Strategy
Paper 2

Valuation of Terrestrial Ecosystem Services

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Karnataka Science and Technology Academy, (KSTA)
Bengaluru
Department of Science and Technology, Government of Karnataka
and
Energy and Wetland Research Group,
Centre for Ecological Sciences,
Indian Institute of Science,
Ranbir and Chitra Gupta School of Infrastructure
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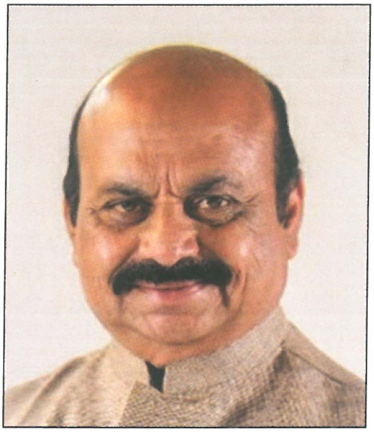
Indian Institute of Technology Kharagpur

GOVERMENT OF KARNATAKA



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Valuation of Terrestrial Ecosystem Services

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Citation:
Ramachandra T.V., Bharath Setturu, Vinay S., and Bharath H Aithal, 2020. Valuation of Terrestrial Ecosystem Services, Strategy Paper 2, Karnataka Science and Technology Academy (KSTA), Bengaluru, Pp. viii+74

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Published by
Karnataka Science and Technology Academy (KSTA)
College of Horticulture Entrance, GKVK Campus
Major Sandeep Unnikrishnan Road, Vidyaranyapura Post, Bengaluru 560097
Tel: 080- 29721 1550; Email: ksta.gok@gmail.com: Website: www.kstacademy.in

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Message

An ecosystem is an interacting system of biotic and abiotic components of our environment. Aquatic and related terrestrial ecosystems are among the most important ecosystems. Ecosystem is being considered as natural capital-a form of capital asset that, along with physical, human, social, and intellectual capital, is one of society's important assets. However, human activities have led to increased pollution, adverse modification, and destruction of ecosystems. Better understanding of the kind of services provided by the ecosystems, the threat they face and how the natural environment matters to human survival are of absolute necessary for sound policy and decision making.

Ecosystem services have received significant attention as more and more countries build sustainable economies. The economic values of the ecosystem goods and services must be known so that they can be compared with the economic values of activities that may compromise them. The valuation of ecosystem services (VES) provides an unbiased framework to value unaccounted ecosystem benefits and also helps in developing meaningful policy interventions.

In this perspective, Karnataka Science and Technology Academy (KSTA) has brought out this Strategy Paper focusing on "Valuation of Terrestrial Ecosystem Services", and is an effort of a group of eminent scientists led by Prof. T.V. Ramachandra, Co-ordinator, Energy and Wetlands Research Group [CES], Centre for Ecological Sciences, IISc.

I thank Prof.T.V. Ramachandra and the esteemed members of the Committee for bringing out this Strategy Paper. I am sure the valuation of ecosystem services carried out by the team and replication of this exercise in other states will undoubtedly play a vital role in conservation planning and ecosystem-based management in India.

Date: 17-06-2022
Place: Bengaluru

S. Ayyappan
Chairman, KSTA

Preface

Humans depend on ecosystems for their basic needs, such as food, fuel, minerals, water, air, etc. All forms of interaction between ecosystems and people, including in situ and remote interactions, are often referred to as ecosystem services. The supply of an ecosystem service is associated with an ecosystem structure or process or a combination of ecosystem structures and processes that reflect the biological, chemical, and physical interactions among ecosystem components. Ecosystem services are broadly categorized as (i) provisioning services are those ecosystem services representing the contributions to benefits that are extracted or harvested from ecosystems, (ii) regulating and maintenance services are those ecosystem services resulting from the ability of ecosystems to regulate biological processes and to influence climate, hydrological and biochemical cycles, and thereby maintain environmental conditions beneficial to individuals and society, (iii) cultural services are the experiential and intangible services related to the perceived or actual qualities of ecosystems whose existence and functioning contributes to a range of cultural benefits.

India is attempting to accelerate economic growth and relax environmental laws, and there is tremendous pressure to divert natural systems to other uses. Hence, there is a pressing need to undertake the natural capital accounting and valuation of the ecosystem services, especially intangible benefits, provided by ecosystems. The value of all ecosystem services, including the degradation costs, needs to be understood for developing appropriate policies for the conservation and sustainable management of ecosystems. Scientific efforts during the past decade have refined the understanding of ecosystem function and demonstrated the links between functions and the provision of ecosystem services. This knowledge needs to be communicated effectively to decision-makers and the public, which will lead to the development of policies that adequately consider the trade-offs between the conservation of ecosystems and natural resources and economic growth.

There is an urgent policy need for more comprehensive assessments of the natural capital of ecosystems, which will aid in comparing these aggregate values with the opportunity cost of this land. Policymakers need such information to gain support for conservation funding, engage local communities, and develop market-based instruments for conservation, which necessitates accounting for the natural capital found in ecosystems and incorporating their economic worth added to the measurement of the wealth of a region.

Ecosystem accounts make the value of ecosystem services visible, allowing them to be internalized into decision-making. Accounting of ecosystem services enables an assessment of trade-offs between economic development and environmental conservation and restoration, resulting in better-informed decisions. It also allows strengthening the economic case for conserving forests in states in India and developing countries where there can be tremendous pressure to relax forest laws and divert forests to non-forest uses without proper consideration of the sustainability of such actions.

The valuation of ecosystem services of terrestrial ecosystems (forests and agriculture) is implemented district-wise for Karnataka State, India, as per the validated statistical framework for natural capital accounting –SEEA: System of Environmental-Economic Accounting (SEEA.un.org). According to SEEA protocol, ecosystem services are defined as the contributions of ecosystems to the benefits that are used in economic and other human activities. The valuation of ecosystem services (VES) provides an unbiased framework to value unaccounted ecosystem benefits and alsohelps in developing meaningful policy interventions. The approach allows for adjusted regional or national accounts which reflect the output of ecosystem services as well as the depletion of natural resources and the degradation costs (externalized costs of the loss of ecosystem services) of ecosystems in economic terms. In this perspective, the strategy paper (KSTA-Strategy Paper 2), focusing on the valuation of terrestrial ecosystem services in Karnataka, India, will help raise awareness and provide a quantitative tool to evaluate the sustainability of policies. The endeavor toward developing the strategy paper was commissioned by the Karnataka Science and Technology Academy (KSTA), Bangalore. The research towards developing the strategy paper was carried out by the Energy and Wetlands Research Group at CES, Indian Institute of Science, in collaboration with the United Nations Environment Programme (UNEP), United Nations Statistics Division (UNSD), the Ministry of Statistics and Programme Implementation (MoSP), Government of India and the ENVIS division, The Ministry of Environment Forests and Climate Change (MoEFCC), Government of India and Ranbir and Chitra Gupta School of Infrastructure Design and Management (RCG SIDM), Indian Institute of Technology Kharagpur (IIT-KGP) as part of the international, EU-funded Natural Capital Accounting and Valuation of Ecosystem Services (NCAVES) project.

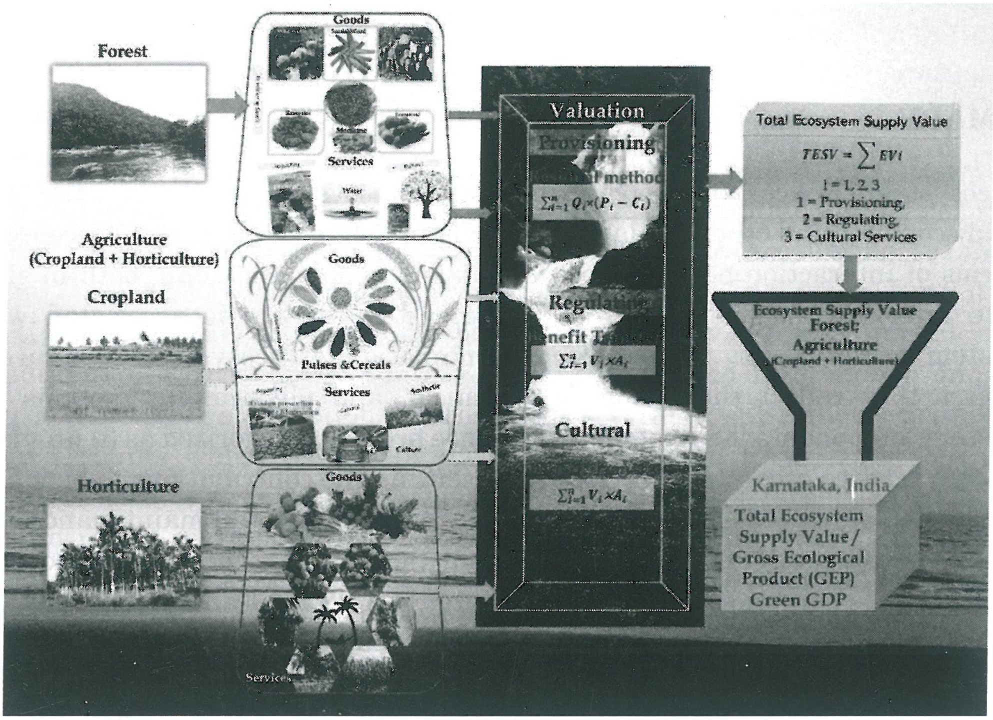
Contents

Abbreviations used

ALT	Anterolateral thigh
AmB	Amphotericin B
BAL	Bronchoalveolar lavage
BD	bis indie
CBC	complete blood count
CE	contrast-enhanced
CISS	Constructive Interference in Steady State
COVID	Corona virus disease
CRP	C-reactive protein
CT	Computed tomography
2D	2-Dimentional
3D	3-Dimentional
DNE	Diagnostic nasal endoscopy
ECHO	Echocardiogram
ESR	Erythrocyte sedimentation rate
ESS	Endoscopic sinus surgery
FBS	Fasting blood sugar
GMS	GrocoffMethenemine Silver
HBsAg	Hepatitis B surface antigen
HCV	Hepatitis C virus
HDU	High dependency unit
HIV	Human immunodeficiency virus
HPE	Histopathological examination
ICA	Internal carotid artery
ICU	Intensive care unit
IV	intravenous
KOH	Potassium hydroxide

LFT	Liver function test
MRI	Magnetic resonance imaging
NG	Nasogastric
OMFS	Oro-maxillary facial surgery
OPG	Orthopentomogram
PNS	Paranasal sinus
PPBS	Post-prandial blood sugar
RFT	Renal function test
ROCM	Rhino-Orbito-Cerebral Mucormycosis
RT	Ryle's tube
SARS	Severe Acute Respiratory Syndrome
SEQ	sequence
STIR	short tau inversion recovery
T2 FAT SAT	T2 fat saturation
TID	ter in die
TM	Temporomandibular
TR	Transcutaneous retrobulbar

Valuation of Terrestrial Ecosystem Services, Karnataka State, India



ACKNOWLEDGEMENT: We are grateful to the European Union (EU), United Nations Statistics Division (UNSD) and United Nations Environment Programme (UNEP) for supporting the study in Karnataka State, India. We acknowledge the efforts of Mr. Karthik Naik and Mr. Vinayka Bhatta (for assisting in field data collection and district wise remote sensing data analyses – extent and fragmentation analyses), Ms. Harita (for help in compiling data related to biodiversity), Ms. Minsa (for compiling data related to fauna), Dr. G R Rao, Mr. Vishnu Mukri and Mr. Shrikanth Naik (for assistance in field data collection related to flora and fauna in 5 districts of Western Ghats), Mr. Vrijulal and Dr. M D Subash Chandran (for verification of data – flora and fauna). Thanks to (i) Dr Prabhuraj, Director, Karnataka State Remote Sensing Centre (KSRSAC), Government of Karnataka (GoK), Bangalore, for providing spatial data of the district administrative boundaries, stream and river network, population data; (ii) Dr Hemanth Kumar, Executive Secretary, Karnataka State Council for Science and Technology (KSCST), GoK for providing spatial data related to geology, lithology, etc. (iii) Director, National Remote Sensing Centre, Department of Space, GoI, Hyderabad and (iii) Director, Department of Agriculture, GoK for providing soil health data – district wise for Karnataka.

