point between the minimum and maximum values.

Multi-layered PES schemes

A PES scheme can focus on more than one ecosystem service, the services being sold then described as having been 'packaged' (Smith et al. 2013)[68]. Ecosystem services can be packaged in three distinct ways:

- **Bundling**: Bundling is defined as grouping multiple ecosystem services together in a single package to be purchased by individual or multiple buyers (Lau, 2013)[69]. A single buyer, or consortium of buyers, pays for the full package of ecosystem services that arise from the same parcel of land or body of water. As an example, an agri-environment scheme may include payment to a farmer for the range of linked ecosystem services arising from selected land use practices, with the payment coming from government on behalf of wider public beneficiaries.
- **Layering**: multiple buyers pay separately for the ecosystem services that arise from the same parcel of land or body of water; layering is also sometimes referred to as 'stacking'. For example, one buyer may pay for improved water quality resulting from land management, whilst another may pay for flood risk benefits.
- **Piggy-backing**: in this case, not all of the ecosystem services generated from a single parcel of land or body of water are sold to buyers. Instead, a single service (or possibly several services), is sold as an umbrella service, whilst the benefits provided by other services accrue to users free of charge (i.e. the beneficiaries 'free ride').

The actors involved in PES schemes

Four principal groups are typically involved in a PES scheme:

- **buyers**: beneficiaries of ecosystem services who are willing to pay for them to be safeguarded, enhanced or restored;
- **sellers**: land and resource managers whose actions can potentially secure supply of the beneficial service;
- **intermediaries**: who can serve as agents linking buyers and sellers and can help with scheme design and implementation; and
- **knowledge providers**: these include resource management experts, valuation specialists, land use planners, regulators and business and legal advisors who can provide knowledge essential to scheme development.

The way that buyers and sellers can be configured in scheme development can also vary. For example:

- ‘one-to-one’: for example, where a company enters into a contract with a single major land-owner to provide enhanced carbon sequestration;
- ‘one-to-many’: for example, where a water utility makes arrangements via a broker to pay many farm businesses for water-sensitive management practices in a key catchment;
- ‘many-to-one’: for example, where multiple buyers together invest in the development and maintenance of urban green space; and
- ‘many-to-many’: for example, where government pays farmers for sympathetic land management practices on behalf of the wider public.

These configurations are illustrated in Figure 5. For any of these configurations, an intermediary or broker may form a key part of the PES scheme and undertake various tasks including overall scheme administration. In particular, where multiple suppliers or buyers are involved, the intermediary may act on their behalf to arrange exchange and distribution of payments.

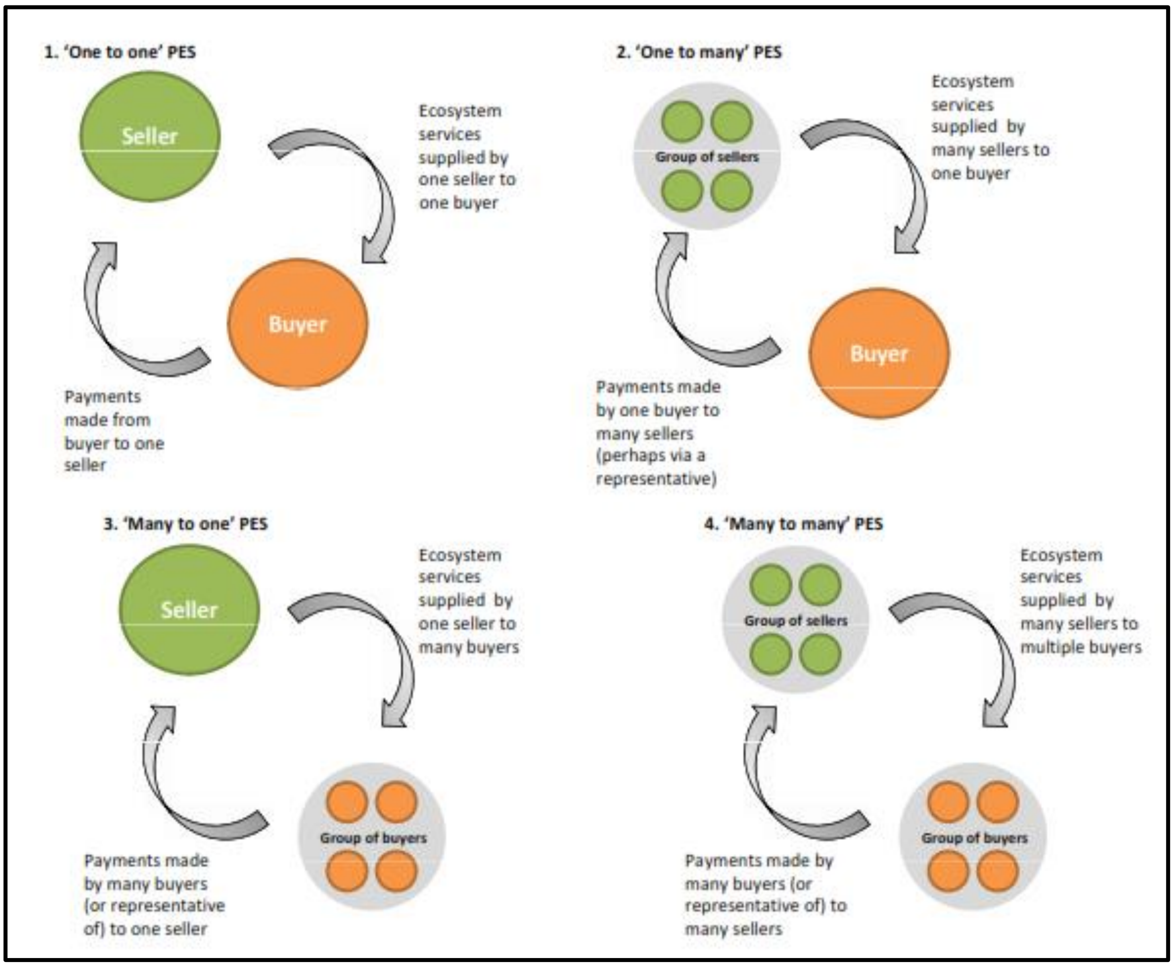


Figure 5: Possible configurations of PES schemes (Source: Smith *et al*. 2013)

Key aspects of scheme design

The mode of payment is one of the key variables in PES design. A distinction can be drawn between 'output-based' and 'input-based' payments:

- **Output-based**

Under this category payments are made on the basis of actual ecosystem services provided. For example, payments might be made for a certain level of carbon sequestration or a measured increase in biodiversity. In an ideal world, output-based payments would form the basis for all PES schemes.

- **Input-based**

Under this category payments are made on the basis of certain land or resource management practices being implemented. For example, payments might be made for the creation and maintenance of buffer strips along watercourses or the restoration and upkeep of green spaces in residential areas.

There are major challenges over the quantification and attribution of ecosystem services and their link to the values of different social groups in complex social-ecological systems at relevant spatial and temporal scales (Spash, 2009[70]; Reed et al., 2015[71]). Monetary valuation of ecosystem services has been widely used to place values on ecosystem services in the context of PES, but these techniques tend to overlook the value of cultural services and the values for ecosystem services that are shared by different social groups, as opposed to the aggregation of individual values (Kenter et al., 2015)[72]. They also tend to overlook the way in which these values may change over time for different groups e.g. due to environmental, social, economic or technological change. Bundling and layering help to resolve issues of quantification and attribution in PES schemes by quantifying and monetizing a number of different ecosystem services at the same time, linked to a specific intervention (such as peatland restoration).

Despite progress in recent years towards the development of bundled and layered schemes, three important challenges remain unresolved.

- First, despite targeting multiple ecosystem services, PES schemes typically only target single habitats and/or ecosystems, and ignore interactions between different ecosystems within the same landscape (Calvet-Mir et al., 2015)[73]. As such, PES schemes may incentivize management activities in ways that lead to trade-offs for the delivery of ecosystem services from different ecosystems within a landscape (Engel et al., 2008). For example, re-wetting peatland to reduce greenhouse gas (GHG) emissions may compromise the growth rate, and hence carbon sequestration potential of adjacent forestry (Freléchoux et al., 2000)[74]. Conversely, planting trees next to a re-wetted peatland may dry out the peat, releasing GHGs, and provide habitat for species that prey on the ground-nesting birds that were a co-benefit bundled with peat land restoration (Amar et al., 2011)[75].

- Second, there has been little consideration of interdependencies between ecological and social systems that may be affected by PES schemes. Linked to this, governance of PES schemes in such complex social-ecological systems remains challenging (Farley and Costanza, 2010[76]; Bennett and Gosnell, 2015[77]). This challenge relates to the inter-connected and quite different spatial and temporal scales at which different ecosystem services are typically managed (Schomers et al., 2015[78]; Jones et al., 2016[79]). Although there are notable exceptions where PES schemes have been developed from the bottom-up in collaboration with local communities, particularly in international development contexts (e.g. Milder et al., 2010)[80], it is common for PES schemes to be developed from the top down by Governments, conservation agencies and NGOs, or developed with only partial involvement of a narrow range of stakeholders (Pascual et al., 2014)[81].
- Finally, with the exception of nature-based tourism, most PES schemes focus on provisioning, supporting and regulating ecosystem services, giving little attention to cultural service (Church et al., 2014)[82]. This is due to: i) measurement issues related to the intangible nature of many cultural services (Chan et al. 2012)[83]; ii) ontological issues related to whether values for these services are held individually or collectively, and hence whether a single value can be ascribed to an ecosystem service in any given location, given that its value will depend on whether social values are aggregated from individual values or negotiated between social groups (Kenter et al., 2015); and iii) philosophical issues over whether cultural services should be monetised via PES schemes (Fourcade, 2011)[84].

Practical steps to assess the feasibility of PES

In practice, identifying the ecosystem services and potential buyers and sellers and then resolving institutional, legal and technical issues can be highly complex. A stepwise approach is necessary, and these stages require significant time and appropriate expertise.

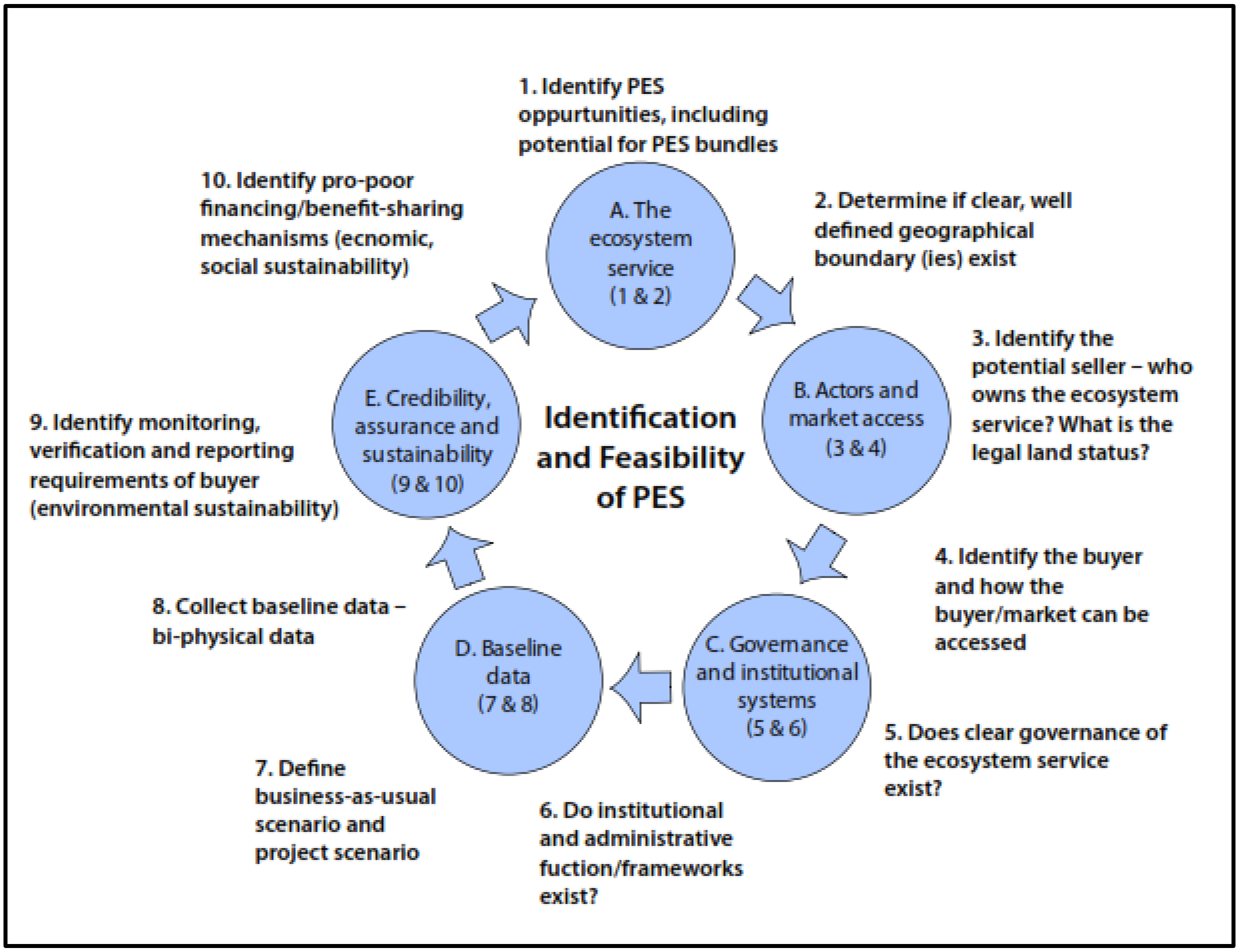


Figure 6: The 10 steps in assessing the feasibility of PES. Source: Fripp 2014[85]

Step 1: Identify the ecosystem service

In most cases, it is apparent what ecosystem service is going to be bought and sold. Usually, the emergence of a problem, such as downstream water pollution or demand for carbon credits, drives the establishment of a PES scheme. However, in some cases, the objective may be to assess the potential of ecosystem services for inclusion in a PES scheme. These assessments will require exploring, at community, district, provincial or even national level, whether the available ecosystem services are suitable for PES.