Valuation of Terrestrial Ecosystem Services, Karnataka State, India

SUMMARY

Ecosystem services are the contributions of ecosystems to the benefits that are used in economic and other human activities. Further, ecosystem services encompass all forms of interaction between ecosystems and people, including both in situ and remote interactions. The supply of an ecosystem service is associated with an ecosystem structure or process or a combination of ecosystem structures and processes that reflect the biological, chemical, and physical interactions among ecosystem components. Ecosystem services are broadly categorised as (i) provisioning services are those ecosystem services representing the contributions to benefits that are extracted or harvested from ecosystems, (ii) regulating and maintenance services are those ecosystem services resulting from the ability of ecosystems to regulate biological processes and to influence climate, hydrological and biochemical cycles, and thereby maintain environmental conditions beneficial to individuals and society, (iii) cultural services are the experiential and intangible services related to the perceived or actual qualities of ecosystems whose existence and functioning contributes to a range of cultural benefits. There is a range of other benefits, for example, concerning relational and intrinsic values, that are not captured in the above categories.

India is trying to accelerate economic growth and relax environmental laws, and there is tremendous pressure to divert natural systems to other uses. Hence, there is a pressing need to undertake the natural capital accounting and valuation of the ecosystem services, especially intangible benefits, provided by ecosystems in India. The value of all ecosystem services, including the degradation costs, needs to be understood for developing appropriate policies toward the conservation and sustainable management of ecosystems. Scientific efforts during the past decade have refined the understanding of ecosystem function, demonstrated the links between functions and the provision of ecosystem services. This knowledge needs to be communicated effectively to decision-makers and the public, which will lead to the development of policies that adequately consider the trade-offs between the conservation of ecosystems and natural resources and economic growth.

There is an urgent policy need for more comprehensive assessments of the natural capital of ecosystems, which will aid in comparing these aggregate values with the opportunity cost of this land. Policymakers need such information to gain support for conservation funding and engage local communities and develop market-based instruments for conservation. This necessitates accounting for the natural capital found in the forest ecosystems (among others) and incorporating their economic worth added to the measurement of the wealth of a region.

The valuation of ecosystem services of terrestrial ecosystems (forests and agriculture) is implemented district-wise for Karnataka State, India as per the validated protocol - System of Environmental Economic Accounting (SEEA EA; SEEA.un.org), which constitutes the statistical framework for natural capital accounting. According to this protocol, ecosystem services are defined as the contributions of ecosystems to the benefits that are used in economic and other human activities. The valuation of ecosystem services (VES) allows for adjusted national accounts which reflect the output of ecosystem services as well as the depletion of natural resources and the degradation costs (externalized costs of the loss of ecosystem services) of ecosystems in economic terms, which will help raise awareness and provide a quantitative tool to evaluate the sustainability of policies. It provides an unbiased and dependable national framework to value so far unaccounted ecosystem benefits and helps develop meaningful policy interventions.

Services of the ecosystem services were quantified considering only the contribution of the ecosystem to the benefit, through the residual value method by taking the gross value of the final marketed good to which the ecosystem service provides input and then deducting the cost of all other inputs, including labour, produced assets, and intermediate inputs.

The current endeavour focuses on ecosystem services in forest and agricultural ecosystems for 2005 and 2019. Values of 2005 were adjusted through the consumer price index or gross domestic product (GDP) deflator. These values reflect the actual measures of ecosystem services, which could be compared with ecosystem services of 2019. Comparison of values of services of 2019 with 2005 highlight that there has been a considerable decline in ecosystem services in Karnataka– a 28.5% reduction in provisioning services (51.6% reduction in forest ecosystems), a 21% reduction in regulatory services (mainly in forest ecosystems - 27.1% reduction), and a 1.9% reduction in cultural services during 2005 to 2019.

Ecosystem services were aggregated to compute the Total Ecosystem Supply Value (TESV). This aggregate measure is also referred to as G*ross Ecosystem Product (GEP), which equals the sum of all final ecosystem services (i.e., by monetary values* *of those services) from ecosystem assets.* The TESV of forest and agricultural ecosystems in Karnataka was 3620 billion INR in 2005 (forest ecosystems: 2841 billion INR and agricultural ecosystems: 779 billion INR). However, overall TESV declined in 2019 to 2912 billion rupees, with forest ecosystems driving this decline with a 35% decline in TESV. The TESV was also compared to the GDP of Karnataka, which is about 10128 billion rupees. TESV of the forest ecosystem is equivalent to 18.1% of the GDP, and the TESV from agriculture ecosystems is equivalent to about 10.6% of the GDP in Karnataka.

There has been a 35.4% reduction in the TESV of forest ecosystems from 2005 to 2019 mainly due to the degradation of ecosystems. The decline in the TESV highlights the degradation of forest ecosystem assets from 2005 to 2019 as shown by the reduction of ecosystem extent and ecosystem condition (Ramachandra et al., 2021a, b). The decrease in value is also demonstrated by a fall in the net present value (NPV) of expected future returns of the ecosystem services supplied by forest ecosystem assets. The NPV of the assessed ecosystems based on 2005 ecosystem flows is about 93130 billion INR (forest ecosystem: 73099 billion INR, agriculture ecosystem: 20031 billion INR). However, the NPV of ecosystems in Karnataka, based on 2019 flows, indicate 74938 billion INR (forest ecosystem: 47214 billion INR, agriculture ecosystem: 27724 billion INR). This highlights that there has been a decline of 35.4% in asset value of forest ecosystems with the transition of forest ecosystems to croplands or horticulture (agriculture ecosystems), which is correlated to an increase in NPV of agriculture ecosystems by 38%.

Ecosystem accounts make the value of ecosystem services visible, allowing them to be internalized into decision-making. This enables an assessment of trade-offs between economic development and environmental conservation and restoration, resulting in better-informed decisions. It also allows strengthening the economic case for conserving forests in states in India and developing countries where there can be great pressure to relax forest laws and divert forests to non-forest uses without proper consideration of the sustainability of such actions.

The ecosystem services computed for Karnataka State also support the viability of markets for ecosystem services. The development of such markets requires additional institutional reforms such as changes with respect to property rights and reforms in land and labour markets. The main policy challenge of the future concerns is to promote conservation and develop such markets so that those bearing the cost of conservation can be adequately compensated.

The current endeavour of the valuation of ecosystem services done in Karnataka State can be replicated in other states so that the accounts can play a vital role in conservation planning and ecosystem-based management across India. This involves (i) inventorying, mapping and identifying ecologically vital regions and (ii) quantification of ecological services (both direct and indirect) of these regions would help in evolving strategies for the conservation of ecosystems to support people's livelihood. Improved knowledge of biophysical links and pre-existing incentive structures experiment would allow establishing compensation schemes, which requires:

i) Strengthening biophysical research on ecosystem services, the loss of which would seem to have the highest economic value potential (e.g., changes in the climatic, hydrologic regime, etc.).
ii) Inventorying, mapping, and monitoring ecosystems' spatial extent and conditions through the application of advanced spatial technologies with temporal remote sensing data.
iii) Promoting valuation studies and internalizing the results in regional policies for revealing current incentives, i.e., the existing distribution of net ecosystem benefits/opportunity costs across stakeholders.
iv) Developing strategies for developmental activities based on optimal land-use (LU) policies.

The ecosystem management objectives need to be defined by societal demands in relation to the ecology of the ecosystem, especially in the case of ecosystems that are strongly influenced by human use. The key role of science in such human dominated systems is to provide insights into the social, economic, and environmental benefits of various levels of biodiversity. This can be achieved through innovative ecosystem management options and communicate more effectively the research results to decision-makers and other stakeholders. The economic valuation of ecosystem services and biodiversity can help clarify trade-offs among conflicting environmental, social, and economic goals in the development and implementation of policies.

Valuation of Terrestrial Ecosystems Services, Karnataka State, India

1.0 Introduction

Humans depend on the environment for their basic needs such as food, fuel, minerals, water, air, etc. In developing countries, nearly 80% of the labour force is engaged in agricultural or resource-based activities, contributing significantly to the GDP (World Bank 1998, 2001). The dependency on the natural resources, over the years, has led to their degradation and depletion owing to the unsustainable practices involved in their extraction. Burgeoning unplanned development activities to cater to the demands of the increasing population have put tremendous pressure on the natural resources, leading to environmental degradation (Kulkarni and Ramachandra 2009; Ramachandra et al., 2018a, 2018b, 2018c, 2007, 2015, 2016, 2017). An increased surge in developmental and technological activities over the last two decades, with no regard to their ecological implications, has led to indiscriminate disposal of wastes (liquid and solid), contributing to the degradation of the natural ecosystems. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth (MEA 2005). And yet, unsustainable utilization of land and other natural resources persists, despite the increasing understanding of the impacts that human activities have on the environment, (Euliss Jr et al., 2010; Ramachandra et al., 2000a,b, 2001, 2010, 2020). Linkages between the health of the environment and the sustenance of humankind make it imperative to maintain a balance considering the carrying capacity of the environment and the availability of natural resources. Conservation of natural ecosystems has long-term benefits for humans in utilitarian terms through their provision of food, timber, minerals, and a variety of valuable resources that have provided the backbone for economic development. Going beyond more utilitarian values, natural ecosystems have also been a source for maintaining gene pools, biodiversity, and other potentially useful factors that are of indirect use to humans. Hence, ecosystems' intrinsic, anthropocentric, instrumental, and relational values, should be considered in the policy design, in addition to considering resources exploited for human settlement, food, and energy production.

The dilemma associated with rapid land-use changes for accommodating the growing demand for natural resources is impacting and degrading the ecosystems (Foley et al., 2005, Ramachandra et al., 2007). The ecosystem service approach capturing the full range of environmental impacts systematically offers a way to understand and deal with the feedback that is created when ecosystems are used up to meet humankind's own needs (Rodríguez et al. 2006). The objectives of the current study are to (i) to assess the ecosystem services values for the forest, agriculture (croplands and horticulture) ecosystems, district-wise for Karnataka State, India for 2005 and 2019 (ii) computation of the total ecosystem supply value (TESV), and (iii) Net present value (NPV) of ecosystem assets.

The current endeavor of valuation focuses on values of anthropocentric origin – i.e., values that are centered on human beings. Further, the measurement focus is on instrumental (is the value attributed to something as a means to achieve a particular end) or use values because these interactions are most readily quantified and because, from a monetary valuation perspective, these values are most readily reflected in monetary terms. From a policy perspective, the focus on anthropocentric, instrumental values may also be considered of high relevance since they concern the types of human interactions with the environment that can place the most pressure on ecosystems (SEEA EA 2021).

1.1. Ecosystem Services: Ecosystem services are the contributions of ecosystems to the benefits that are used in economic and other human activities, which include direct physical consumption, passive enjoyment, and indirect receipt of services. An ecosystem services approach to foster an understanding of the relationship between humans and the environment has been emphasized in various initiatives, including The Economics of Ecosystems and Biodiversity initiative (Costanza et al. 1997, 2014; Markandya et al. 2002; MEA 2005; Van der et al. 2010; TEEB 2010a, b; Ten Brink 2011; De Groot et al. 2002, 2012, 2017, 2020; Perelet et al. 2014), the Mapping and Assessment of Ecosystems and their Services (MAES) framework (Maes et al. 2013, 2016, 2018, 2020); the Natural Capital Project at Stanford University; the Integrated System for Natural Capital Accounting (INCA) project (Vallecillo et al., 2019); and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Diaz et al., 2015), etc.

Most resource management decisions are influenced by ecosystem services (ESs) entering markets; thus, the non-marketed benefits often remain unaccounted. Both renewable resources (water supply, air quality, etc.) and non-renewable resources (mineral deposits, some soil nutrients, fossil fuels, etc.) are capital assets and provide the backbone for numerous economic activities that account for the development of a region. Yet, traditional national accounts do not include measures of resource depletion or their degradation. GDP (Gross Domestic Product), a measure of the current economic well-being of a population, based on the market exchange of material well-being, will indicate resource depletion/degradation only through a positive gain in the economy and will not represent the decline in these assets (wealth) at all. Thus, the existing GDP growth percentages used as yardsticks to measure the development and well-being of citizens in decision-making processes are substantially misleading, and yet they are being used (De Groot et al., 2002; Haripriya et al., 2006). GDP cannot be a true measure of the country's sustained economic wealth and cannot be a proxy to understand its future economic well-being. Quantitative evidence on the economic value of such assets is thereby necessary for most of these services, most of which are not traded in the markets and hence do not have a market value. The monetary valuation of ecosystem services can help in building a better understanding of their influence on well-being and can further facilitate information-driven decisions and policy reforms that align with the Sustainable Development Goals (SDGs). Environmental accounting systems seek to determine a region's environmental and economic assets and can be used to assess whether economic development is consistent with sustainable development or to help ensure optimal use of natural resources and the environment. The expansion of a worldwide research base with a multidisciplinary scope of ecosystem services is resolving issues that arise in quantification, terminology, classification systems, research methods, and reporting requirements (Polasky et al., 2015; Mengist and Soromessa 2019). Recent efforts, especially the System of Environmental-Economic Accounting, Central Framework (SEEA CF), and Ecosystem Accounting (EA), aim to extend and integrate the national accounts for environmental and ecosystem assets (SEEA 2017; SEEA EA 2021).

Ecosystem services encompass all forms of interaction between ecosystems and people, including both in situ and remote interactions. The supply of an ecosystem service is associated with an ecosystem structure or process or a combination of ecosystem structures and processes that reflect the biological, chemical, and physical interactions among ecosystem components. Ecosystem services are broadly categorised as (i) provisioning services, which are those ecosystem services representing the contributions to benefits that are extracted or harvested from ecosystems; (ii) regulating and maintenance services, which are those ecosystem services resulting from the ability of ecosystems to regulate biological processes and to influence climate, hydrological and biochemical cycles, and thereby maintain environmental conditions beneficial to individuals and society; and (iii) cultural services, which are experiential and intangible services related to the perceived or actual qualities of ecosystems whose existence and functioning contributes to a range of cultural benefits. There is a range of other benefits, for example, concerning relational and intrinsic values, that are not captured in the above categories.

A key feature of ecosystem accounting is its capacity to integrate spatially referenced data about ecosystems, i.e., data about the location, size, and condition of ecosystems within a given area and how these are changing over time. Recording these stocks and changes in stocks in a coherent and mutually exclusive manner supports the derivation of indicators. Understanding the size and location of ecosystems also supports the measurement of ecosystem conditions and the quantification and valuation of many ecosystem services, the flows of which will vary from ecosystem to ecosystem.

Ecosystem services contribute to economic welfare in two ways – (i) contributions to the generation of income and wellbeing and (ii) the prevention of damages that inflict costs on society. Both types of benefits are accounted for in policy appraisal with a broader focus on valuing the benefits provided by ecosystems. Policy options that enhance the natural environment are more likely to be considered, demonstrating that investing in natural capital can make economic sense. There is considerable complexity in understanding and assessing the underlying links between a policy, its effects on ecosystems and related services, and valuing its impacts in economic terms. Collaboration between those working in policy, science, and economics disciplines is essential in implementing this approach in practice. The critical importance of the links to scientific analysis, which form the basis for valuing ecosystem services, needs to be recognized.

There is a growing interest in ecosystem services (ESs), and Ecosystem conservation management strategies, and the valuation of ecosystem services would help equip society with the means to incorporate the values of nature into decision-making at all levels. It also provides a baseline for evaluating management changes. This helps evaluate and prioritize different policies, evaluate potential trade-offs in management decisions, and assess the damages caused by natural disturbances. Apart from these, other benefits are (i) enhance communication with stakeholders about the economic benefits and costs of potential changes in forest management, as communities' preferences for different ecosystem services may be affected by estimates of economic performance; (ii) a baseline for evaluating management changes. This helps policymakers to consider the value of ecosystems in development planning and resource allocations and take adequate measures for conservation to ensure the sustenance of the flow of ecosystem services.

The objective of the current analysis is to develop the ecosystem services flow accounts in physical and monetary terms, as well as the monetary asset account. The ecosystem service accounts were developed using spatially explicit estimates of the supply of ecosystem services in physical terms and their contributions to benefits in monetary terms for major terrestrial ecosystems (forests and agriculture). The following set of services is covered:

(i) Provisioning services
- forest ecosystems - timber, bamboo, fodder, fuelwood, non-timber forest produce, fish and other aquatic products provisioning services, medicine, water supply service, and genetic material service for forest ecosystems
- agriculture (croplands and horticulture) ecosystems - food (cereals, pulses, oilseeds, vegetables, and commercial crops), fodder, and wood

(ii) Regulating services (global climate regulation services/carbon sequestration, local (micro and meso) climate regulation services, pollination service, soil conservation, groundwater recharge, water purification, waste treatment (for forest ecosystem), carbon fixation, soil carbon, ground water recharge, nitrogen fixation, soil fertility, remediation – organic and inorganic materials, genetic diversity, biological control (for agriculture ecosystem), air filtration services, and

(iii) Cultural services (aesthetic, recreational, spiritual and historical, artistic and culture, education, scientific and research).

There has been a growing interest in ecosystem services (ESs), and ES conservation management strategies (de Groot et al., 2012, 2020; Costanza et al., 1997, 2014; MEA 2005; TEEB initiative 2010a, 2010b). Ecosystem management approaches are (i) focusing on the anthropocentric factors in ecosystem management to maximize the number of humans that can use a resource or ecosystem, subject to environmental constraints, (ii) biocentric approach promoting sustainable human use while maintaining the ecological integrity of the ecosystem, and (iii) an eco-centric approach, promotes sustainable human use while managing at the eco-regional level with focuses on maintaining and restoring ecosystem function (Yaffe, 1999). Considering the relevant ecosystem function and the current demand by humans, the assessment of the ecosystem would support better planning and decision support to forest management (Pagiola et al., 2005).

1.2 Forest Ecosystems: Forests worldwide are critically important habitats in terms of biological diversity and the ecological functions. These ecosystems provide direct and indirect contributions to human welfare by supporting various economic activities. The contributions range from the provision of clean water to the sequestration and storage of carbon to opportunities for recreation and relaxation. Forests support 300-350 million people across the globe (Chao 2012) and about 240 million people live in forests, and 1.2 billion people rely on agroforestry farming systems. Forests have multifunctional uses to society and quantifying the relative and full range of forests services will be useful in designing forest management strategies

(Wu et al., 2010) considering a societal demand for a rational, transparent decision process and threat due to climate change (Wolfslehner and Seidl, 2010) without losing the intrinsic features of forests in terms of quality and biodiversity. Thus, forests are natural capital/ principal assets aiding human development and support numerous functions (Leemans and de Groot 2003). Forest ecosystems support numerous ecosystem goods, services and catering to the nation's economy directly or indirectly, evident from the earlier estimate of US$ 18 trillion/year (Costanza et al., 1997).

Globally, the forest ecosystems are under severe threat due to the anthropogenic pressures, which are mostly related to the nation's GDP, followed by unprecedented natural disturbances such as wildfires, torrential hurricanes/cyclones, landslides, etc. The loss of forests has been a causal factor for enchaining the disasters such as increased frequency of floods and droughts, global warming, extreme climatic conditions such as large scale variations in rainfall characteristics, increasing temperatures (Ramachandra and Bharath 2019a,b), etc. The appraisal of forest ecosystem services and biodiversity can help clarify trade-offs among conflicting environmental, social, and economic goals in the development and implementation of policies and to improve management in order biodiversity.

There is an urgent policy need for more comprehensive assessments of the total ecosystem supply value of entire biodiversity-rich ecosystems and compare with the opportunity cost of this land. Policymakers need such information to gain support for conservation funding and engage local communities and develop market-based instruments for conservation (Carrasco et al., 2014; Mullan, K., 2014; Madsen et al., 2011; Mullan and Kontoleon, 2008). Valuation studies have uncovered the significance of forest resources and provided a deeper understanding of many ways in which forest resources benefit humankind (de Groot et al., 2002; Amirnejad et al., 2006).

The ecosystem accounts have been developed as per the protocol of the System of Environmental-Economic Accounting –Experimental Ecosystem Accounts (SEEA EEA). In the current analysis, the accounts were developed using spatially explicit estimates of the supply of ecosystem services in physical terms and their benefits in monetary terms. Ecosystem supply accounts are presented in physical terms, and monetary terms considering of most broad types of ecosystem services: production of wild biomass (timber, bamboo, fuelwood, etc.), reared animal production, cultivation (including horticulture), carbon storage and sequestration, pollination, soil conservation, recreation, aesthetic, etc. as listed in Table 1.1, grouped broadly under-provisioning, regulating and cultural services

Table 1.1. Goods and Services valued for forest ecosystems

Provisioning Services	Regulating Services	Cultural Services
1. Timber 2. Bamboo 3. Fodder 4. Fuelwood 5. Non-Timber Forest Produce 6. Fish 7. Genetic Material	1. Carbon Sequestration 2. Carbon Storage 3. Pollination and Seed Dispersal 4. Soil Conservation 5. Ground Water Recharge 6. Water Purification 7. Waste Treatment	1. Recreational (Tourism) 2. Spiritual and Historic 3. Aesthetic 4. Artistic and Culture 5. Science and Education

1.4 Agriculture Ecosystem: Agrarian landscape constitutes over 40% of the terrestrial surface across the globe (Power, 2010; Robertson et al., 2014), and the Indian landscape is predominantly composed of agriculture, with 70% of rural households dependent for livelihood and. Natural landscapes are being engineered to produce food, improving the livelihood of the poor, and alleviating poverty (Nayak et al., 2019). The importance of agriculture ecosystems for their services in sustaining people's livelihood has been recognized globally (Millenium Ecosystem Assessment, 2005).