Step 2: Set clear boundaries

A fundamental requirement for any PES scheme is the establishment of clear, well-defined geographic boundaries. In practice, this means that if, for example, clean water is provided to a downstream user, the water catchment must be clearly defined, with no risk of leakage. There must be a clear link between the cause and effect of any change in behaviour. A watershed may have more than one source of sedimentation, such as different users or subsidiary watersheds feeding into the ecosystem and thus affecting the ecosystem service to be supplied.

Step 3a: Identify the seller(s)

This step considers the need to clearly identify who owns the service and therefore who is eligible to sell the service. This may seem like an obvious point, but knowing who can rightfully sell the ecosystem service is not always straightforward. For example, when dealing with sales of carbon credits from a forest area, the seller may need to "own" the carbon stocks in order to be allowed to sell credits for them. This may require owning the trees, the land on which the trees grow, or both; ownership rules are likely to vary from one country to another. Forested areas may be leased to a community or private company for use, which may or may not include the sale of carbon credits. Ownership must therefore be clearly established.

Step 3b: Identify the buyer(s)

Having a buyer is essential. There is no point in investing time and resources in establishing a product or service to sell if there is no buyer or market. Some programs have begun assessing the technical and biophysical capabilities of the ecosystem service provision, without checking that there is in fact a buyer willing to pay for the ecosystem service, and a thus a market.

Step 4: Identify the market

The process of determining how to access the market and set the price involves several considerations. For example, does the price take into account the costs, as is the case for a product? Or does the producer have to accept a price set by the international markets (as in carbon markets) or by an international body (as for a debt-for-nature swap)? Or is the price negotiated according to the buyer's willingness to pay (WTP) for the service and a supplier's willingness to accept (WTA) that price? This is a critical step in establishing and implementing PES.

4a: Access to the market

Determining access to the market is a key issue that is often overlooked, or project proponents assume that it will simply happen and leave it until last. However, as for the launch or sale of any product, the market must be researched and, if necessary, the appropriate transaction infrastructure or market mechanisms established. The market must be accessible to both buyer and seller.

4b: Setting the price to ensure sustainable financing

The price set has to be satisfactory for both parties. The income that local stakeholders receive must be enough not just to cover the total costs of the project but to exceed them, in order to provide an incentive to stakeholders to refrain from business-as-usual and ensure permanence of the ecosystem service. Alternatives to providing the ecosystem service must be more expensive for both buyer and seller, thus ensuring that alternative land uses, or business-as-usual, are seen as inferior options to providing the ecosystem service.

Step 5: Determine governance of the ecosystem service

It is necessary that governance of the ecosystem service be clear. It is therefore essential to understand the governance framework in the village, group of villages or landscape, the potential seller, where the ecosystem service will be produced, managed and sold.

Step 6: Identify institutional and administrative functions/frameworks

The first step is to identify a suitable institution with clear ownership rights to the ecosystem service. The next consideration is whether institutional and administrative capacity is sufficient. The "institution" may be a local community group, an individual, a government body or an intermediary body such as a local NGO. It must have adequate administrative and technical capacity to manage and sell the ecosystem service.

Step 7: Establish and compare business-as-usual and project scenarios

Establishing the baseline is a prerequisite for all PES projects, including those for REDD+ or those dealing with carbon sequestration, watershed management or biodiversity protection. The baseline scenario sets out the forecast for what would happen in the absence of the PES scheme. This scenario is then compared to the forecast outcomes of the PES scheme. The baseline scenario then provides the basis against which the performance of the PES project will be assessed

Step 8: Collect biophysical data

The need for additionality or an improvement in the ecosystem service provided, including a shift away from business-as-usual to an improved situation, is a key principle. To define this change and monitor and report on progress, robust technical data will be required to establish a credible baseline or business-as-usual scenario that considers environmental, social and economic factors. Biophysical data of appropriate detail and quality must be collected. For each landscape, the technical requirements and skills for data collection will vary depending on the particular ecosystem service provided.

Step 9: Set requirements for measuring, reporting and verification (MRV)

In PES, MRV serves to prove adequate performance, to justify payments and, ultimately, to maintain the credibility of the scheme. This role becomes even more important when payments are based on performance, as is the case for most PES. The buyer and seller must agree upon

MRV requirements during negotiations, unless the market stipulates MRV requirements, as is the case of carbon stocks. Communities should be involved in MRV activities.

Step 10: Develop pro-poor benefit-sharing mechanisms

Ensuring that the financial, environmental and social gains from the provision of an ecosystem service are equitably distributed is a fundamental requirement for sustainability. Equitable sharing of rewards is particularly critical when the service is provided by a community or a collective of individuals. To avoid conflict and ensure all costs of service provision are adequately compensated, a fair and equitable system for sharing the rewards should be developed, to the agreement of all parties. Benefit-sharing mechanisms may vary according to whether the payment is received as cash, as non-cash or in-kind (Fripp 2014)[86].

The impact of PES can be very high by generating measurable conservation outcomes, e.g. carbon sequestration, reforestation, water control. Outcomes are intrinsically dependent on the ecosystem flows that are enhanced and or preserved. PES is fundamentally different from conventional environmental policy instruments in operating through incentives rather than disincentives like legal regulations, sanction mechanisms or taxes. This inherent incentive feature is both its virtue and its major challenge. If well-designed, payments can be a least-cost Pareto efficient solution to correct market failures. However, poor design could lead to wasted financial resources and potentially adverse environmental or social outcomes, for example, through unintended effects on human behaviour. In many aspects, PES is thus a demanding policy tool that can synergistically complement environmental policy mixes if carefully designed and implemented in appropriate contexts.

Chapter 3: Challenges in Mechanisms of PES

Introduction

Recognizing the limited success of protected areas for biodiversity conservation in developing countries, Wells and Brandon (1992)[87] argued in favour of what they termed "integrated conservation and development projects (ICDP)". Gaining wide acceptance during the first Rio de Janeiro 'Earth Summit', ICDPs shaped the agenda of biodiversity conservation in the subsequent decade. Christensen (2004)[88] pointed out that the main reason for the rapid dissemination of ICDPs was that "they offered something for everyone. They promised to defuse the major threats to biodiversity, create better opportunities for people to earn a decent living and gain access to basic services, and equitably address the rights and interests of everyone who uses land and resources in and around protected areas". In other words, ICDPs came with the promise of "win-win" solutions. A decade later, however, more or less coinciding with the 2002 Johannesburg 'World Summit on Sustainable Development' (WSSD), scholars and practitioners acknowledged that success with ICDPs was rather elusive (Hughes and Flintan 2001)[89]. Christensen (2004) noted that the "the myth of win-win solutions created a culture in which overly ambitious projects proliferated, based on weak assumptions and little evidence". PES is a rather elegant approach, in principle, but in practice, developing and implementing PES projects can be very challenging.

Key challenges in PES

The key challenges in PES, particularly in the context of developing countries, emerge as follows:

Lack of knowledge about ecosystem functions and economic values

Success of incorporating natural capital into resource- and land-use decisions hinges on the ability to quantify the ecosystem services, forecast the returns to the investments and convert these values into effective policy and finance mechanisms (Daily et al., 2009). However, ecosystem production functions are often poorly understood. In addition, we also lack information about the economic value of ecosystem goods and services. Hence, the science of ecosystem services needs to advance rapidly to deliver the knowledge and tools necessary to forecast and quantify the services in return from investments in nature.

Environmental leakage

When a PES financed reforestation/conservation in a certain area directly causes deforestation pressures in a neighbouring area, then the PES scheme is said to have a high leakage: It achieves high additionality only for the project area, but not for the broader regional or global goal. So, PES projects should target not just localised conservation, but sustainable behaviour changes in land use.

Arranging for users to finance PES and permanence of payments

PES schemes require clearly identified buyers and sellers, voluntary transactions, etc. so that the checks and balances of the market can ensure proper allocation of resources and quality control. By majority, PES schemes in developing countries are government-financed. Wunder et al. (2008) found that government-financed programmes tend to resemble conventional subsidy programmes. However, in the absence of understanding about ecosystem processes and how fair delivery of services results, service beneficiaries tend to be unwilling to pay. Therefore, not only do the dynamics of ecosystem services need to be understood, but there is also a need for institutions and a regulatory mechanisms that simulate/create markets and promote user based finance.

High transaction costs

PES involves costs that are necessary for the parties (the buyer and seller, or donor and recipient) to transact a PES payment. These costs are incurred in the process of identifying the PES programme, negotiating the transaction, monitoring, reporting and verifying the benefits (such as tons of emission reductions, improvement in water quality, etc.) Transaction costs are also incurred by the implementers of the PES programme and third parties such as verifiers, certifiers, and lawyers. These costs are separate from implementation costs as, by themselves, they do not reduce deforestation or forest degradation. They are nevertheless necessary for the transparency and credibility of the PES programme and therefore add value to the whole process.

Addressing the concerns of rural poor and promoting inclusive growth

The interests of the rural poor, promoting inclusive growth, should also ideally be considered in benefit realisation from PES arrangements, requiring a significant amount of institutional development and capacity building.

Lack of secure property rights

Resource regimes lacking well-defined property rights are generally vulnerable to overexploitation and free riders. Hence, literature since the 1960s has been arguing for the need to establish well-defined – generally private – property rights to facilitate efficient market regulation of environmental issues.

Ensuring the integrity of the payment scheme

The primary objective of PES incentives is to secure the flow of specific ecosystem services. However, as the payments are to be made to people who agree to protect and conserve natural resources for benefit to society, these programmes are susceptible to hijacking for political purposes. Payments may be diverted to specific persons or areas to support political and other objectives. Therefore, it is important to define transparent principles and criteria for eligibility for payment that are publicized and defensible from a biogeographic standpoint, rather than based on political considerations.

Getting public participation and support

Early and extensive communication with key stakeholders can help overcome challenges, avoid misunderstandings and increase participation. Communication media such as radio and television, as well as local institutions, including government and NGOs, as demonstrated by Vietnam's experience, are valuable communication channels. The growing numbers of PES programmes in the region are also valuable resource on which to draw understandings and exemplify applications.

Securing buyer confidence

The confidence of the buyer that their investments will pay off is very important to ensure the sustainability of PES programmes. Mechanisms to ensure transparency of the use of funds are extremely important to secure the buyer's confidence.

Achieving fair outcomes

Equity is an important consideration in programme design. A key challenge to achieving fair outcomes is overcoming existing inevitable inequalities in the design process. While PES transactions are voluntary, it does not mean that those participating have sufficient information and understanding to ensure that they are not being exploited.

Ensuring organizational coordination and support

Natural resources are often managed by multiple agencies in many countries. Land use planning may be the responsibility of one agency, while water supply the responsibility of another. The success of PES programmes depend on successfully coordinating the policies and efforts of relevant authorities. There are two key challenges faced by PES programmes. First is to ensure the coordination of policies and efforts of all the authorities directly involved in the PES programmes themselves. The second is ensuring that objectives are coordinated and supported by the larger environmental management context. This coordination is needed to ensure that PES objectives are not compromised by contradictory policies or efforts.