Agriculture in India with different types of practices, crops, and cropping patterns has been the backbone of the Indian economy, with a 23% share in the nation's economy (GDP) (Kellengere Shankarnarayan and Ramakrishna, 2020). However, with changes in climate due to significant scale land-use changes, the agriculture sector would be at stake, which may lead to large-scale imports from other nations hampering the nation's revenue. The contribution of agriculture in India is declining compared to other sectors (Kellengere Shankarnarayan and Ramakrishna, 2020).

The agricultural ecosystems are traditionally valued for their provisioning services by the human society due to the direct trade (market) value. Besides providing marketed commodities such as food and fiber, catering livelihood of people (TEEB, 2009), agricultural ecosystems act as consumers by utilizing other ecosystems and their processes such as soil retention, nutrient cycling, pest control, water capture, pollination, etc. (Nelson et al., 2011).

Current agriculture management practices with external inputs such as fertilizers and pesticides lead to most of the disservices from agriculture landscapes harming the biodiversity through multiple pathways (Kaneko, 2014). The green revolution though has aided in enhancing the production, but the practices have led to environmental damages such as i) depletion of ground water levels, ii) soil erosion,

iii) loss of biodiversity, iv) nutrient runoff - escape of nitrogen, phosphorous and other elements from fertilizers and pesticides to surface water bodies and ground water, v) land fertility, vi) accelerated carbon and nitrogen cycling, vii) loss of habitat with the land-use changes (Pal, 2018; Robertson et al., 2014), etc.

The goods and services provided by the agriculture ecosystem are highly influenced by land use and management practices. The agriculture policies, targeting to enhance the production of crops, with the significant market values, taxes, subsidies, incentives and ease of maintenance, agricultural ecosystems (Swift, Izac and van Noordwijk, 2004) are impacting the crop diversity, agriculture efficiencies, etc. The agricultural ecosystem depends on the rainfall, climate, soil, and topographic conditions. According to the local requirements, it is necessary to maintain the diverse cropping pattern to sustain the people's livelihood. To sustainably produce food in the future, there is an increase in the need for healthier and sustained agriculture practices, which are non-destructive in nature. Appropriate management of agrarian ecosystems would sustain goods and services, reducing the negative impacts, protecting the eco-system services that make production more resilient, sustaining rural livelihood, and ensuring food security(FAO, 2016, 2018; Power, 2010).

Karnataka state has diverse cropping patterns across the six major agroecological zones. In addition to this, numerous irrigation projects have supported growing various food crops, commercial/horticulture crops across the state. Different crops grown in the state can be classified under cereals, pulses, oilseeds, fruits, vegetables, commercial crops (horticulture, spices, etc)., (Table 1.2) according to Directorate of Economics and Statistics, Government of Karnataka (Directorate of Economics and Statistics, 2017; District Statistical Office, 2019).

Table 1.2. Crop classification

Sl.no.	Classification	Crops
1	Cereal	Paddy, Jowar, Bajra, Maize, Ragi, Wheat, Minor Millets etc
2	Pulses	Tur Dal, Green Gram, Horse Gram, Black Gram, Avare, Cowpea, Bengal Gram, Others
3	Oil Seeds	Ground nut, Sunflower, Safflower, Castor, Sesamum, Soybean, Nigerseeds, Linseeds, etc.
4	Fruits	Banana, Mango, Lemon, Pineapple, Guava, Grapes, Sapota, Pomogrannate, Papaya, etc.
5	Vegetables	Potato, Tomato, Onion, Brinjal, Beans, Cluster Beans, Chillies, Leafy Vegetables, Other Vegetables
6	Commercial Crops	Cotton, Sugarcane, Tobacco, Coffee, Rubber, Coconut, Arecanut, Cashew, Cocoa, Cardamom, Pepper. etc

2.0 Study Region - Karnataka State, India

Karnataka is one of the four southern states of Peninsular India and came into existence with the States Reorganisation Act (1956, November 1). Extending 760 km N-S (11°34' N and 18°27' N) and 420 km E-W (74°3' E and 78° 34' E), Karnataka has a spatial extent of 1,91,846 sq. km, which accounts for 5.8% of India's geographical area (Figure 2.1).

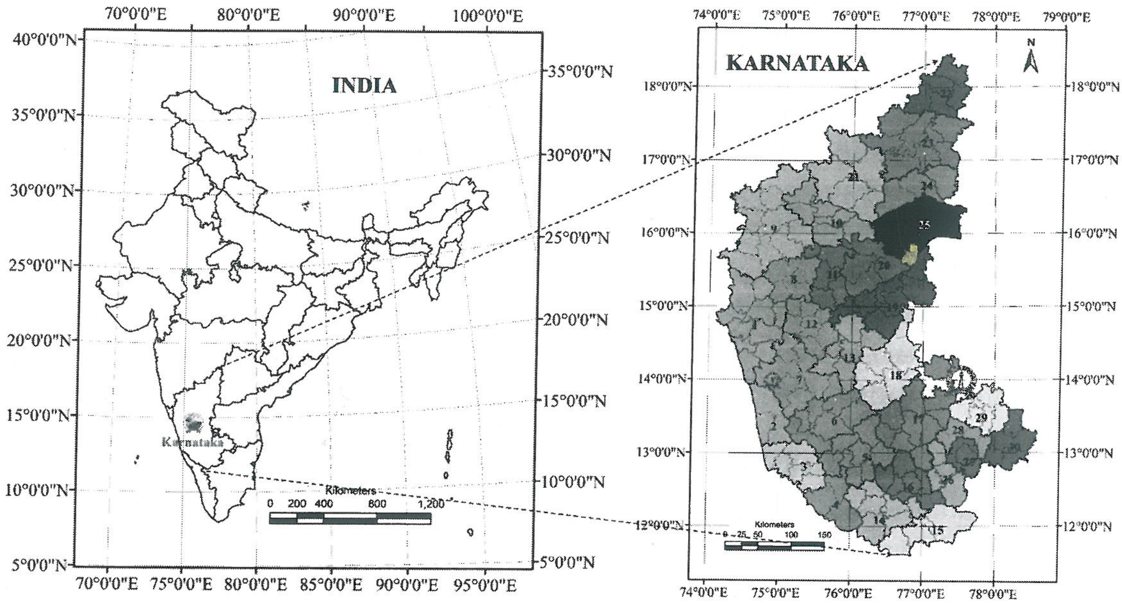


Figure 2.1. Karnataka State, India, with the administrative (district and taluk) boundaries

Karnataka is bounded by the Arabian Sea and the Laccadive Sea on the west, Goa on the north-west, Maharashtra on the north, Telangana on the north-east, Andhra Pradesh on the east, Tamil Nadu on the south-east and Kerala on the south-west. It is situated on a tableland where the Western and Eastern Ghats' ranges converge into the Nilgiris hill complex. According to the Census of India, Karnataka is divided into 30 Districts consisting of 178 Sub-districts (taluks), with 367 towns and 27397 villages (Table 2.1 and Figure 2.1). Belgaum district has the largest district with 13392 sq. km land area, and Bengaluru Urban district has the smallest area of 2193 sq. km. Tumkur and Hassan have the most significant number of villages, i.e., 2582 and 2418.

Table 2.1. Karnataka administrative divisions (Census 2011)

Sl.no.	District	Area (km^2)	Taluks	City/town	Villages
1	Uttara Kannada	10306	11	21	1243
2	Udupi	3573	3	21	233
3	Dakshina Kannada	4850	5	42	331
4	Kodagu	4105	3	5	291
5	Hassan	6821	8	14	2418
6	Chikmagalur	7214	7	9	1022
7	Shimoga	8479	7	9	1444
8	Dharwad	4258	6	6	361
9	Belgaum	13392	10	34	1263
10	Bagalkot	6567	7	15	613
11	Gadag	4658	5	9	322
12	Haveri	4821	7	10	696
13	Davanagere	5919	6	6	800
14	Mysore	6321	7	20	1199
15	Chamarajanagar	5636	4	5	428
16	Mandya	4946	7	9	1368
17	Tumkur	10600	10	12	2582
18	Chitradurga	8436	6	9	948
19	Ballari (Bellary)	8457	7	13	522
20	Koppal	5578	4	6	595
21	Vijayapura	10965	5	6	679
22	Bidar	5446	5	8	595
23	Kalaburagi (Gulbarga)	10507	7	13	871
24	Yadgir	5282	3	7	487
25	Raichur	8468	5	9	815
26	Ramanagara	3524	4	6	820
27	Bengaluru (Urban)	2193	4	19	562
28	Bengaluru (Rural)	2298	4	8	957
29	Chikkaballapura	4245	6	8	1324
30	Kolar	3981	5	8	1608

Forest resources: Karnataka State has 3.83 million ha of recorded forest cover, covering about 20% of its geographical spread. Having been endowed with the most magnificent forests in the country, it harbours the Western Ghats region, one of the 36 global priority hotspots for conservation, with a significant variety of flora and fauna endemic and threatened species. The forest ecosystem of Karnataka is unique and highly diverse. It forms an important component of the natural resources of the environment. Different forest ecosystems result from the interplay of topographic, climatic, and edaphic differences influenced by altitude and the distance from the sea. Forest types include tropical evergreen, semi-evergreen, moist deciduous, dry deciduous, thorny scrubs, sholas, and coastal mangroves, which account for the second-largest land use (LU) after agriculture. The total forest cover in the state is 43,356.47 sq. km (2016-17). i.e., about 22.61% of the State's geographical area is under forest cover (NRSC, 2018; 2020). Of the total forests, reserve forest constitutes 15.48%, protected forest constitutes 1.85%, village forest constitutes 0.03%, unclassified forest constitutes 5.23% and private forest constitutes 0.03%.

Forest resources in the State are under severe pressure, with a drastic fall in dense forest cover areas between 2001 and 2015. The state's forest cover has slightly declined compared to the country's forest cover during the period. Increased deforestation and degradation of the environmental resources have severe implications for the ecosystem's production and resilience. The loss of forest cover is a serious threat to the environment, sustainable development, and the livelihoods of millions of people in the state. Forest resources significantly contribute to the State's GDP by being a major source of timber, medicinal plants, non-timber forest products (NTFPs), grazing, recreational activities, carbon sequestration, watershed provisions, etc. The state has formed 4467 Biodiversity Management Committees at the Grama Panchayat level as per the Biological Diversity Act of 2002 (BDA 2002, Government of India) to protect and monitor biodiversity. Biodiversity heritage sites (such as the 400-year-old tamarind grove at Nallur, Devanahalli taluk) are being protected to conserve and develop unique genetic biodiversity.