Identifying and agreeing on the economic value of ecosystem services

The economic valuation of ecosystem services provides the basis for determining the payments made and received by services buyers and providers. While there are several approaches to determining these values, each with its specific strengths and weaknesses, any approach should be based on local contexts. Where there is significant capacity with respect to valuation methodology, it is more difficult to find expertise with experience in its practical application for PES, thus the development of local expertise and capabilities is needed if PES is to succeed.

Ensuring 'real' additionality

PES programmes should be able to demonstrate that they are cost-effectively providing ecosystem services that would not have otherwise been provided, i.e. there is real additionality. This means that there should be a high degree of certainty that the improvements in ecosystem management are attributable to the PES programme. It also means that the services should not be lost to deteriorating ecosystems elsewhere, as environmental pressures move from an area protected via PES to an area which is not protected.

Limiting transaction costs

Transaction costs describe all the costs associated with setting-up and managing a PES programme. High transaction costs divert money away from the direct contracting of ecosystem service provision, and consequently reduce the amount of services that a given budget can acquire. If transaction costs are added to the amount charged to service buyers, they can reduce the demand for these services. If transaction costs are borne by the service seller, they reduce the willingness to participate (ESCAP 2009)[90].

While PES can certainly contribute to poverty reduction, the resources allocated are unlikely to be sufficient to solve long-standing deprivation problems or the structural lack of economic and employment opportunities. Moreover, in certain instances, environmental compensation schemes can reinforce rather than reduce inequalities. This is more evident in regions where land ownership is concentrated and impoverished communities are excluded from accessing natural resources. A resource plan to account for sellers' and communities' access to forest resources remains essential for ensuring that there is no loss of economic rights by vulnerable groups.

Chapter 4: The Need for PES Projects for Sanjay Gandhi National Park

Ecosystems provide numerous goods and services maintaining sustainable livelihoods and supporting economic and wider life aspirations. However, global environmental changes, coupled with other stressors, are affecting the ability of ecosystems to continue providing the same quality and quantity of ecosystem services. Historically, many ecosystem benefits (e.g. improved water availability due to vegetation management) were regarded as 'free services'. Land managers and policymakers often ignore these 'externalities', unintentionally or wilfully, and hence fail to achieve anticipated conservation and development results. Many scholars (Merlo & Briales 2000[91]; Wunder et al. 2005; Cubbage et al. 2007[92]) have described the progress of environmental and forest policies in order to achieve multifunctional objectives of ecosystem management. PES is one mechanism that is increasingly being used to sustain both the natural environment and local livelihoods (Hubermann 2009)[93].

Arranging payments for the benefits provided by forests, fertile soils and other natural ecosystems is a way to recognize their value and ensure that these benefits continue well into the future. Across the world, environmental conservation is critical to secure the flow of ecosystem services that are essential for people and nature. With funding for natural resource management dwindling, a variety of PES schemes has emerged as potential sources of sustainable financing for conservation. PES schemes encourage the maintenance of natural ecosystems through environmentally friendly practices that avoid damage for other users of the natural resources. In addition to preserving natural resources, this method improves rural areas and rural lifestyles. The idea behind PES is, essentially, to pay landowners to protect their land in the interest of ensuring the provision of one or more "services" rendered by nature, such as clean water, habitat for wildlife, amenity or carbon storage in forests.

PES has been used for conservation benefits including under major developing world examples include the Miaro forest corridor project in Madagascar (WWF, 2009)[94], the Pagos por Servicios Ambientales (PSA) scheme in Costa Rica (FAO, 2007)[95] and the forest protection or enhancement for socio-ecological benefit under New Zealand's Nga Whenua Rahui conservation reserve programme (Funk 2006[96]; Nga Whenua Rahui. Undated[97]). A PES feasibility study carried out by Forest Action and the International Centre for Integrated Mountain Development (ICIMOD) in Shivapuri Nagarjun National Park, Nepal, revealed ample scope for developing a PES scheme (ICIMOD 2011)[98]. Nicole et al. (2012)[99] explored the potential for PES to reconcile conservation and development goals, using a case study of an experimental PES intervention around the Nyungwe National Park in Rwanda. Thapa (2015)[100] concluded that PES-type practices in Kulekhani watershed area and community forest users group in far west Nepal demonstrated the positive potential of PES in Nepal. If ecosystem services are brought into payment mechanism through PES, then protected areas can rely not only on their own income for the management activities but also provide surplus money to the national treasury and for investment in community development activities in the buffer zone to alleviate rural poverty.

The importance of SGNP to Mumbai's environment

Urban areas are facing excessive rise in population along with the pressure of unplanned economic development, industrialization and vehicular emissions, which in turn affect air, water and land quality. Air pollution has increased rapidly in many cities and metropolises, especially due to vehicular traffic and industrial emissions and due to insufficient green belt areas in the city, which can aid in absorbing these noxious or toxic gases. The rising population in Mumbai has led to a decrease in open spaces, further depleting climate and air quality regulation services within the built environment.

The situation of Sanjay Gandhi National Park (SGNP) is a key part of its unique characteristic, i.e. surrounded by Greater Mumbai. The Park belongs to one of the least represented biogeographic zone – the Malabar Coast of the Western Ghats – and is the only National Park that exists within this biogeographic zone. SGNP also is a fragile ecosystem. Being representative of the Northern Malabar coast, it spans a diversity of various types of forests, grasslands, moist teak forest, mangroves, mixed deciduous forest and sub-tropical hill forest, and supporting substantial faunal and floral diversity including a number of endangered species.

The importance of the SGNP for the survival of the cities of Mumbai and Thane cannot be over-emphasized. The Park's contribution to the city's water resources is highly significant as two of the lakes that supply water to Mumbai and Thane – Vihar Lake and Tulsi Lake – are located within the SGNP. The catchment areas of both these lakes also lie within the SGNP, thus ensuring that the quality of water supplied by both these lakes is among the best in the country. The fact that it is supplied nearly free of cost is another great bonus for the citizens of Mumbai and Thane.

The security of water supply from the SGNP is a significant additional element of its overall benefits, the lakes never having dried up. In the event of delayed arrival of monsoons, water retained in these lakes provides security for the cities of Mumbai and Thane.

Another substantially underappreciated benefit is the vital role played by the forests of SGNP in reducing the atmospheric pollution caused by anthropogenic activities in Mumbai and Thane. The vegetation in SGNP absorbs or helps break down aerial pollutants, settling fine particulate matter, significantly improving the air quality of surrounding urban areas. The SGNP's forests also play important roles in temperature control, both within the Park (visitors immediately notice the drop in temperature when they walk into the SGNP) and in breaking down 'heat island' effects in surrounding urban areas. At most times of the year, the temperature within SGNP is lower by 3-5 degrees Celsius than the temperature outside the Park. The forests of SGNP thereby literally act as a natural air conditioner for the cities of Mumbai and Thane, and significantly help in reduction of the electricity consumed by those residents residing along the periphery of the SGNP Division.

Four rivers of Mumbai – the Mithi River, the Poisar River, the Oshiwara River and the Dahisar River – originate from the SGNP, their flows and quality dependent upon ecosystem processes in the Park. Finally, in this era of climate change, we cannot but be conscious of the huge amounts of carbon that have been sequestered by these City Forests of SGNP.

The need for a PES project

The annual influx of tourist as per the data of 2010-11 was 48.28 lakhs (Management Plan SGNP)[101]. The park provides various ecosystem services not only to the tourists visiting the Park and to the entire city of Mumbai and Thane, but also some that have national and international benefit. However, despite the diversity and value of these ecosystem services, almost all are ignored. Traditionally, ecosystem services have been considered as free services provided by nature, leading to the economic values of these services being ignored or underestimated when forests are used or converted, with an alarming rate of global forest depletion, degradation and loss. Conservation and effective management of ecosystems for sustaining services requires innovative approaches and enabling policies. PES offers an approach that can be considered for the management of the Park.

The Park faces threat in various forms. Some of the major threats are:

1. Destruction of natural habitats, due to encroachment and illicit tree cutting.
2. Disturbances to natural habitats by mining, i.e. mainly stone quarrying in areas just outside the external boundaries of the park.
3. Human-animal conflict, mainly with Leopards.
4. Insufficiency of space and peripheral garbage and domestic animals, leading to the dispersal of young panthers outside the protected area, contributing to increased mortality e.g. by speeding vehicles, etc.
5. Thirty-nine padas (hamlets) inside the SGNP area, leading to all types of disturbance to the adjoining areas.

The very existence of the SGNP is under threat. However, this can be curbed by making people aware of its diverse values, both economic and non-monetary. One means to raise awareness of the value of these services is to represent them as marketable values, or ideally to create markets for them. These markets can also potentially increase the economic value of forest ecosystems in the park.

There are three major drivers to demand market for ecosystem services: (i) a shift in environmental protection policies from command and control (C&C) to economic and market based instruments such as charges and user fees and eco-taxes; (ii) improved capacity to value the goods and services provided by forest ecosystems; and (iii) raising demand for ecosystem services by public authorities, private entities and consumers as a result of environmental obligations of these user agencies. It is essential to consider a broader range of market and other drivers to ensure that Sanjay Gandhi National Park continues to provide a diversity of beneficial ecosystem services supporting human well-being.

At the very least, representation of the value of these services in economic terms will challenge the misplaced assumption that these services are infinite and 'for free', and therefore inherently worthless as part of policy decision-making.

Objective of this study

The purpose of this study is to identify the range of ecosystem services produced by the Sanjay Gandhi National Park, and particularly to identify those for which it may be possible to develop markets under potential PES programmes.

Chapter 5: Project Area

Sanjay Gandhi National Park division located at Borivali, Mumbai. Sanjay Gandhi National Park division, popularly known as Sanjay Gandhi National Park or Borivali National Park, has unique combinations of rich biodiversity, very high biotic pressure due to its typical location, complete biological fragmentation leading to “fenced island” type case for its south block, and high values for nature tourism and Eco-tourism. Sanjay Gandhi National Park division has immense values for its assimilative capacities and life support services. The natural capital of this area, which includes material resource, assimilative capacities and life support services, has significant values. It is an “Oasis” in Thane and Mumbai cities of India. It protects the catchments of two water reservoirs, which supply water to Mumbai and Thane. This area has more than forty years of history of conservation. Krishnagiri Upvan, well known for tourism in Borivali, is a part of this division. Leopard, the only big cat of the area, exists with very high density. The forests are mostly of the moist deciduous type and, in general, they are dense throughout the area. The park is an example of one of the least represented biographic zones – the Malabar Coast of the Western Ghats – which forms only 0.4% of the Protected Area network.

The SGNP falls between longitude 720 53” E to 720 58” E and latitude 190 8.8”to 190 21” N. Sanjay Gandhi National Park division is situated partly in Thane District and (59.24 sq. km.) and in Mumbai Suburban District (44.44 sq. km.) of Maharashtra State. Originally, areas of this division were within Thane Forest Circle. Now this division is under the administrative control of Additional Principal Chief Conservator of Forest (Wildlife) Borivali. The total area of Sanjay Gandhi National Park is 103.68 sq. km, out of which the notified area constitutes 86.96 sq. km. SGNP has been finally declared by Maharashtra Government Resolution No. WLP/1094/ OR 177/F-1 dated 16.01.96 Bassein creek passes through this division from west to east and divide it into north block (Nagla block) with an area of 16.93 sq. km. and south block with an area of 86.43 sq. km.

Sanjay Gandhi National Park division, a tiny green tract amid thickly populated metropolis is bestowed with immense biological, ecological and recreational values. These values scale from local to national significance. This area is unique in that its major portions i.e. that on the south of Bassein Creek is completely fragmented yet it harbours high density of leopard. As a true representative of the Northern Malabar Coast, this area has vast faunal and floral diversity. It protects the Catchments of two-water impoundment that supply water to Mumbai and Thane (Management Plan SGNP).