Karnataka has a repository of rich biodiversity with more than 1.2 lakh[1] known species, including 4,500 flowering plants, 800 fishes, 600 birds, 160 reptiles, 120 mammals, and 1,493 medicinal plants. Fifty percent of the Western Ghats' biodiversity is present in Karnataka. These forests support a wide range of flora and fauna (biodiversity) through a network of well-connected and protected Wildlife Sanctuaries and National Parks. The State has five national parks and 30 wildlife sanctuaries covering an area of 9,586.02 km square. Apart from the national parks and sanctuaries, the State has 15 conservation reserves and one community reserve comprising 652.369 km square. All these areas form 23.59% of the total forest area. These are spread over evergreen to scrub forests, representing different ecosystems with rare and endangered species of plants, animals, and birds. The State has been active in formulating and implementing various programs to develop forests and protect its natural environment. Among the Forest Department's schemes

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[1] One lakh is equal to a hundred thousand.

concerning wildlife and national parks, long-term measures to mitigate 'Man-Animal Conflict' incurred an expenditure of 24.80%, Project Tiger 30.40%, Integrated Development of Wildlife Habitats 2.47%, nature conservation activities attracted 13.38% and Rs. 27.50 crores[2] of total expenditure were incurred towards voluntary rehabilitation of families from tiger reserves and national parks during 2016-17.

Topography: Karnataka comprises varied topographical structures that include high mountains, plateaus, residual hills, and coastal plains. It is enclosed by chains of mountains in its west, east, and south. The Western Ghats generally exhibit a narrow coastal plain followed to the east by small and short plateaus at different altitudes, then suddenly rising to great heights, followed by the gentle east and east-north-west sloping plateau. The state's entire landscape rests on undulating terrain, broken up by various mountain ranges and deep ravines. However, it mainly consists of a plateau with elevations ranging between < 0 m to > 1900m AMSL (above mean sea level), and slopes between 0 to 65 degrees (Figure 2.2).

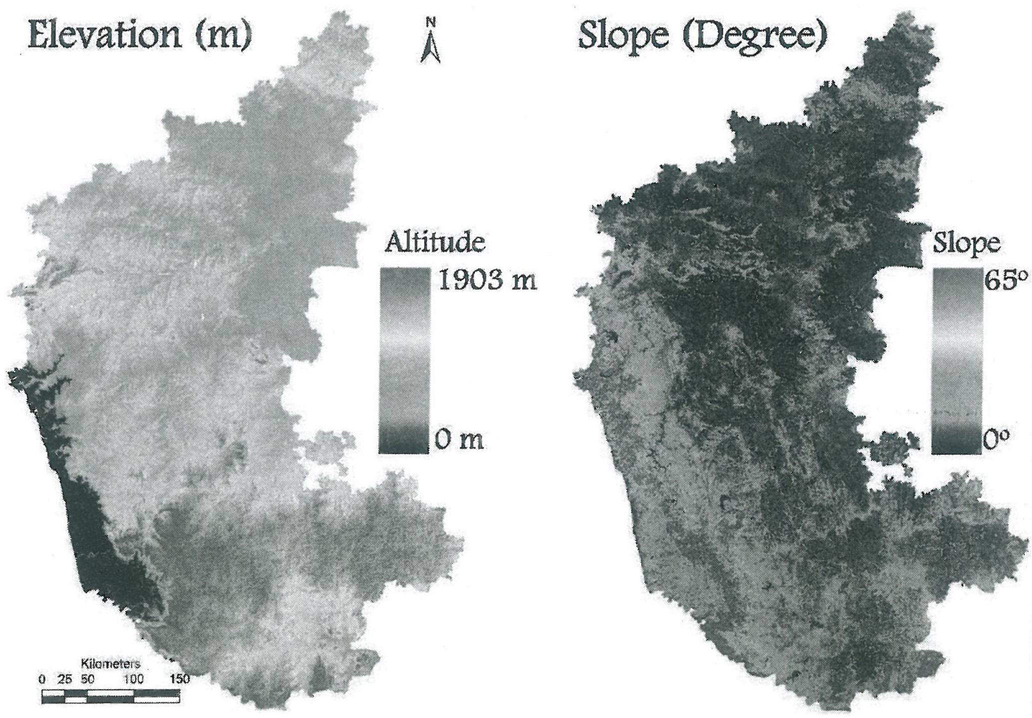


Figure 2.2. Karnataka – Topography

[2] One crore is equal to ten million, or one hundred lakhs

The thin strip coastal plains facing the Arabian sea along the west coast districts of Uttara Kannada, Udupi, and Dakshina Kannada have flat slopes with elevations ranging just over 50 m and slopes less than 10 degrees. There are a few high peaks in the Western and Eastern Ghats systems with altitudes of more than 1,500 m. Among the tallest mountains of Karnataka are the Mullayyanagiri (1,925 m), Bababudangiri (Chandradrona Parvata 1,894 m), and the Kudremukh (1,895 m) from the Chikmagalur district and the Pushpagiri (1,908 m) in the Kodagu district. These Ghats have highly undulating terrain with slopes ranging over 30 degrees. The Deccan plains expanding to the east are flat with slopes less than 10 degrees with altitudes ranging over 700 m.

Agro-ecological zones: Regions with similar geographic, edaphic, meteorological characteristics and length of crop growing period (LGP—length of the growing period) are grouped and referred to as agro-climatic zones. The state is divided into seven agro-ecological zones based on physiography, soil, bio-climate, and details are given in table 2.2 (as per National Bureau of Soil Survey & Land Use Planning, NBSS & LUP, Indian Council for Agricultural Research, ICAR). Agro-ecological zones, district-wise and at decentralized level grid wise are presented in Figure 2.3.

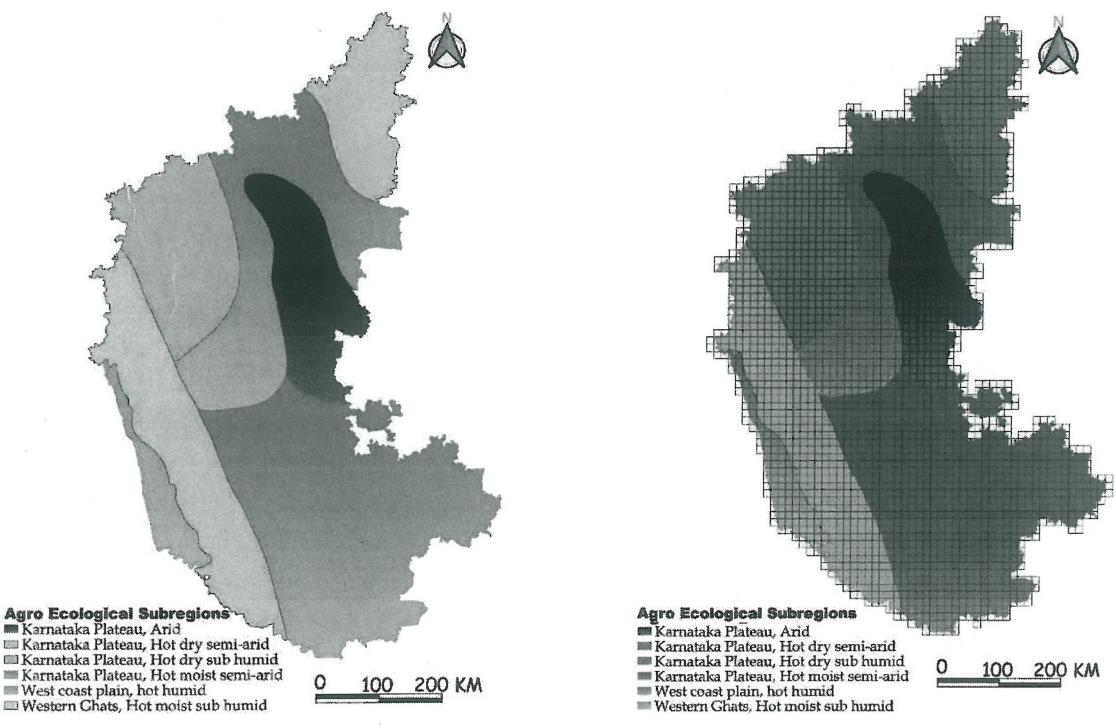


Figure 2.3. Agro ecological sub-regions in Karnataka

Table 2.2. Agro-ecological zone and distinct feature

Agro-ecological zone	Regions in Karnataka	Length of growing period (LGP)
Karnataka plateau, Arid	The northern part, Northwest part, Southern parts, and Eastern part	90 days
Karnataka plateau, moist semi-arid	Interior Karnataka	90-120 days
Karnataka plateau, Hot dry semi-arid	Northern part	120-150 days
Karnataka plateau, Hot moist semi-arid	Southern parts	150-180 days
Karnataka plateau, Hot dry sub-humid	the coastal part	180-210 days
Western Ghats, Hot moist sub-humid	hilly regions - the Western Ghats	210-240 days
West coast plain, hot humid	the coastal part of Karnataka	240-270 days

Based on physiography, meteorological parameters (air temperature, rainfall, and water deficit), soil types, crops, and cropping pattern, the state has been divided into ten agro-climatic zones - North-eastern transition zone, North-eastern dry zone, Northern dry zone, Central dry zone, Eastern dry zone, Southern dry zone, Southern transition zone, Northern transition zone, Hilly zone and Coastal zone (delineation as per National Bureau of Soil Survey & Land Use Planning, NBSS & LUP, Indian Council for Agricultural Research, ICAR), which are depicted in figure 2.4 (district-wise and at grid-level).

- Coastal zone includes districts like Dakshina Kannada, Udupi, Uttara Kannada.
- Hilly zone includes districts like Belgaum, Shivmogga (Shimoga), Chikmagalur, Madikeri, Kodagu, and Hassan.
- The north-eastern transition zone includes Bidar and parts of Kalaburagi (Gulbarga).
- The north-eastern dry zone includes Kalaburagi (Gulbarga), Yadgir, and parts of Raichur.
- The northern dry zone includes Ballari, Vijayapura (Bijapur), Dharwad, Raichur.
- The Central dry zone includes Chitradurga, Tumkur, and some parts of Hassan and Chikmagalur.
- Eastern dry zone includes Bengaluru, Kolar, Ramanagara, Bengaluru Rural

- The southern transition zone includes Hassan, Shimoga, and parts of Mysore.
- The northern transition zone includes Belgaum and Dharwad.