Birdwatchers, local morning walkers, and foreign as well as Indian tourists use SGNP as a green space for its recreational activities, its history, its ecosystem or its simple outdoor trails. The rising population in Mumbai has led to a decrease in open spaces, but the presence of Sanjay Gandhi National Park has provided many lucrative 'Environmental Gains'

Figure 7: Map of Sanjay Gandhi National Park with Google Representation

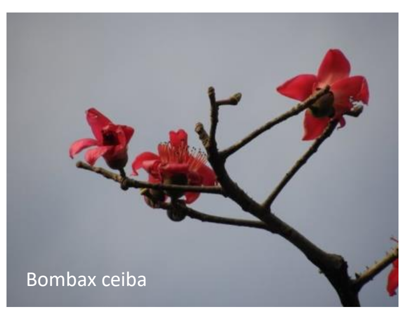
Biological values of the SGNP forming a basis for beneficial ecosystem services

Flora

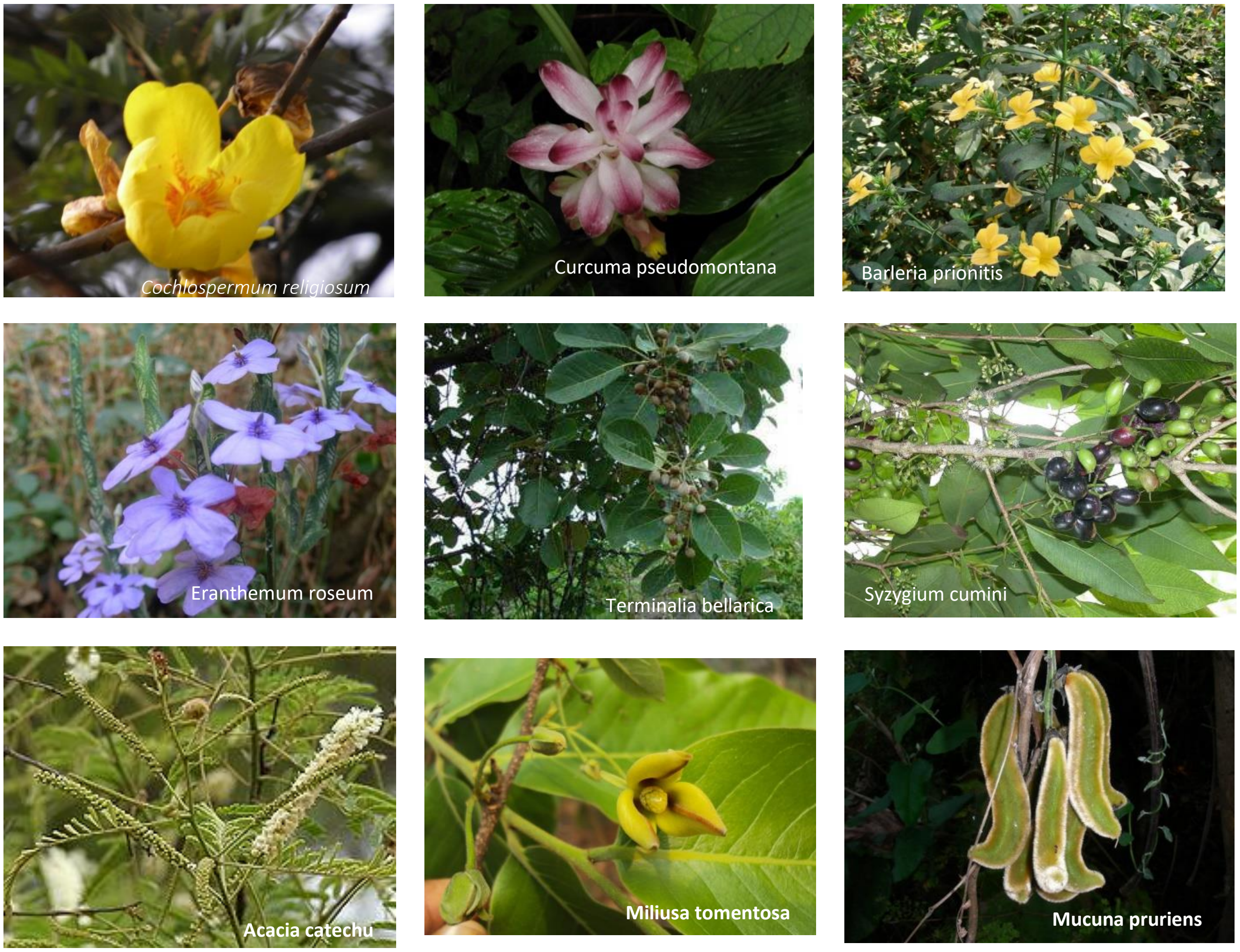
The vegetation of this area ranges from littoral forests to western sub-tropical hill forests. Large numbers of vertebrate and invertebrate species belonging to various classes and orders are only indicators of immense biological diversity of this area. The Botanical Survey of India (BSI) published records of the flora of Sanjay Gandhi National Park. The BSI accounts 151 Angiospermic families, 581 genera, 1078 species and 31 infraspecific taxa from the park. Some of the dominant families are Poaceae, Fabaceae, Cyperaceae and Acanthaceae (Pradhan SG., 2005)[102]. *Chlorophytum borivilianum* is a rare herb recorded from the park and is listed as endemic to the National Park. The herb is also reported to now be endangered and vulnerable due to over collection. *Ceropegia vincifolia,* an annual climber, found in the park, is also reported to have attained the status of being endangered due to over collection (Kehimkar I., 2000)[103]. A floristic survey at disturbed and undisturbed areas of the park categorized 84 different species of trees belonging to 28 families. Similarly, 17 species of Shrubs belonging 8 families, 37 species of Herbs belonging to 19 families, 20 species of Climbers belonging to 11 families, 3 species of Bamboos from one family, 1 species of Epiphyte and 1 species of Parasite and 4 species from one family of Palms have also been recorded from the park.

Of the recorded 84 species of trees, at least 81 of them are known to have an intrinsic value as either as food, commercial, medicinal, religious or all values. From the trees recorded, flowers of *Nyctanthes arbor – tristis, Cochlospermum religiosum*, *Michelia champaca, Mitragyna parvifolia* and *Mammea suriga* are known to be used as religious offerings. *Ixora brachiata* and *Aegle marmelos* possess both religious and medicinal values. . 6 of the 84 species of trees recorded are known to be endangered, vulnerable, rare or endemic to the region. These include *Garcinia indica*, *Atalantia racemosa*, *Flacourtia montana*, *Syzygium cumini*, *Ixora brachiata* and *Miliusa tomentosa*. Of the total recorded species of trees, 40 percent possess medicinal value. They include *Miliusa tomentosa, Terminalia chebula*. *Bauhinia racemosa* and *Syzygium cumini* to name a few. 13 percent of the trees that include *Anacardium occidentale, Mangifera indica, Annona reticulate, Annona squamosa* and *Tamarindus indica* are known to be economically important while serving as food source with high monetary returns. *Tectona grandis*, *Acacia chundra*, *Acacia catechu Pterospermum canescens*, *Manilkara hexandra*, *Gardenia latifolia*, *Peltophorum pterocarpum*, *Diospyros melanoxylon, Wrightia tinctoria Samanea saman, Terminalia elliptica Macaranga peltata*, *Melia dubia* and *Mitragyna parvifolia* found in the park are known for their timber. Apart from the trees known to produce commercial timber and fuel wood, species like *Bombax ceiba* and *Cochlospermum religiosum* are known for the cotton obtained from their fruit that is, used for filling economically priced pillows, quilts, sofas etc. Parts of *Butea monosperma* are used for timber, resin, fodder, medicine, and dye. (Joshi et.al., 2016)[104]


Butea monosperma


Bombax ceiba


Saraca ashoka



Photograph 1: Example of Flora of Sanjay Gandhi National Park

Floral Species of conservation importance

1. *Saraca ashoka* (Sita ashok)

It is rare and endemic species of the national park. Nearly 75 ha Patch of *Saraca ashoka*; popularly known as 'Ashok Van' is seen near Kanheri Caves Flowers are seen from March to May. Monkeys, Langurs and other herbivores eat the pods.

2. *Garcinia indica* (Kokam)

It is an evergreen species seen mostly at the highest point area. Monkeys, langurs and some birds eat fruits. Fruits are of medicinal value and are used as an antidote for stomach upset.

3. White Orchids

Two species of white orchids are found at the highest peak. Orchids are seen in the month of September. They have been identified as species of *Platanthera* and *Habernaria*.

Fauna

Studies have revealed that the Park is very rich in fauna. 30 spp. of Pisces, 7 spp. of Amphibia, 23 of Reptilia, 64 of Aves & 48 spp. of Mammalia have been observed and recorded (Yazdani et.al., 1992)[105]. There are more than 150 species of butterflies. At least 21 individual leopards have been identified within the park's boundaries. Dominant fauna include:

Mammals – 48 spp. of mammals were observed in the Park. The fauna is typical of the Sahyadri region with a predominance of spotted deer, leopard, etc. A good variety of bat species have been observed. It is interesting to note that the bats inhabit only a few (2-3) caves out of about a hundred caves in Kanheri. Another interesting feature is the presence of both Bonnet & Rhesus monkeys in the Park. A large number of domestic dogs have been seen near the MAFCO factory area. Their behaviour is almost like the wild ones and have started hunting and attacking in packs (Yazdani et.al., 1992). Some of the other species present are Indian hare, Barking deer, Porcupine, Asian palm civet, Mouse deer, Grey langur, Indian flying fox, Sambar deer, etc.

Photograph 2: Herd of Deer seen commonly at Sanjay Gandhi National Park

Birds – The bird fauna of the Park is rich and diverse with species composition that is typical of the Konkan region. (Yazdani et.al., 1992). Some of the birds seen are Kingfishers, Woodpeckers, Drongos, Sun bird, White bellied sea eagle, Paradise flycatcher, The elusive Trogon, Blue flycatcher, Jungle owlets, Golden orioles, Minivets, Magpies, Hornbills, Bulbuls, Peacocks, Swifts, Egrets, Herons etc.

Spiders – Giant wood spiders, Signature spiders, Black wood spider etc.

Fishes - 30 species of fishes (freshwater & marine) were recorded from the Park. The freshwater sources are Tulsi & Vibar lakes, Dahisar & Rewat rivers. Numerous small tributaries join these rivers during their course through the park. As the rivers are of a short length, indigenous fish fauna includes rather smaII sized varieties like *Puntius,* Rasbora, *Garra* etc. A hill stream CyprInid, *Parapsilorhynchus tentaculatus* was found in seasonal streams flowing down the Kanheri caves from an altitude of about 486 MSL. In summer, these fishes are seen in water filled stone cisterns along the caves. (Yazdani et.al., 1992)

Amphibia - Most of the common species occurring elsewhere in India are represented here. *Rana breviceps,* the Indian burrowing frog, is found in the Kanheri caves area during early monsoon months. The common tree frog *Polypedates maculatus,* is quite commonly seen during the monsoon. (Yazdani et.al., 1992)

Reptiles – The outstanding feature of the reptilian fauna of the Park is the occurrence of Crocodile, *Orocodilus palustris,* in Tulsi lake. The Indian Python & Cobra are also found in the forested areas of the Park (Yazdani et.al., 1992). Some other species include Monitor lizards, Russell's viper, Bamboo pit viper, Ceylonese cat snakes etc.

Faunal Species of conservation importance

1. Leopard (*Panthera pardus*)
2. Sambar (*Cervus unicolor*)
3. Brown fish owl (*Bubo zeylonensis*)
4. Mottled wood owl (*Strix ocellata*)
5. Blue mormone (*Papilio_polymnestor*) State Butterfly of Maharashtra
6. Atlas moth (*Attacus atlas*) - Largest Moth

Geological values of the SGNP forming a basis for beneficial ecosystem services

SGNP is characterised by steep rocky forests, the physical structure and topography of the landscape forming characteristic features but also contributing to a range of ecosystem services. Cultural values of geodiversity are seen in the formation and continuing value of Kanheri Caves, as the uses of rocky outcrops for hiking and other informal recreation.

Additional environmental values of the SGNP forming a basis for beneficial ecosystem services

This area acts as a carbon sink for Mumbai and Thane cities and veritably it is known as green lung for Mumbai and Thane. It absorbs and filters the high levels of pollution in the area released from the exhaust of vehicles and industries. It maintains the ecological balance of the city. It helps to conserve endangered Flora and Fauna. It cools the atmosphere and provides fresh air. It protects the catchments of Tulsi and Vihar Lakes that are important source of water supply for the city as they supply water to the metropolis. Forests in SGNP also regulates temperature, encourages precipitation of clouds and help to recharge ground water.

Archeological value:

Kanheri caves located within the park, were built by Buddhist monks and are said to date from the 1st century BC to the 9th century AD. This site is looked after by the Archaeological Survey of India. The caves are arranged in several viharas or monasteries, solitary cells for hermits, lecture halls and temples. Most of the 109 caves chiseled into the volcanic rock are simple; the small chambers known as “Vihars” whereas the larger and deeper chambers known as “Chaityas”. Outside the caves are small tanks for water, separate for each cell, and couches carved out of rock, may be, for the monks to recline on. The caves are said to have been occupied by a well-organized Buddhist establishment of monks on an ancient trade route connecting a number of Indian sea ports.

Photograph 3: The Archeological Caves at Kanheri

Recreational and Educational Values:

In a city which has turned into a thick concrete jungle, SGNP plays an important role in terms of “citizen to open spaces ratio” and as an alternative green cover present in the city limits. The unique location of this area makes it a paradise amidst thickly populated surroundings. Large numbers of visitors come to this area every year. They receive the message of wildlife conservation.

Chapter 6: Methodology

In order to assess potential services for which markets may be identified under PES arrangements, the ecosystem services flowing from SGNP were first reviewed. This review was based on the Millennium Ecosystem Assessment (2005) framework of provisioning, regulating, cultural and supporting services, with a number of commonly applied addenda.

The assessment framework was adapted from the Ramsar Commission-adopted RAWES (Rapid Assessment of Wetland Ecosystem Services) approach (Ramsar Convention, 2018[106]; RRC-EA, in press[107]). RAWES was developed to support ecosystem service assessment of wetlands recognizing practical time and resource limitations faced by operational staff, providing a simple, user-friendly, cost-effective approach supporting systemic assessment of the full range of wetland ecosystem services (McInnes and Everard, 2017[108]). Though RAWES specifically was developed for wetland assessment, it is in essence adapted from a wider approach already used extensively in a range of habitat types (for example by Everard, 2009[109]; Everard and Waters, 2012[110]). RAWES makes a semi-quantitative judgement of the significance of each ecosystem service, as well as the geographical range over which the benefit is realised. Another of the key facets of RAWES is that is integrates different available and observable forms of knowledge – quantitative, qualitative, interviews with local stakeholders, expert judgement, etc. – recording the evidence base upon which assessment of service provision is based.

The RAWES approach

The objective of the RAWES approach is to facilitate a comprehensive assessment of the plurality of benefits provided by a wetland, using an approach that can be considered genuinely rapid recognising limited resources. The approach has at its core the realisation that in many situations the access to time, money and detailed information will be limited and such barriers need to be overcome if the full range of values is to be recognised. Furthermore, the development of the RAWES approach recognises that less time-intensive methods can be more practically applied on a wide-scale (Villa et al., 2014)[111].

RAWES is designed as a simple and rapid site assessment system that may obtain input from existing studies but does not rely on detailed, quantitative assessments. As such, it is a genuinely rapid approach that may typically take less than two hours per site with trained assessors working in pairs for cross-referencing. Significantly, the RAWES approach is also systemic, addressing all ecosystem services as a connected set rather than selecting only the most readily evaluated or exploited services, and thereby overlooking other services. The RAWES assessment form is a simple table with cells into which assessors record the importance of each ecosystem service produced at the surveyed site, with space for free text descriptions of key features supporting that assessment. Assessors are encouraged to interact with stakeholders so that assessments are informed by local perspectives and indigenous knowledge, ensuring that all services are recognised. Early interaction is recommended in order to refine the list of services to be assessed.

The RAWES approach also seeks to link the service to beneficiaries. For each ecosystem service, an assessment is made as to the scale at which the benefits accrue. An initial three-point scale is provided but this can be modified to the specific assessment context, for instance if the assessment is considering a finite entity such as a county or metropolitan region. The outputs from applying the RAWES approach can be used to inform subsequent quantitative assessments of targeted ecosystem services, by effectively providing an initial screening, or in more general local or national policy frameworks and decision-making process such as environmental impact assessments (McInnes and Everard 2017).

Chapter 7 records the results of this assessment, built from the evidence in this report (including literature reviews), interviews with SGNP stakeholders and the expert knowledge of the assessment team.

This RAWES-based assessment forms the basis for identification of potential PES markets.

Using the framework of ecosystem services from the Millennium Ecosystem Assessment (2005), as applied using the RAWES approach to recognise the perceived service benefit as well as the geographical scale over which benefits arise, the project team used the evidence in the preceding overview with additional inputs form stakeholders and expert judgment to identify potential ecosystem service markets. This is represented in Table 2 below, with comments or other evidence on how the judgment was made.

		Perceived service benefit	Scale of benefits	Potential markets (who and how?)	Are there any comments or observations you'd like to make about your assessment of consequences?
Provisioning services	Fresh water available for abstraction and use	Significantly positive	Local and city	Water service beneficiaries (government, local water providers, direct users)	Draw upon hydrological data of water flows from the Park, and quantification of abstracted and directly exploited water (including monitored output from/through Tulsi Lake)
	Food production (e.g. crops, fruit, fish, etc.)	Positive	Local	Quantify by replacement cost for food used.	Land crabs are harvested by local people (and there is small-scale illegal subsistence fishing in Tulsi Lake)
	Fibre and fuel production (e.g. timber, wool, etc.)	Positive	Local	Local users (possibly monetised by replacement cost with bottle gas)	Local people take a limited amount of fallen wood for fuelwood and other domestic needs (though technically illegal)

	Genetic resources (used for crop/stock breeding and biotechnology)	Not exploited	-		This is a potential service but against exploitation is against the principle of setting up the park
	Biochemicals, natural medicines, pharmaceuticals	Not exploited	-		This is a potential service but against exploitation is against the principle of setting up the park
	Ornamental resources (e.g. shells, flowers, etc.)	Positive	Local and city	Estimate the value of resources collected versus the cost of mementos bought in tourist shops	Limited informal collection by Park visitors of leaves, feathers and other ornamental resources
	Harvesting of clay, mineral, aggregates, etc.	Not exploited	-		This is a potential service but against exploitation is against the principle of setting up the park
	Waste disposal	Not exploited	-		Not allowed
	Energy harvesting from natural air and water flows (if relevant)	Not exploited	-		Not allowed

Regulating services	Air quality regulation	Significantly positive	Local and city	Comparison of air quality in central versus park periphery with (if possible) health costs	Mumbai air quality is a major problem, substantially ameliorated locally by SGNP
	Local climate regulation - microclimate, temperature, precipitation	Significantly positive	Local and city	Use met office data from inside and outside the park to get a metric of microclimate amelioration effect. Quantify, if possible, heat stress effects of human health	Mumbai's microclimate, heat island effect, etc. is a major challenge, but the p Park habitat has a major ameliorating effect
	Global climate regulation - greenhouse gas sequestration, etc.	Significantly positive	Global	Use literature on carbon sequestration rates in different dominant habitat types do produce a metric, and use international carbon market values to monetise. (Potential PES market could be drawn directly from REDD+.)	The varied habitats across the park have high biomass and soil carbon sequestration potential

	Water regulation (timing and scale of run-off, flooding, etc.)	Significantly positive	Local and city	Quantify the area of Mumbai real estate at flood risk were the service of the park not to be there, multiply by economic detriment of buildings at flood risk to derive a total. (PES potential from insurance providers.)	Complex forest habitat buffer water flows regulating extremes of drought and flood. The buffer effect of Tulsi, Vihar and Powai lakes also result in rivers flowing for realtively longer times in the dry season. The Mithi Flow disaster is an example of flooding and spreading of urban pollution, raising questions about how much worse the flood would have been were the Park's buffering effect not there
	Natural hazard regulation (i.e. storm protection)	Significantly positive	Local and city	Quantification of damage averted to buildings and infrastructure can potentially be monetised. (PES potential exists, but difficult to identify buyers.)	Storm buffering by trees and also the geological structure of the Park dissipates wind energy, averting damage to surrounding buildings and infrastructure
	Pest regulation	Significantly positive	Local and city	Costs of artificial pest control could be quantities. (Potential PES could be based on cost savings to urban	The Park hosts many pest predators (birds, insects, bats, etc.) There are few croplands close to the Park, which limits realisation of the service, though benefits also accrue to gardens, street trees, parkland, etc.

				park management services.)	
	Disease regulation - human	Unknown	?		Aside from health benefits of green exercise, air and water quality, additional health benefits need to be investigated
	Disease regulation - livestock	Unknown	?		Few livestock surround the park, so the benefit may be small positive or negative but more study is needed
	Erosion regulation	Significantly positive	Local	Can we estimate the cost saving from desilting dams and nullah downstream?	Extensive green cover stabilises Park soils, also stabilising river courses and averting the costs of desilting downstream
	Water purification and waste treatment	Significantly positive	Local and city	Could be related to substitution costs of additional water treatment were the service not occurring. (PES market possible with urban water service providers.)	Diverse SGNP habitat slows the flows and purifies water, Tulsi and Vihar Lakes also serving not only as an intermediate storage facility but also further purifying water in transit from remote catchments into the city

	Pollination	Positive	Local and city	This may be a tough one to monetise in a Mumbai context!	Substantial numbers of pollinating species (insects, sunbirds and other birds, bats, etc.) occur in the park maintaining its diversity, with benefit spreading to food, gardening and urban parkland beyond the SGNP boundary
	Salinity regulation - implications for soil salinity build-up	Positive	City	It may be possible to quantify through a plant regeneration survey in the SGNP, including whether insect, bird or other pollinated	Regulation of salinity in estuaries outside the SGNP and influences by outflowing streams, maintaining the salinity regimes upon which mangrove survival (and associated biodiversity and services) depends
	Fire regulation - tendency of ecosystems in the catchment to burn	Not relevant	-		Fire regulation happens in the forest through moisture in leaf litter, benefitting the ecosystem in many ways, but there is not necessary a benefit to people
	Noise and visual buffering - impacts on the buffering effects of ecosystems	Significantly positive	Local and city	Quantification could be based on the stress of urban as opposed to 'green' views (for which there is health-related literature)	Massive noise and visual buffering effects result from the presence of geological structure and biodiversity (particularly trees) in SGNP, quietening the noise of the city and blocking intrusive lights and other visual blight

Cultural services	Cultural heritage	Significantly positive	Local, city and national		The presence of SGNP is a defining feature of Mumbai city, the surrounding area and of Maharashtra, also with as National Park part of Indian national identity
	Recreation and tourism	Significantly positive	Local, city, national and international	Quantify visitor numbers and investment in travel, accommodation, food, gate fees, related small businesses, etc. (Effectively, gate fees are a type of PES, or 'payment for a service)	Substantial recreation and tourism occurs in SGNP, with the Bhuddha pournima festival (on the full moon in the beginning of May) and other festivals drawing people internationally to the SGNP Kanheri Caves
	Aesthetic value	Significantly positive	Local, city, national and international		This value is effectively subsumed into cultural, spiritual, tourism and other values
	Spiritual and religious value	Significantly positive	Local, city, national and international		This value is effectively subsumed into description of recreation and tourism values above
	Inspiration of art, folklore, architecture, etc.	Positive	Local and city		The Kanheri Cave within SGNP is based on the geology of the region. Park regulations do not allow other artistic/festival activities within the SGNP boundary

	Social relations (e.g. fishing, grazing or cropping communities)	Positive	'Local, city and national	Valuation may be subsumed in visitor number quantification above	The natural beauty, biodiversity, culture and other attributes of SGNP is a focal point for many special interest groups (birders, botanists, etc.) as well as communal walking and other activities
	Educational and research	Positive	'Local, city, national and international	Possibly assess by travel cost methods. (PES markets may be hard or impossible to identify for this service)	SGNP host substantial local, national and international research activities as well as providing teaching and learning resources
Supporting services	Soil formation	Significantly positive	Local	Underpins other services, for which valuation may be possible	Substantial intact habitats build soil fertility and structure
	Primary production	Significantly positive	Local and city	Underpins other services, for which valuation may be possible	Substantial and diverse habitats have high productivity, some of which will leave the park down river and in the diets of visiting birds, etc.
	Nutrient cycling	Significantly positive	Local and city	Underpins other services, for which valuation may be	Substantial and diverse habitats recycle nutrients efficiently, retaining the in the Park and also providing nutrient flows downstream

				possible	
	Water recycling	Significantly positive	Local and city	Underpins other services, for which valuation may be possible	Substantial and diverse habitats recycle water efficiently, retaining moisture in the biota and contributing the the Regulating Service of Water Regulation (hydrology)
	Photosynthesis (production of atmospheric oxygen)	Significantly positive	Local, city, national and international	Underpins other services, for which valuation may be possible	Substantial and diverse habitats have high photosynthetic activity, generating oxygen that contributes to local, national and international atmospheric contribution
	Provision of habitat	Significantly positive	Local, city, national and international	Underpins other services, for which valuation may be possible	The purpose of SGNP is to conserve characteristic wildlife and genetic diversity, or value to all geographical scales and for its inherent value

Table 2: RAWES-based ecosystem service assessments with commentary on evidence based and potential for PES market development

To express and compare production of the four ecosystem service categories at SGNP, the semi-quantitative importance of each service was scored on a scale from +1.0 to -1.0 (or alternatively '?' if unknown as outlined in Table 3. Groups of ecosystem services were summed and divided by the number of relevant services in that service category to derive an ecosystem services index (ESI), based on similar index methods by Butchart et al. (2010)[112], Davidson et al. (in press)[113] and McInnes et al. (in press)[114]. The ESI is calculated using Equation 1, where 'n TOTAL' was adjusted to remove generic services that were not relevant in this specific context (e.g. waste disposal or fire regulation). The potential ESI range is from +1 to -1, calculated for each of the four ecosystem service categories or a compound value for all services.