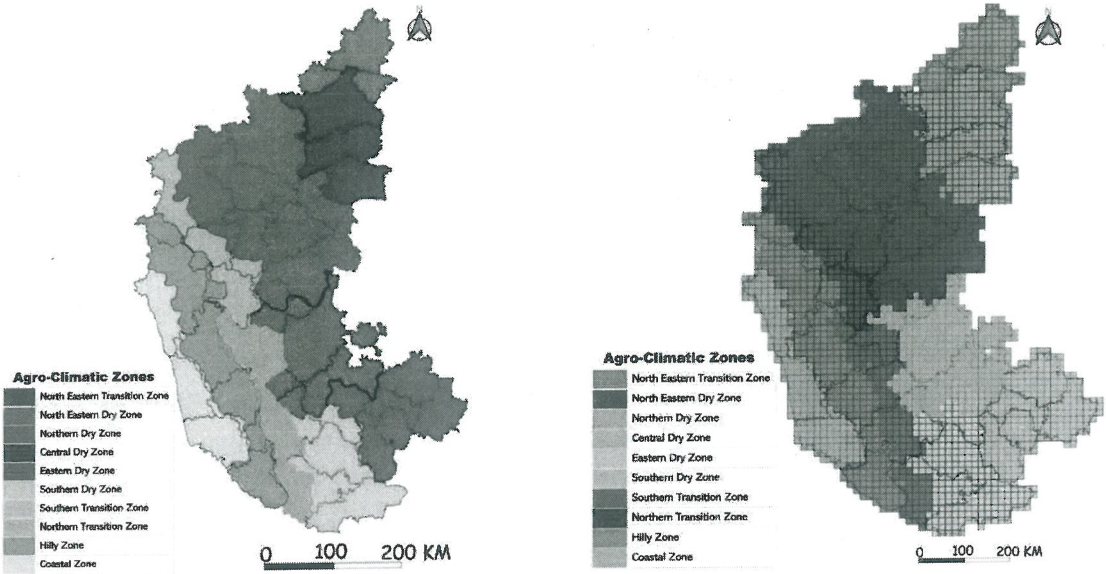


Figure 2.4. Agro-climatic zones in Karnataka

Water resources: Karnataka has seven river systems and their tributaries flowing through the state. The major river basins of Karnataka are Krishna (59.48%), Cauvery (17.99%), West Flowing Rivers (12.76%), North Pennar (3.64%), Godavari (2.31%), South Pennar (2.29%), Palar (1.56%). Karnataka has 26 east-flowing rivers and ten west-flowing rivers. The west-flowing rivers of Karnataka provide 60% of the state's inland water resources. Figure 2.5 depicts various water bodies of Karnataka categorized under rivers (rivers, reservoirs, and estuaries) and lakes. The state has over 12 highly productive estuaries along its west coast, namely Kali, Bedti, Aghanashini, Sharavathi, Venkatapura, Chakra, Varahi, Netravati, Barpole, Payaswini, Sita, and Souparnika, and numerous small creeks. Based on the water availability in the region, the rulers/administrators in the past have created interconnected lakes for sustaining regional water requirements. Hence, the transition zone and the Deccan traps have a large number of lakes. Karnataka has over 39000 water bodies with areas ranging from 2500 sq. m to more than ten sq. km. In the recent past, dams have been constructed in the state to encourage irrigation and power generation. Karnataka has more than 15 major reservoirs, namely Alamatti, Bhadra, Varahi, Hemavarhi, Kabini, Krishna Raja Sagara (KRS), Harangi, Ghataprabha, Malaprabha, Narayanapura, Supa, Linganamakki, Kadra, Gersoppa, Chakra, Mani, Kodasalli, Renuka Sagar, Vanivilasa Sagara, Basavaragara, etc.

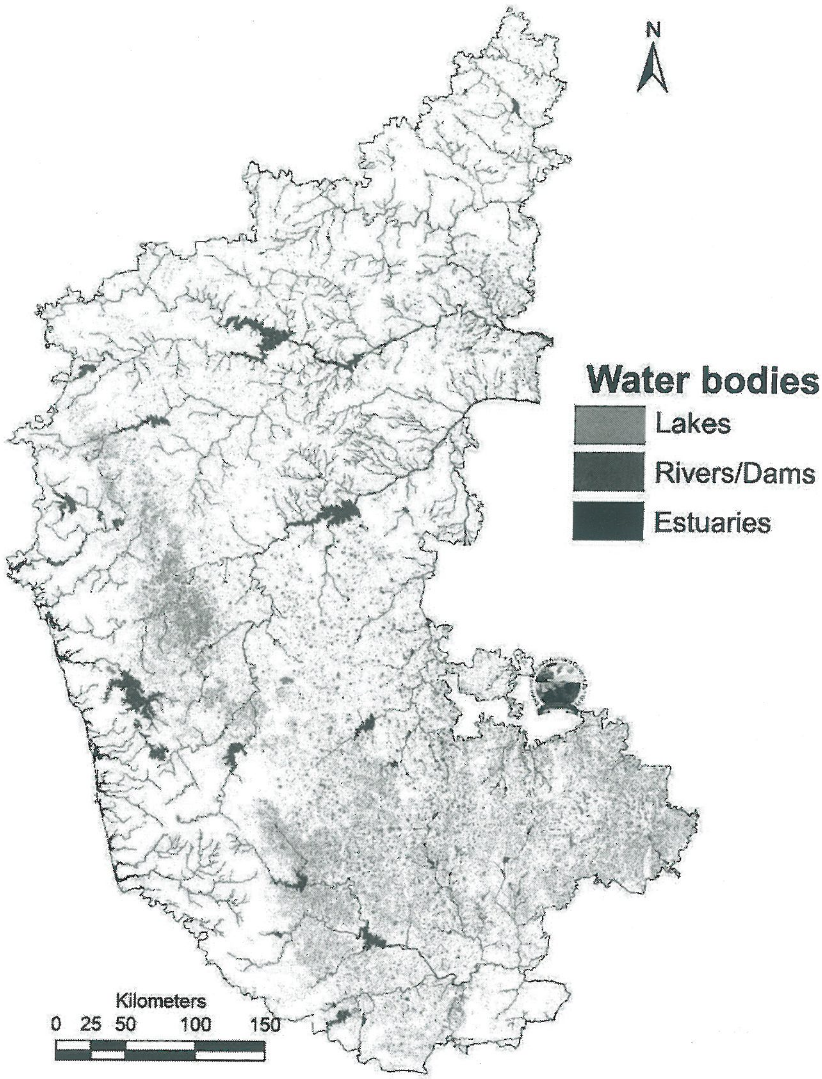


Figure 2.5. Water Resources and Agro-climatic Zones of Karnataka

Groundwater: The state is covered by peninsular gneisses, granites, schists, and basalts, along with sedimentaries of Kaldagi and Bhima groups. The recent alluvium is restricted to coastal areas and stream courses. The extent of weathering and fracturing primarily controls the water-bearing and yield characteristics in hard rock. In limestone areas, solution cavities impart secondary porosity, which aids in the percolation of water. The yield of tube wells tapping hard rocks is as high as 50 m^3/hr. The tube wells in sedimentaries can yield up to 15 m^3/hr. Groundwater depth (Figure 2.6) in most parts of the state goes beyond 10 m (BGL-Below Ground

Level) in the post-monsoon season, while in the monsoon, groundwater depth raises to less than 10 m (BGL). Topography, lithology, and soil play a major role in holding the groundwater. At the coasts, the groundwater depth varies over 2.5 m between post-monsoon and monsoon, while in the Deccan plains, the groundwater depth variations are less than 2.5 m. Very high depths were observed in cities such as Bangalore, Belgaum, etc.

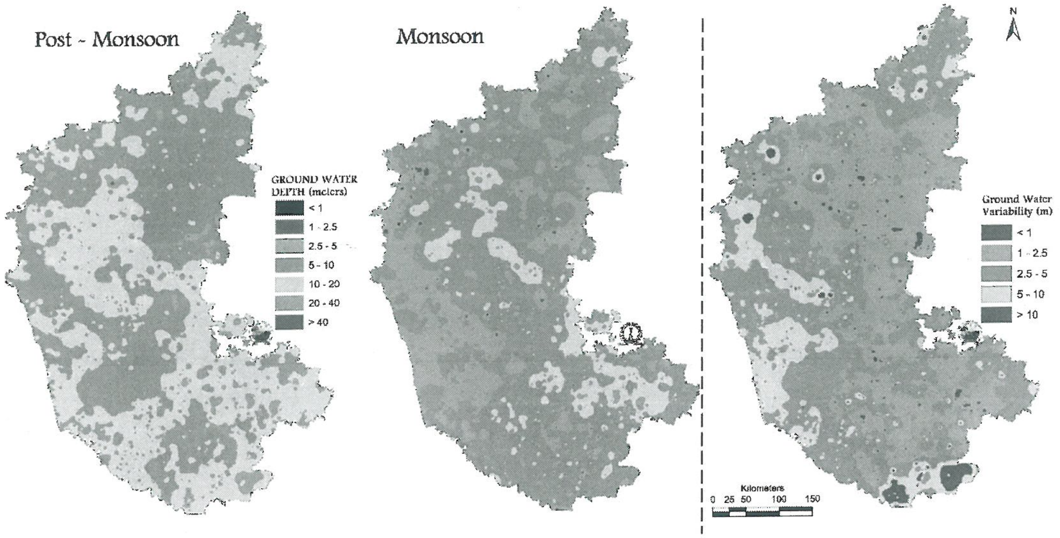


Figure 2.6. Ground Water dynamics

Demography: The population dynamics of Karnataka are depicted in Table 2.3 and Figure 2.7. Taluk level population were collated from the District at a Glance reports and the Census of India. Karnataka is the eighth largest state by population and forms 5.1% of India's population, with a growth rate of 15.7% from 2001-2011. The state's total population as per 2011 census is 6.1 crores, of which male (31,057,742) and female (30,072,962), respectively, with a density of 319 persons per km^2. The population growth rates in rural and urban areas are 6.49% and 27.16%, respectively. Bangalore Urban District accommodates 11.59% population of the state, which exhibited the highest growth rate in the urban population (46.68%). The state has a birth rate of 2.2%, a death rate of 0.72%, an infant mortality rate of 5.5%, and a maternal mortality rate of 0.195%. The total fertility rate of the state is 2.2. The state has a 75.6% literacy rate.

Table 2.3. Population Dynamics

District	2001	2011	2021*
Bagalkot	16,51,892	18,89,752	21,62,334
Bangalore Rural	8,50,968	9,90,923	11,55,649
Bangalore Urban	66,29,636	96,21,551	1,40,66,760
Belgaum	42,14,505	47,79,661	54,25,978
Ballari (Bellary)	20,27,140	24,52,595	29,75,288
Bidar	15,02,373	17,03,300	19,32,227
Vijayapura (Bijapur)	18,06,918	21,77,331	26,27,733
Chamarajanagar	9,65,462	10,20,791	10,79,330
Chikballapur	11,49,007	12,55,104	13,71,243
Chikmagalur	11,40,905	11,37,961	11,36,720
Chitradurga	15,17,896	16,59,456	18,15,242
Dakshina Kannada	18,97,730	20,89,649	23,02,443
Davangere	17,90,952	19,45,497	21,16,812
Dharwar	16,04,253	18,47,023	21,31,178
Gadag	9,71,835	10,64,570	11,66,583
Kalaburagi (Gulbarga)	21,74,742	25,66,326	30,35,650
Hassan	17,21,669	17,76,421	18,35,717
Haveri	14,39,116	15,97,668	17,73,991
Kodagu	5,48,561	5,54,519	5,60,631
Kolar	13,87,062	15,36,401	17,02,729
Koppal	11,96,089	13,89,920	16,16,467
Mandya	17,55,212	18,05,769	18,59,496
Mysore	26,41,027	30,01,127	34,27,465
Raichur	16,69,762	19,28,812	22,33,133
Ramanagara	10,30,546	10,82,636	11,38,947
Shimoga	16,42,545	17,52,753	18,75,975
Tumkur	25,84,711	26,78,980	27,86,076
Udupi	11,12,243	11,77,361	12,46,320
Uttara Kannada	13,53,644	14,37,169	15,28,709
Yadgir	9,56,180	11,74,271	14,42,157
Total	5,29,34,581	6,10,95,297	7,15,28,983
			*Projected

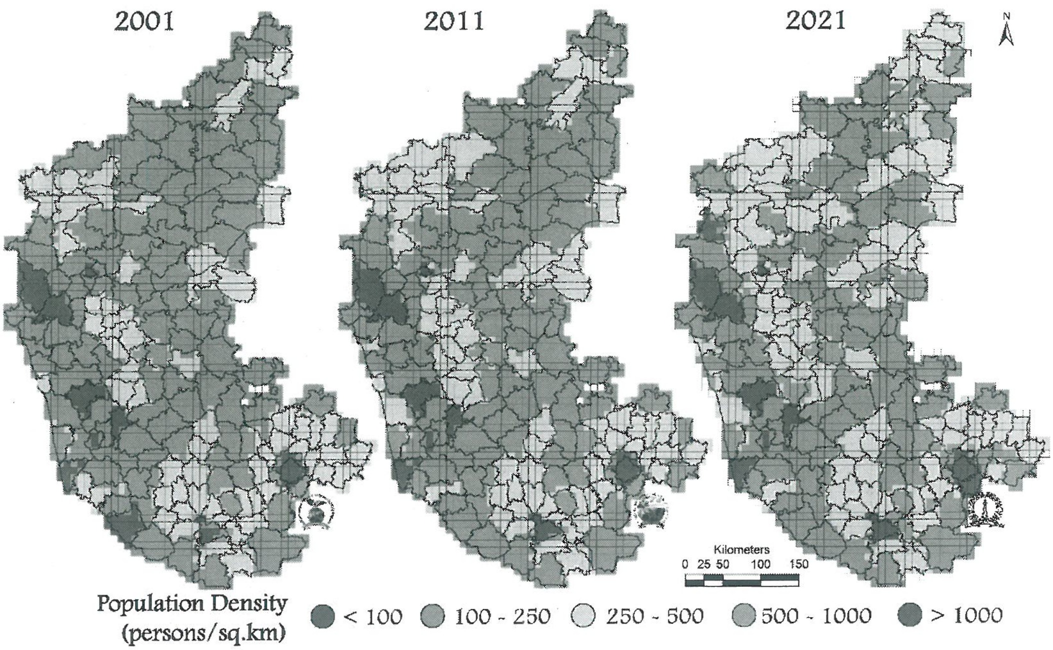
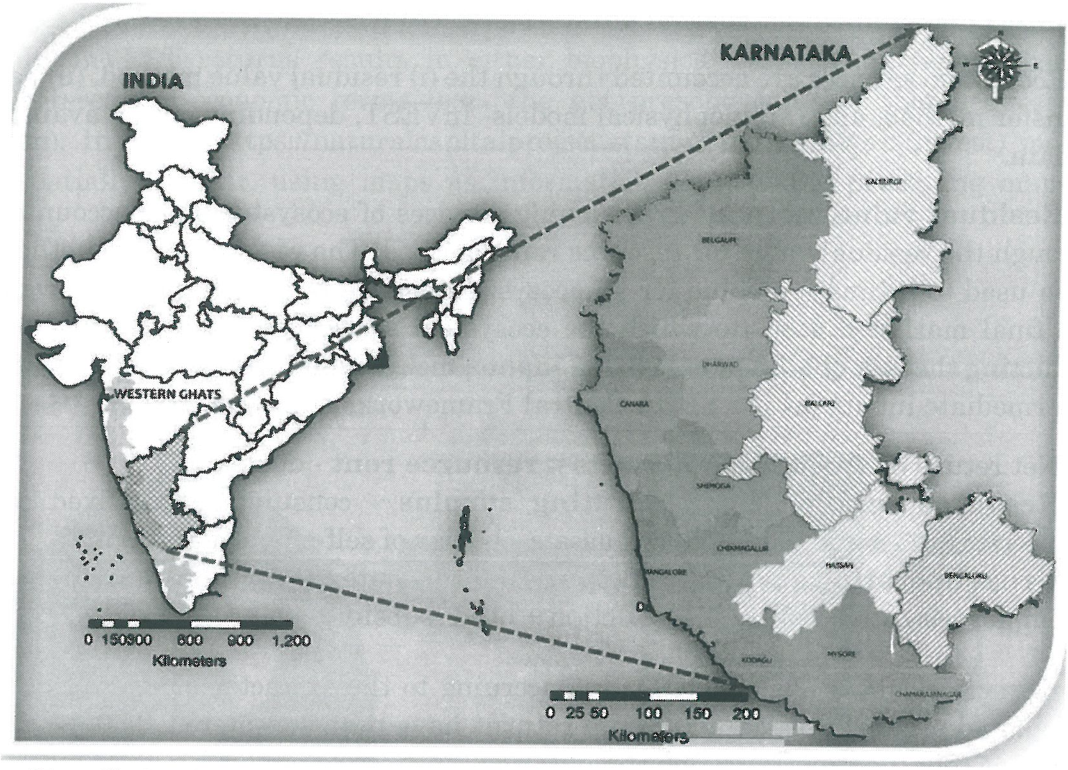


Figure 2.7. Population dynamics

3.0 Data

Ecosystem extent account: An important foundation for estimating ecosystem services is the ecosystem extent account. Temporal remote sensing data is used for assessing the spatial extent of ecosystems in Karnataka.

Forest ecosystems: Forest ecosystems in Karnataka are managed by the Karnataka Forest Department, and decentralized administration is practiced through (i) forest circles (note: A forest circle is a term used to signify an area containing one or more (usually) demarcated and (usually) protected or resource-managed forests, for administration and coordination, at decentralised levels), and (ii) divisions. The data for provisioning services of forest ecosystems for five years intervals (2001-2005 and 2014-2019) were collected from forest circles. The Karnataka state has 13 forest circles for decentralized administration, and the spatial extent of forest circles is depicted in Figure 3.1. Global biodiversity hotspot – Western Ghats spread across circles - Canara, Chikmagalur, Shimoga, Mangalore, Kodagu, Chamarajanagar. The state has a protected area network of five national parks (2431.3 km^2), and 21 wildlife sanctuaries (3887.83 km^2) covering nearly 16% of the forest area. The spatial extent of protected areas in each circle and district are listed in Table 3.1.



Note: Circles shaded in green are part of the Western Ghats (a global biodiversity hotspot)

Figure 3.1. Karnataka state, India with forest circles

Table 3.1. The districts covered in each forest circle of Karnataka State

Forest circle name		District	Area -Ha
1	Canara	Uttara Kannada	175,937
2	Mangalore	Dakshina Kannada; Udupi	170,703
3	Kodagu	Kodagu	109,825
4	Chamarajanagar	Chamarajanagar	273,667
5	Belgaum	Belgaum; Bagalkot; Vijayapura	10,973
6	Dharwad	Dharwad; Haveri; Gadag	6,310
7	Shimoga	Shivamoga; Davanagere (Channagiri Taluk); Chikmagalur (Tarikere)	84,976
8	Chikmagalur	Chikmagalur	45,450
9	Mysore	Mysore; Mandya	105,278
10	Kalaburagi	Kalaburagi (Gulbarga); Raichur; Yadgir; Bidar	0
11	Ballari /Bellary	Ballari; Davanagere; Chitradurga; Koppala	4,793
12	Hassan	Hassan; Tumkur;	0
13	Bengaluru	Bengaluru (Rural); Bengaluru (Urban); Ramnagara; Kolar; Chikballapur	25,513

4.0 Method

Ecosystem services are accounted through the (i) residual value method, (ii) benefit transfer method, and (iii) biophysical models- InVEST, depending on the availability of data.

Residual value method: Provisioning services of ecosystems are accounted for through the residual value (or resource rent) method. The residual value method has been used to estimate a value for an ecosystem service by taking the gross value of the final marketed good (to which the ecosystem service provides input) and then deducting the cost of all non-ecosystem inputs, including labour, produced assets and intermediate inputs (as per SEEA Central Framework, given below).

Net return on environmental assets = **resource rent** - depletion
Resource rent = gross operating surplus - consumption of fixed capital (depreciation) - return on produced assets - labour of self-employed persons
Gross operating surplus = Output - intermediate consumption - compensation of employees - other taxes on production + other subsidies on production

Economic rent is the surplus value accruing to the extractor or user of an asset calculated after all costs, and normal returns have been considered. The measure of resource rent (i.e., surplus value of environmental assets) provides a gross measure of the returns to the environmental asset as a direct capital value, giving a reasonable approximation of the market price of the service.

The benefit transfer method or unit value transfer refers to applying economic value estimates from one location to a similar site in another place. Values for ecosystem services at a study site, expressed as a value per unit (usually per unit of area or beneficiary), combined with information on the number of units at the policy site, are used to estimate policy site values. Unit values from the study site are multiplied by the number of units at the policy site. When using the benefit transfer method, unit values are adjusted to reflect differences between the study and policy sites. In this report, ecosystem services values are based on case studies from India, which are compared with the global ecosystem service valuation database (ESVD) [https://www.es-partnership.org/wp-content/uploads/2020/08/ESVD_Global-Update-FINAL-Report-June-2020.pdf] and published literature (of case studies from India) considering GDP (PPP) per capita for India (https://data.worldbank.org/indicator/ NY.GDP.PCAP.PP.CD?locations=IN) and the currency exchange rate (https://www.xe.com/currencyconverter/convert/?Amount=1&From=USD&To =INR).

InVEST: InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) is a suite of models used to map and value ecosystem services. It helps explore how changes in ecosystems can lead to changes in the flows of many different benefits to people. InVEST returns results in either biophysical terms (e.g., tons of carbon sequestered) or economic terms (e.g., the net present value of that sequestered carbon). InVEST (https://naturalcapitalproject.stanford.edu/software/invest) models are spatially explicit, using maps as information sources and producing maps as outputs.

4.1 Valuation of forest ecosystem services

Figure 4.1 and Table 4.1 summarises the method adopted for the computation of services from forest ecosystems.