Assigned importance	significantly positive	Positive	Neutral	Negative	Significantly negative	Not relevant or Unknown
Numerical value	1.0	0.5	0.0	-0.5	-1.0	Remove from analysis

Table 3: Transposition of RAWES 'importance of service' scores into numeric values for analysis and representation

Equation 1: $$\text{ESI} = \frac{\sum(n_{+1.0}+n_{+0.5})+\sum(n_{-1.0}+n_{-0.5})}{\sum n_{\text{TOTAL}}}$$

The same mathematical transformation was used to calculate ESI for total ecosystem service benefits accruing across the four geographical ranges used in this ecosystem services assessment (local, city, national, international) for the 30 relevant services. Total ESIs for geographical scales can exceed 1.0 where benefits accrue across multiple scales. Table 4 outlines ESI scores, service category by service category, and Table 5 outlines ESI scores for geographical scales at which services are expressed.

ESI by ecosystem service category			
Ecosystem service category	Cumulative importance scores	Number of relevant services (out of total in category)	ESI
Provisioning	2.5	6 (out of 9)	0.42
Regulating	10	11 (out of 14)	0.91

Cultural	5.5	7 (out of 7)	0.79
Supporting	6	6 (out of 6)	1.00
COMBINED SERVICES	24	30 (out of 36)	0.85

Table 4: ESI scores for each ecosystem service category

ESI by ecosystem service category			
Ecosystem service benefit realisation range	Cumulative importance scores	Number of relevant services (out of total services)	ESI
Local	22.5	30 (out of 36)	0.75
City	20	30 (out of 36)	0.67
National	7	30 (out of 36)	0.23
International	6.5	30 (out of 36)	0.22
COMBINED RANGES	56	30 (out of 36)	1.87

Table 5: ESI scores across the four geographic benefit realisation ranges

These results demonstrate that the value of withholding exploitation of resources in the park (the ESI for provisioning services is the lowest at 0.42) is achieving its goal of providing substantial benefits stemming from the functioning of the park's diverse ecosystems (maximum ESI of 1.00 for supporting services, with 0.92 for regulating services) with substantial cultural benefits (ESI = 0.79).

ESIs for the geographical scales at which benefits accrue emphasise the substantial scale of benefits locally (ESI = 0.75) and to the adjacent city (ESI = 0.67), with lower scores for national and international scales (ESIs of 0.23 and 0.22 respectively) for services that are nonetheless important (such as global climate regulation and tourism resource). The substantial ESI of 1.87 demonstrates that many benefits accrue at multiple geographical scales.

There results must be treated with some caution as they arise substantially from expert judgment, albeit with stated evidence to support assignments of importance scores, and of course also relating to one site (albeit a large on: the SGNP). However, the primary purposes of the RAWES and related methods underpinning this analysis are that assessment is rapid, integrates different forms of knowledge, is fully systemic not prejudging or overlooking the importance of all services, and is illustrative. Further detailed study of individual services may be necessary to substantiate market development of more informed management decisions.

Chapter 8: Development of PES Markets for SGNP

Benefits and beneficiaries of services generated by the SGNP

These results of ESI analysis, illustrative as they are, highlights the multiple societal values that stem from withholding exploitation of resources in SGNP, retaining ecosystem structure and functioning and the flow of a diversity of supporting, regulating and cultural services. There benefits accrue at scales from the local to the international, weighted towards local/city scales but with important benefits right up to global scale. That many provisioning and some cultural services have established financial values, but virtually all supporting and regulating services are externalised, is a major market failure undervaluing ecosystems and other natural resources and driving their unsustainable exploitation.

Table 2 outlines the beneficiaries of services produced by SGNP, with some indicative thoughts on potential markets.

Exploring and developing PES markets for services generated by the SGNP

One of the purposes of PES is to bring into the market services that are currently excluded. The diverse and multi-scalar services provided (or potentially provided) by SGNP are considered in this context in Table 6, which also breaks down services identified as relevant at SGNP into the seven categories of:

- Tangible and monetisable services amenable to market development;
- Tangible services requiring more work to develop and/or hard to quantify;
- Tangible but technically illegal services that nonetheless are current utilized;
- Tangible but banned services for which highly controlled market expansion could be considered;
- Services for which there are already de facto markets (the state recirculates taxpayer revenues for public good);
- Services for which further research is required to understand benefits and possible markets;
- Services that are both banned and inappropriate; and
- Services that should not be marketed due to risk of double-counting.

Cells in the right-hand ‘Recommendations’ column of Table 6 are colour-coded using a three-colour ‘traffic lights’ approach: green signifies ready for market development; amber indicates that further research or dialogue is necessary to explore potential markets; whilst red indicates no potential for market development. In each cell is a recommendation for marketing, further exploration of abandonment of the notion of marketing each service

Ecosystem services	Positive or negative considerations		Recommendation
	☺	☹	
Tangible and monetisable services amenable to market development			
Provisioning: Fresh water	The park is already used for transfer of water, and outputs can be measured	-	Quantify and identify all beneficiaries and explore charging mechanisms where not currently exist
Provisioning: Ornamental resources	People already take some items (feathers, etc.) from the park	Risk of over-exploitation so limitations are necessary	Explore nominal 'license' of similar voluntary of imposed fee
Regulating: Global climate regulation	The park sequesters carbon and international markets are in place	-	Explore: (1) REDD+; and/or (2) carbon offset arrangements with local institutions or businesses
Tangible services requiring more work to develop and/or hard to quantify			
Regulating: Air quality regulation	Benefits certainly occur to Mumbai city, and particularly adjacent neighbourhoods	Linking to beneficiary end- points is complex	Discuss quantification of benefits for different stakeholders with city planners, real estate enterprises and health professionals
Regulating: Local microclimate	Benefits certainly occur to Mumbai city, and particularly adjacent	Linking to beneficiary end-points is complex	Discuss quantification of benefits for different stakeholders

(property values?)	neighbourhoods		with city planners, real estate enterprises and health professionals
Regulating: Water regulation – hydrological buffering	The diverse habitats of SGNP buffer water flows, of substantial and tangible flood control and drought buffering to the adjacent city	Many beneficiaries may not be aware that they benefit from this services	Open discussions with municipality officials, insurance companies and other institutions who receive or may see benefit in this service
Regulating: Natural hazard regulation	The diverse habitats of SGNP dissipate storm energy and in other ways buffer natural hazards benefitting adjacent buildings, occupants, crops and green spaces	Many beneficiaries may not be aware that they benefit from this services	Open discussions with municipality officials, insurance companies and other institutions who receive or may see benefit in this service
Regulating: Pest regulation	The diverse habitats of SGNP buffer host the predators of pest organisms (insects, birds, bats, reptiles, etc.)	Some disbenefits may arise if pests breed in the park (requiring evaluation), but the bigger obstacle is determining how this benefit is expressed outside the park	Further research is required to explore the manifestation of this benefit beyond the park perimeter, and to identify the beneficiaries of the service
Regulating: Erosion regulation	Extensive green cover in the park avert erosion and builds soil structure	Many beneficiaries may not be aware that they benefit from this services	Open discussions with those involved in desilting nullahs and drains, and dredging undertakers, to explore potential markets for this

			benefit
Regulating: Pollination	The diverse habitats of SGNP buffer host the pollinating organisms (insects, birds, bats, reptiles, etc.)	There is a lack of quantification at preset of this benefit	Further research is required to explore the manifestation of this benefit beyond the park perimeter, and to identify the beneficiaries of the service
Regulating: Salinity regulation	Buffered fresh water flows from the park maintain salinity regimes in surrounding mangroves and other intertidal areas	There is a lack of quantification and a wide under-appreciation at preset of this benefit	Open discussions with those involved in maintaining or otherwise benefitting from mangroves and other intertidal habitats (fisheries, conservation institutions, etc.)
Regulating: Noise and visual buffering	The diverse habitats of SGNP, particular trees and other large and complex vegetation, confer substantial noise and visual buffering services	There is a lack of quantification and a wide under-appreciation at preset of this benefit	Open discussions with municipality officials, real estate interests adjacent to the city, insurance companies and other institutions who receive or may see benefit in this service
Tangible but technically illegal services that nonetheless are current utilised			
Provisioning: Food	Tangible food resources (e.g. land crabs, fruits) are taken by occupants of villages in the park	This practice is technically illegal	Consider the risks of legitimizing an illegal use; probably not a viable service for market development

Provisioning: Fuelwood	Occupants of villages in the park are known to take dry wood for fuel	This practice is technically illegal	Consider the risks of legitimizing an illegal use; probably not a viable service for market development
Tangible but banned services for which highly controlled market expansion could be considered			
Provisioning: Genetic resources	The biodiversity of the part contains a diversity of genetic resources of potential value to humanity	Extraction from the park is not permitted	Sustainable levels of bioprospecting may be feasible, if tightly controlled and for research purposes only
Provisioning: Biochemicals, natural medicines, pharmaceuticals	The biodiversity of the part contains a diversity of chemical resources of potential value to humanity	Extraction from the park is not permitted	Sustainable levels of bioprospecting may be feasible, if tightly controlled and for research purposes only
Services for which there are already de facto markets (the state recirculates taxpayer revenues for public good)			
Cultural services: Recreation and tourism	Tangible benefits accrue from SGNP	-	It could be fairly argued that state support for park management and maintenance is already a form of PES scheme, recirculation taxpayer revenues for a largely unquantified 'basket' of public services.
Cultural services: Cultural heritage (aesthetic, spiritual, artistic/crating inspiration, social relations)	Tangible benefits accrue from SGNP	-	
Cultural services: Education and	Tangible benefits accrue from SGNP	-	

research			Opportunities may exist to further quantify these benefits ion making a case for a higher rate of public investment for clearly-articulated public benefits
Supporting services: All services	Tangible benefits accrue from SGNP	-	
Services for which further research is required to understand benefits and possible markets			
Regulating: Human health regulation	Benefits through parasite/disease regulation are likely	There is no science to quantify this benefit	Remain vigilant for more relevant research, tough marketization would be difficult
Regulating: Livestock health regulation	Benefits through parasite/disease regulation are likely	There is no science to quantify this benefit, and there is no livestock within the park n(though some is adjacent)	Remain vigilant for more relevant research, though marketization would be difficult
Services that are both banned and inappropriate			
Provisioning: Waste disposal	-	No waste disposal is permitted in the park	Avoid. Development of this service would degrade the park ecosystem
Provisioning: aggregate extraction	-	No clay, mineral or other aggregate extraction is permitted in the park	Avoid. Development of this service would degrade the park ecosystem
Provisioning: Energy harvesting from natural air	-	No hydropower or wind turbines are permitted in the park	Avoid. Development of this service would degrade the park

and water flows			ecosystem
Services that should not be marketed due to risk of double-counting			
Regulating: Water purification	This service is a substantial output of the SGNP's ecosystems	In the absence of any wastewater treatment service, it's outcomes contribute to the provisioning service of fresh water	Do not seek to market this service as it will double-count with the provisioning service of fresh water provision

Table 6: Consideration of potential PES markets for service generated by the SGNP

Chapter 9: Implications of encroachment into SGNP

Although encroachment into SGNP is not a primary focus of this study, it does have economic as well as biological implications and so is briefly considered here as something to which PES considerations may have relevance.

A report by Wildlife and We Protection Foundation (2018)[115] highlights that human encroachment on protected areas is a significant factor behind the global decline in large carnivores, particularly in UPAs (Urban Protected Areas), and specifically in SGNP posing threats to the leopard population. Allied to encroachment is an increase in perceived crime, both domestic and related to theft and degradation of natural resources. Encroachment, in addition to being inherently illegal, also therefore tends to work against the five priorities of management in protected areas, namely: maintaining and increasing biodiversity; preserving or improving ecological balances and quality; satisfying the cultural demand; promoting environmental education and awareness; and adaptation to the consequences of climatic changes.

Encroachment, also known as illegal hutments or settlements, is therefore inconsistent with nature conservation objectives, but also the production of ecosystem services as outlined in this PES report. Specifically at SGNP, Wildlife and We Protection Foundation (2018) reported 25,000 occupants as part of increasing urban sprawl that is eating into the green cover of the national park. The encroachment report sets out an online portal to map encroachment, mapping a total encroachment area in SGNP of nearly 2.55 km^2.

The physical area of encroachment will substantially underestimate the area of actual wildlife disturbance as well as other impacts (water, wood and other resource use, noise, traffic, waste, etc.) Peripheral encroachment is a particular problem, also related to increasing wildlife-human conflicts.

The Table 7 below describes potential impacts of encroachments on ecosystem services produced by SGNP.

Ecosystem services		Potential encroachment impact	Justification for assessment
Provisionin	Fresh water available for abstraction and use	Negative	Water extraction, waste impacts on water resources and any modification of habitat will have negative impacts on

			water flows and resources
	Food production (e.g. crops, fruit, fish, etc.)	Not relevant	As food is not (legally) taken from SGNP, the impact is zero
	Fibre and fuel production (e.g. timber, wool, etc.)	Not relevant	As wood and other sources of fibre and fuel are not (legally) taken from SGNP, the impact is zero
	Genetic resources (used for crop/stock breeding and biotechnology)	Not relevant	As genetic resources are not taken from SGNP, the impact is zero, though impacts on potential future uses may be a consideration
	Biochemicals, natural medicines, pharmaceuticals	Not relevant	As biochemical resources are not taken from SGNP, the impact is zero, though impacts on potential future uses may be a consideration
	Ornamental resources (e.g. shells, flowers, etc.)	Needs investigation	Visitors take minimal ornamental resources (feathers, leaves, etc.) from the park, but the extent of extraction potentially for trade by those encroaching the park is unknown
	Harvesting of clay, mineral, aggregates, etc.	Not relevant	As aggregates are not (legally) taken from SGNP, the impact is zero
	Waste disposal	Not relevant	As waste is not disposed of in SGNP, the impact is zero
	Energy harvesting from natural air and water flows (if relevant)	Not relevant	As energy is not harvested from natural flows of wind and water within SGNP, the impact is zero
Regulating	Air quality regulation	Negative	Any perturbation of natural habitat surrounding encroached habitations, as well as the aerial emissions from fires,

			vehicle exhausts, etc., will undermine air quality regulation services. This may be particularly significant where activities of encroachments on the park margins most directly affect urban residents immediately peripheral to the park who are the main beneficiaries of this service
	Local climate regulation - microclimate, temperature, precipitation	Negative	Any perturbation of natural habitat surrounding encroached habitations, as well as the aerial emissions from fires, vehicle exhausts, etc., will undermine microclimate regulation services. This may be particularly significant where activities of encroachments on the park margins most directly affect urban residents immediately peripheral to the park who are the main beneficiaries of this service
	Global climate regulation - greenhouse gas sequestration, etc.	Negative	Any perturbation of natural habitat surrounding encroached habitations, as well as the aerial emissions from fires, vehicle exhausts, etc., will undermine global climate regulation services
	Water regulation (timing and scale of run-off, flooding, etc.)	Negative	Any perturbation of natural habitat within and surrounding encroached areas may affect park hydrology
	Natural hazard regulation (i.e. storm protection)	Negative	Any perturbation of natural habitat within and surrounding encroached areas may affect the capacity of the park to buffer storm energy and other natural hazards
	Pest regulation	Negative	Any perturbation of natural habitat

			within and surrounding encroached areas may affect pest regulation services from the park
	Disease regulation - human	Negative	Any perturbation of natural habitat within and surrounding encroached areas, and the effluent of encroached communities, may affect human disease regulation services from the park
	Disease regulation - livestock	Unknown	This impact is unknown
	Erosion regulation	Negative	Any perturbation of natural habitat within and surrounding encroached areas may affect erosion regulation services from the park
	Water purification and waste treatment	Negative	Any perturbation of natural habitat within and surrounding encroached areas, and any waste arising from them, may affect purification processes in the park
	Pollination	Negative	Any perturbation of natural habitat within and surrounding encroached areas may affect pollination services from the park
	Salinity regulation - implications for soil salinity build-up	Negative	Any perturbation of natural habitat within and surrounding encroached areas may affect salinity regulation services both within the park and in terms of the influence of outflowing streams on adjacent mangroves and other habitats
	Fire regulation - tendency of ecosystems	Significantly negative	Any perturbation of natural habitat within and surrounding encroached areas

	in the catchment to burn		may affect the resistance of park habitat to fire, and activities in and around encroachments may also pose fire risks
	Noise and visual buffering - impacts on the buffering effects of ecosystems	Significantly negative	Any perturbation of natural habitat within and surrounding encroached areas may affect the capacities of the park to buffer noise and visual intrusion, and encroachments may also directly create noise and visual disturbance
Cultural services	Cultural heritage	Negative	Whilst it may be argued by encroachment residents that their homes represent a form of heritage, the presence and activities of encroachments within SGNP reduces the overall cultural value of the park
	Recreation and tourism	Negative	The presence and activities of encroachments within SGNP reduces the overall recreational and tourism values of the park
	Aesthetic value	Negative	The presence and activities of encroachments within SGNP reduces the aesthetic values of the park
	Spiritual and religious value	Negative	The presence and activities of encroachments within SGNP reduces the spiritual and religious values of the park
	Inspiration of art, folklore, architecture, etc.	Negative	The presence and activities of encroachments within SGNP reduces the inspirational values of the park
	Social relations (e.g. fishing, grazing or	Negative	Whilst encroachment communities are a form of social capital, the presence and

	cropping communities)		activities of encroachments within SGNP reduces community values for other users of the park
	Educational and research	Negative	The presence and activities of encroachments within SGNP reduces the educational and research values of the park (aside from anthropological studies of encroachment communities and their interactions)
Supporting services	Soil formation	Negative	Encroachments and activities within them may reduce soil formation processes within the park
	Primary production	Negative	Encroachments and activities within them may reduce or appropriate primary production within the park
	Nutrient cycling	Negative	Encroachments and activities within them may reduce nutrient cycling processes within the park
	Water recycling	Negative	Encroachments and activities within them may reduce water recycling processes within the park
	Photosynthesis (production of atmospheric oxygen)	Negative	Encroachments and activities within them may reduce photosynthetic processes within the park
	Provision of habitat	Significantly negative	Encroachments and activities within them may directly as well as indirectly (for example through smoke, movement of people and vehicles, artificial lights, etc.) affect habitat for wildlife in the park

Table 7: Potential impacts of encroachments on ecosystem services

Potential ecosystem service impacts from encroachment given in Table 7 above have not been quantified nor was the quantification possible within the limitations of this study. However, when considering potential PES markets, the marginal impacts on service values from encroachments and the activities of their significant population of residents should also be considered within an economic case for management decisions.

Chapter 10: Conclusions

Sanjay Gandhi National Park hosts a wealth of biological and geological diversity and cultural history. It confers a wide range of benefits locally, into the surrounding city, nationally and internationally, spanning a diversity of types of value from the tangible and tradeable to the cultural and spiritual.

Whilst some ecosystem services have established financial value, particularly provisioning and some cultural services, virtually all supporting and regulating services are externalised from markets, so the many values generated by SGNP are substantially underappreciated, or more commonly entirely overlooked, even by those that benefit substantially from them. This represents a major market failure.

This study has looked at the ecosystem services generated by SGNP using the lens of the Millennium Ecosystem Assessment (2005) framework of provisioning, regulating, cultural and supporting services, including a number of commonly applied addenda, further considering the significance of these benefits and the geographical scales at which they manifest using the RAWES (Rapid Assessment of Wetland Ecosystem Services) approach.

From this analysis, a range of services are identified and stratified into those that:

- Are closer to market identification and development;
- Require further research or dialogue to explore potential markets; or
- Have no potential for market development.

That the Sanjay Gandhi National Park confers very substantial benefits locally, to the surrounding city, nationally and internationally is beyond doubt. Generating recognition of that fact beyond the scientific and nature conservation community remains challenging, but its clear exposition using the language of ecosystem services is greatly helpful. Demonstration, and ideally further market development, of the economic importance of this interconnected set of ecosystem services serves as an additional lever towards wider recognition and investment in the many benefits provided by SGNP and other natural assets.

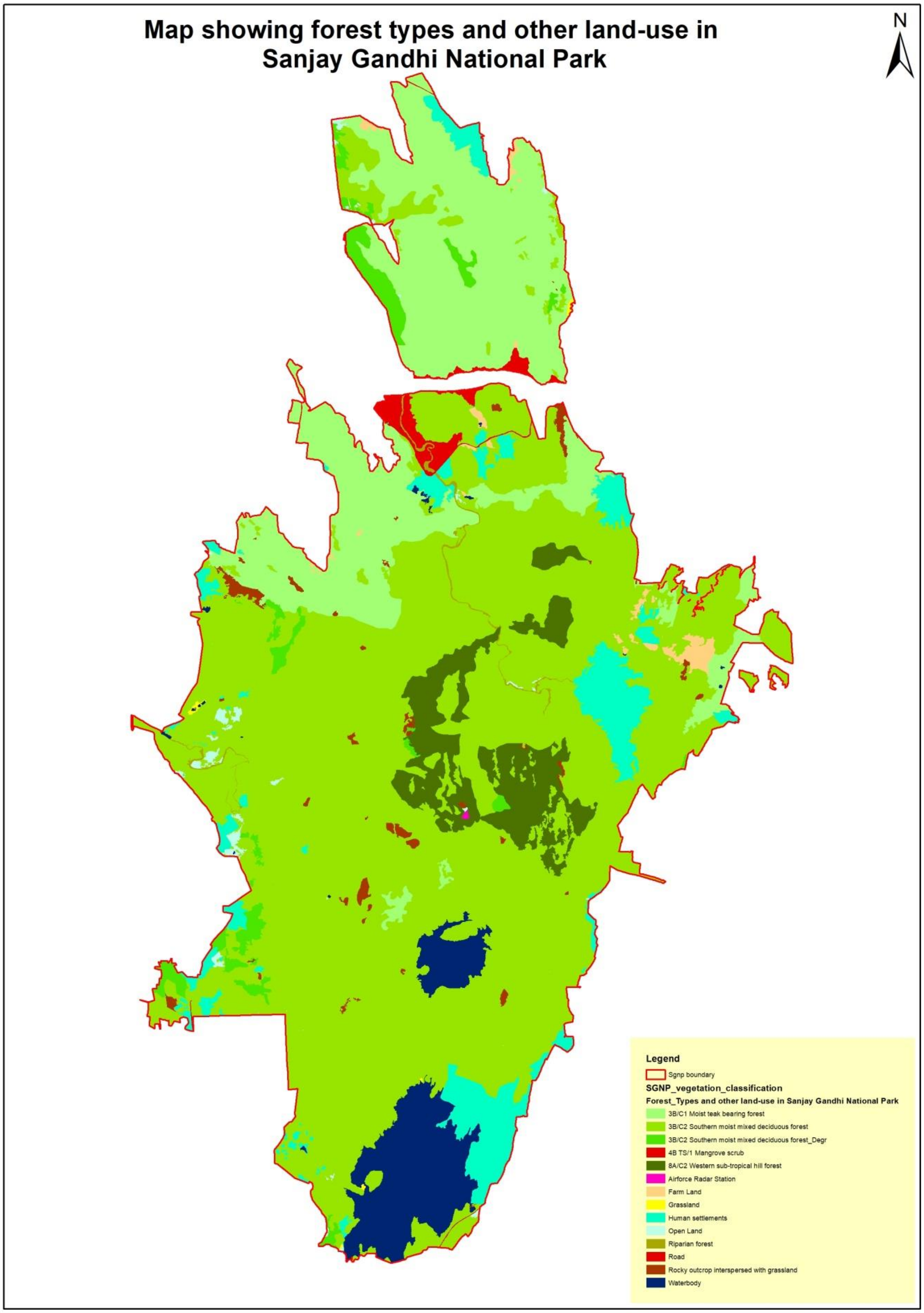
The impacts of encroachments on the ecosystem services of SGNP and their associated values are also addressed in this report, and should be considered in relation to the economic case for PES market development as well as wider park management decisions.

Appendix 1: Ecosystems of SGNP-Preliminary Findings

Ecosystems in SGNP

Filed survey and review of secondary literature undertaken to identify the ecosystems in Sanjay Gandhi National Park has revealed that there are following types of major ecosystems in the Park.

1. 3B/C1 Moist teak-bearing forests
2. 3 B/C2 Southern moist mixed deciduous forest
3. 4B/TS1 Mangrove scrubs (coastal margin)
4. 8 A/C2 Western sub-tropical hill forests
5. Degraded forest
6. Plantations
7. Wetland and marshes (lake catchments) / large water bodies
8. Streams
9. Riparian areas – fringing forest adjacent to streams and rivers
10. Creeks
11. Rocky expanses and outcrops interspersed with grassy patches
12. Grasslands
13. Agriculture
14. Human settlements – (encroachments)
15. Human settlements enclaved in the forests



Map 1: Map of Sanjay Gandhi National Park depicting location of various identified ecosystems

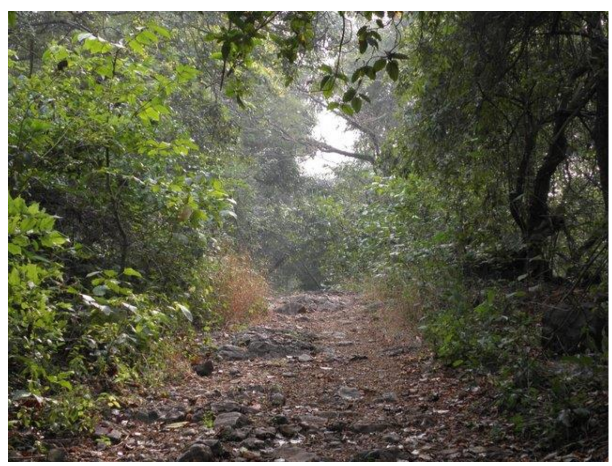
All the listed ecosystems were identified and a map was prepared in Arc GIS. The map depicts the location of all the identified ecosystems in the National Park. Some ecosystems couldn't be depicted on the map as the area covered by them is very small.

1. 3B/C1 Moist teak-bearing forests

The moist teak bearing forests occur in 3-5 % of the areas. These forests exist where the soil condition is relatively better. Density of the crop is generally above 0.4 and it goes upto 0.7. The forests are mostly concentrated in Yeur and Ghodbander rounds. Earlier Nagla block had vast area under teak forest but teak has been almost wiped by illicit cutting from this area.

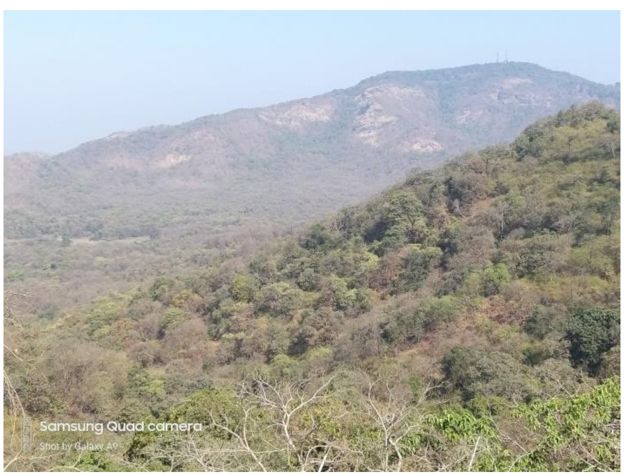
Important tree species of this forest type include *Tectona grandis* (Teak), *Garuga pinnata* (Kakad), *Lannea grandis* (Shemat), *Schleichera oleosa* (Koshimb), *Mimusops hexandra* (Ranjan), *Mangifera indica* (Amba), *Adina cordifolia* (Hed), *Pterocarpus marsupium* (Bija), *Bombax malabaricum* (Sawar), *and Syzygium cumini* (Jambul).

Important shrubs include Carissa carandus (Karvand), *Helicteres isora* (Murudsheng), *Adhatoda vasica* (Adulsa), *and Thespesia lampas* (Ranbhendi). The climbers are *Abrus precatorius* (Gunj), *Climatis triloba* (Ranjai). *Zizyphus rugosa* (Toria). Bamboo species found in the forests are *Dendrocalamus strictus* (Manvel), *Bambusa arundinacea* (Katas). Important grass species are *Cynodon dactylon* (Harali), *Dicanthium anulatum* (Ranbangdi), *Coix gigantea* (Ranjondhala), *Eragrostis spp.* (Darbha), *and Panicum glabrum* (Varai).



2. 3 B/C2 Southern moist mixed deciduous forest

The Southern moist mixed deciduous forests are profusely found in the area. Teak is occasionally found in low proportions. The density varies from 0.4 to 0.7. Clumps of manvel bamboo (*Dendrocalamus strictus*) and Katas Bamboo (*Bambusa arundinacea*) are found in the area. This forest type covers major part of the division. The soil is deep, loamy, and generally rich in humus content. The semi evergreen species found in this forest type are mango, lokhandi, shendri, koshimb and ashok, though ashok is mostly localised along the nalla courses in Kanheri, Chena and Krishnagiri Upvan forests.



3. 4B/TS1 Mangrove scrubs

The coastal line of Maharashtra is about 720 km. (NIO GOA 1998) and numerous river mouths, creeks, small bays, headlands, cliffs etc indent it. Bassein creek is one of the 37 stations that were surveyed by NIO for the floral and faunal diversity. Bassein creek is the longest creek with 41-km. length. However only 23% area i.e. approximately 2000 ha. has mangrove coverage (NIO 1998). This creek passes through Sanjay Gandhi National Park. The extent of mangrove forests included within the boundaries of this area is not precisely known. *Avicennia marina* is dominating the vegetation and has stunted growth. *Bruguiers gymnorhiza* and *Lumnizera racemosa* have almost vanished from the estuaries of Bassein Creek, while species like *Sonneratia alba, Rhizophora apiculata, Axrosticham sureum* are absent from this region. The marine Algae found in Bassein creeks are *Entromorpha clathrate* etc.


4. 8 A/C2 Western sub-tropical hill forests

These are supposed to be few of the remnant patches of natural forests of higher elevations that occur on low lying hills (Bio-diversity of the Western Ghats, 1997).

The western sub-tropical hill forests are found in very small patches at high altitude. Density is around 0.6. It is semi-evergreen type of forest with many evergreen species present in the crop. The Bamboo is typically absent. The floristic include, besides climbers, orchids and ferns. *Mangifera indica* (Mango), *Pongamia pinnata* (Karanj), *Garcinia indicia* (Kokam), *Syzygium cuminii* (Jambul), *Calophyllum inophyllum* (Undi), *Sideroxylon tomentosum* (Kate-Kumbal), *Ixora* (Lokhandi), *Murraya paniculata* (Pandari). Garcinia is located on the highest peak in Kanheri Forests.

5. Degraded forest

There are patches of degraded forest mainly near human habitation. The degradation mainly has happened due to extreme pressure that these areas are being subjected to due to anthropogenic activities.

6. Plantation

Some plantations have been taken up in the past in Yeur and Nagla forests. In the period from 1981-82 to 1991-92, over 500 ha area has been brought under plantations of fruit & fodder species. These plantations are successful. *Glyricidia* has been extensively planted on the western side of the area. Also, the exotics like Subabul and Australian Babul have been planted in the past.

7. Wetland and marshes (lake catchments) / large water bodies

Tulsi and Vihar Lakes are two water impoundments, which supply water to Mumbai and Thane cities. Though these two lakes are geographically situated within the national park, their water spread areas are not included in the national park. However, their catchments are included within the national park. These two lakes and their surrounding forests constitute a prime habitat for the wildlife of this division.

The Vihar Lake situated at the extreme south has a water spread of about 731.492 ha. Its catchment is roughly 851.488 ha. At present the catchment of only 366 ha. is under the management of the national park division while the basin of the lake, and the rest of the catchment are under the control of the Mumbai Municipal Corporation. The Catchment of Tulsi Lake is about 745.25 ha. The actual water spread being 130.918 ha. The management of the water spread of this lake is also under the control of the Mumbai Municipal Corporation. The lake covers an area of about 1400 acres, and has a gathering ground, exclusive of the area of the water surface, of about 2550 acres. It is formed by three dams, two of which had to be built to keep the water from flowing over ridges on the margin of the basin which were lower than the top of the main dam. The quantity of water supplied by the reservoir is about 8,000,000 gallons a day. The wilderness of the surrounding area keeps the water free from the risk of outside fouling.

8. Streams

The Bassein Creek that flows in East-West direction divides the division area unequally into the northern and the southern blocks. The main sources of water in the park are the rain-fed lakes - Tulsi and Vihar, the river Dahisar, Revat nalla and numerous forest streams.

The river Dahisar originates from Tulsi Lake and flows through the forest of Magathane village and joins Manori Creek to the northwest of Dahisar village which finally meets Arabian Sea. The catchment area of Dahisar River extends to over 2023.500 ha. Numerous small nallas join this river during its course through the park. Very few perennial water springs or waterholes are seen in the beds of the Dahisar River and its tributaries.

The Revat nalla starts from Avaghada Hill. It then flows towards north through the reserved forests of Yeur village and then through the reserved forests of Chena village and ultimately joins the Bassein creek (Ulhas River). This nalla is locally known as Laxmi River, while near its origin it is known as 'Vagbacha khonda'. The catchment area of this nalla extends to over 2225.850 ha. The nalla however is not perennial. There are a number of spots in this nalla-bed, which can be developed as perennial waterholes.

9. Riparian areas

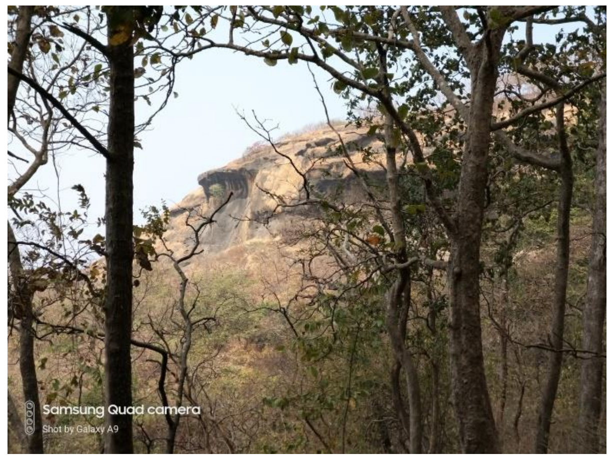
Riparian areas are ecosystems adjacent to a river or waterway that, in an undisturbed state, provide habitat for wildlife and help improve water quality. Riparian areas are usually transitional zones between wetland and upland areas and are generally comprised of grasses, shrubs, trees, or a mix of vegetation types that exist within a variety of landscapes. There are a number of small rivulets running in the park. The forests along the banks of these rivulets are the biodiversity rich riparian areas.

10. Creek

The Bassein Creek that flows in East-West direction divides the Division area unequally into the northern and the southern blocks. Bassein creek is one of the 37 stations which were surveyed by National Institute of Oceanography for the floral and faunal diversity. Bassein creek is the longest creek with 41-km. length. However only 23% area i.e. approximately 2000 hectares has mangrove coverage (NIO 1998). This creek passes through SGNP. There are mangrove patches along the banks of the creek. *Avicenna marina* is dominating the vegetation. *Bruguiera gymnorhiza* and *Lumnitzera racemosa* have almost vanished from the estuaries of Bassein Creek, while species like *Sonneratia alba*, *Rhizophora apiculata, Acrosticham sureum* are absent from this region. The marine Algae found in Bassein creeks are *Entromorpha clathrata* and *Claloglossal epureurii*. (Management Plan SGNP)

11. Rocky expanses and outcrops interspersed with grassy patches

Dry rocky surface on the top of hills with sparse forest mainly shrub can be seen in higher reaches of the Park. In monsoon these areas get covered by ephemerals and grasses that dry out soon after monsoon. Vegetation in these areas is sparse. Rocky outcrops can be seen around Kanheri caves.



12. Grasslands

Grasslands seen in the Park cannot be classified as actual grasslands because these are openings in the forest that have developed into patches of grass. Some grassland development was undertaken by the park management with the view of providing forage to the herbivores.

13. Farmlands

There are some farmlands especially around the Yeur range. The villagers living in the vicinity for the park have fields where they practise agriculture. These agricultural are usually on the periphery of the forested patches.

14. Human settlements – (encroachments)

The total area encroached throughout the Park is 255.359 Ha. These encroachments are at the fringe of the forest. The interaction between different elements of the forest and human habitation has led to the formation of a different type of ecosystem.

15. Human settlements enclaved in the Forests

There are a number of hamlets in the park that are inhabited mostly by the tribal. Due to habitation, the ecosystem of the nearby forest has changed due to influence of the elements associated with human presence.

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