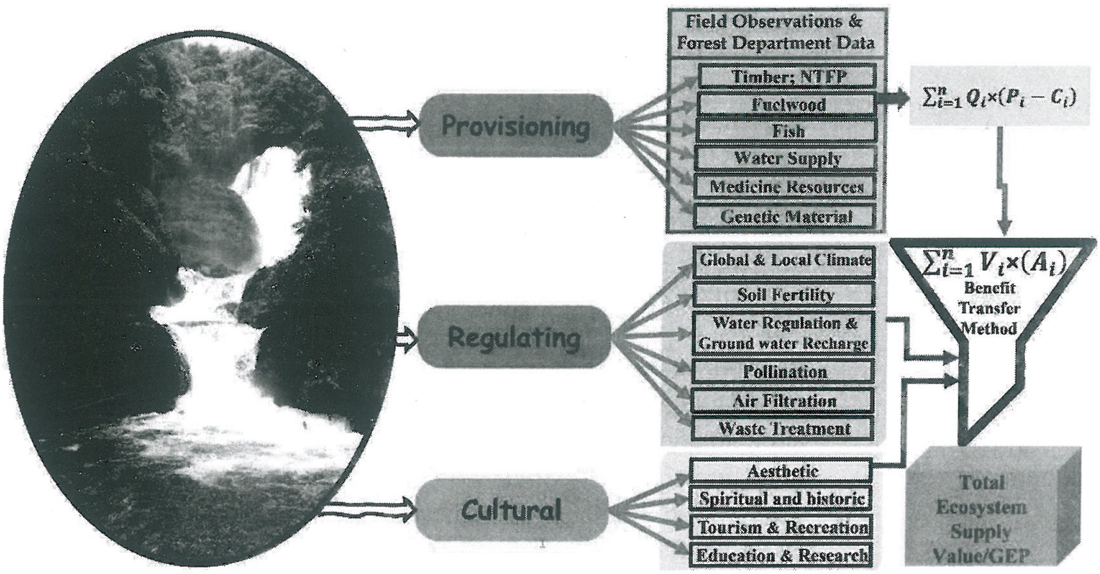


Figure 4.1 Method adopted for the valuation of ecosystem services

Table 4.1. Method for computing goods and services from forest ecosystems

Services	Variables	Data source	Approach
Provisioning services	Timber	Collected from Forest Department, circle wise (the state has 13 circles for the decentralized administration of forests), KFD e-resources: https://aranya.gov.in/aranyacms/English/AnnualReports.aspx; https://aranya.gov.in/aranyacms/downloads/	**Residual Method**; $\sum_{i=1}^{n} Q_i \times (P_i - C_i)$ Where Qi represents quantity, Pi is the price,

		Annual%20Reports/AnnualReportEnglish_19-09-2020_05.06.05.pdf; https://aranya.gov.in/aranyacms/downloads/ Annual%20Reports/English %20Annual%20Report%202018-19_28-02-2020_10.58.25.pdf Google (2020) ▪ The ecosystem supply value of rosewood is 140,017 Rs/Ha/yr (2005) and 140,998 Rs/Ha/yr (2019) based on the data collected across the circles from Karnataka Forest Department. ▪ Teak wood is 79,881 Rs/Ha/yr (2005) and 79,961 Rs/Ha/yr (2019). ▪ Eucalyptus wood is 4,304, and 4,265 Rs/Ha/yr for 2005, 2019 respectively. ▪ Softwood is 2,692 Rs/Ha/yr for 2005, 2019. ▪ Other kinds of timber are accounted as 4644, and 4297 Rs/Ha/yr for 2005, 2019 respectively. ▪ Pulpwood is 3369 Rs/Ha/yr (2005) and 3381Rs/Ha/yr (2019). ▪ Round poles wood is assessed as 4434, 4261 Rs/Ha/yr for 2005 and 2019, respectively. ▪ Sandalwood is accounted as 4573, 4652 Rs/Ha/yr for 2005 and 2019 respectively.	Ci is the cost involved in the harvest
	Bamboo	The ecosystem supply value of Bamboo for the Karnataka state is assessed as 3938 and 4402 Rs/Ha/yr for 2005 and 2019, respectively	**Residual Method**; $\sum_{i=1}^{n} Q_i \times (P_i - C_i)$
	Non-Timber Forest	▪ The ecosystem supply value of honey is 13177	**Residual Method**; $\sum_{i=1}^{n} Q_i \times (P_i - C_i)$

	Produce (NTFP)	Rs/Ha/yr (2005) and 13186 Rs/Ha/yr (2019). ▪ Soapnut is 12724, 12977 Rs/Ha/yr for 2005 and 2019, respectively. ▪ Cashew nut is 13812 Rs/Ha/yr (2005) and 13945 Rs/Ha/yr (2019). ▪ Tamarind is 14315 and 14346 Rs/Ha/yr for 2005 and 2019, respectively. ▪ Rampatri (nutmeg - *Myristica malabarica*) is 12997 Rs/ Ha /yr (2005) and 14436 Rs/ Ha /yr (2019). ▪ Murugalu (Kokkum) is 11717 Rs/Ha/yr (2005) and 11740 Rs/Ha/yr (2019).	Where Qi represents quantity, Pi is the price, Ci is the cost involved in the harvest (Planning Commission, 2011)
	Fuelwood	Fuelwood required per person is estimated based on a socio-economic survey carried out in select taluks. The ecosystem supply value of fuelwood is assessed as 5,097, and 23,623 Rs/Ha/yr for 2005 and 2019 based on the fuelwood consumption data collected for the Karnataka state.	**Residual Method**; $\sum_{i=1}^{n} Q_i \times (P_i - C_i)$
	Fish and other aquatic products	https://des.karnataka.gov.in/english; District wise fish catch from districts The ecosystem supply value of fish is 65,000 Rs/Ha/yr based on the fish and other aquatic products from inland aquatic ecosystems	**Residual Method**; $\sum_{i=1}^{n} Q_i \times (P_i - C_i)$
	Fodder	Quantity of fodder (estimated forest type-wise) and assuming a 10% cost factor on the market price of fodder, cost-adjusted price of fodder is	**Residual Method**; $\sum_{i=1}^{n} Q_i \times (P_i - C_i)$

		obtained which is used in the estimation of the economic value of fodder production from forests in each state. Ecosystem supply value from fodder is assessed as 7,736 and 15,476 Rs/Ha/yr for the years 2005 and 2019, respectively.	
	Water	Quantity of water and price of water with the cost of labor, etc. Sector-wise (industries, residential, irrigation, etc.) water demand, water tariff, revenue, and expenses related to the supply of water (labor, treatment, pumping, etc.). Water services ranges from 2,61,360 ₹/Ha/Yr (MDF), to 4,80,315 ₹/Ha/Yr (VDF), to 2,61,360 ₹/Ha/Yr (MDF), to 4,80,315 ₹/Ha/Yr (VDF)	**Residual Method**; $\sum_{i=1}^{n} Q_i \times (P_i - C_i)$
	Medicine	(i) Data of type, quantity, and royalty – received by the government, Karnataka Biodiversity Board, (ii) data of type and quantity extracted by local people from Karnataka Forest Department, (iii) estimates of quantity and type of medicinal plants from Medicinal Plant Conservation Authority. The medicinal plant services of forest ecosystem based on the primary data range from 221 Rs/Ha/Year (MDF) to 445 Rs/Ha/Year (VDF). They are comparable to studies from India and the global database (EVSD), considering	**Residual Method**; $\sum_{i=1}^{n} Q_i \times (P_i - C_i)$ Supplemented with benefit transfer method – based on studies from India (Verma et al., 2013) and compared with the per hectare values based on EVSD, considering GDP (PPP) per capita for India and exchange rate

		GDP(PPP) per capita for India and exchange rate.	
	Genetic material	Genetic material service: the economic value of gene-pool conservation in terms of bioprospecting based on i) number of medicinal plants found in each district; (ii) number of species of conservation importance in each district, and (iii) all species. Compared with genetic material values per hectare based on case studies from India (Verma et al., 2013), values are 2,25,856 Rs/Ha/Year (evergreen forests, VDF), 1,79,680 Rs/Ha/Year (evergreen, MDF), 1,09,940 Rs/Ha/Year (moist deciduous), 67,812 Rs/Ha/Year (dry deciduous)	The estimate is based on all species in the study region and ecosystem extent. Species details obtained from Karnataka Biodiversity Board (kbb.karnataka.gov.in), Medicinal plants conservation authority (https://ayush.karnataka.gov.in/) and genetic resource per hectare as per case study from India (Verma et al., 2013)
Regulating Services	Global climate regulation - carbon sequestration	Spatiotemporal land use analysis; temporal data - above ground, below ground biomass is estimated based on field data collection across various forest types, integrated with standard literature. Carbon sequestration services value is calculated by considering the social cost of carbon per tonne. The social cost of a tonne of CO_2 is taken as US$ 80 using the GDP deflator (MoSPI 2020). The carbon sequestration from forests depicts the forest circles located in the Western Ghats have higher	InVEST carbon model, quantity of carbon sequestered annually and the social cost of carbon from MOSPI (MoSPI 2020)

		sequestration than other parts of the State due to lower disturbances. Carbon sequestration in forest ecosystems of Karnataka is 124153 Gg/Yr (2005) and 89194 Gg/Yr (2019) due to a decline in the ecosystem spatial extent and also conditions (Note: Gg – Gigagram, which is equivalent to 1000 tonnes)	
	Soil conservation & soil fertility	Ranges from 7320 Rs/ha/year (Open canopy forests) to more than 48,800 Rs/Ha/year (VDF) in evergreen forests. Similarly, in deciduous forests, ranges from 732 Rs/ha/year (open forests) to 17080 Rs/Ha/year (VDF). Spatiotemporal land use analysis and meteorological data (rainfall, temperature, evapotranspiration). InVEST provides the quantum of soil (sediment) retained within the natural forested areas and considering Rs 48.8 per ton retention of sediments and on the condition of forests (Verma et al., 2013)	RUSLE, InVEST - quantum of soil (sediment) and valuation based on Benefit transfer method based on case studies from India
	Water regulation and groundwater recharge	2600 Rs/ha/year (MDF) to more than 5000 Rs/ha/year (VDF) in evergreen forests and 663 Rs/Ha/year to more than 3700 Rs/ha/year in deciduous vegetation. Based on reference data of groundwater availability combined with the economic value of water compiled from the groundwater authority.	InVEST provides the quantum of water recharge within the natural forested areas.

		The economic value of groundwater (after deducting costs) is about 262.5 Rs/kilo cum of water.	
	Pollination service	The spatial extent of forest ecosystems and pollination services of forest ecosystems - 10167 INR/Ha/Yr (MDF) to 11907 INR/Ha/Yr (VDF) Pollination services are quantified based on the spatial extent of forests, and the economic value of pollination are accounted for through the comparative assessment of natural regeneration of forest patches (with fencing protection from external pressures: (Ray et al., 2015; Balachandran et al., 2017) and compared with the afforestation cost. These values are comparable to case studies from India (Verma et al., 2013) of natural forest regeneration and its replacement cost if done artificially as recommended by the National Afforestation Programme Guidelines (NAP 2009) and based on the success stories of National Beekeeping & Honey Mission (NBHM, 2019).	Benefit transfer method $\sum_{i=1}^{n} V_i \times A_i$ Where Vi represents the monetary values per hectare and Ai represents the area
	Water purification	The spatial extent of forest ecosystems and water purification values 2,950 Rs/ha/yr based on studies from India (Verma et al.,, 2013).	Benefit transfer method – based on case studies from India
		The spatial extent of forest ecosystems and	

	Waste treatment	waste treatment is estimated at 4716 Rs/ha/yr (Ramachandra et al., 2017, Verma et al.,, 2013). These values are comparable to the studies across the globe (De Groot et al., 2020) after adjusting for GDP (PPP) per capita for India and currency exchange value.	
	Air filtration services	The spatial extent of forest ecosystems and air filtration services of forest ecosystems - 8,368 INR/Ha/Yr (MDF) to 22,617 INR/Ha/Yr (VDF) based on published literature from India (Ninan and Kontoleon, 2016, Joshi J and Negi GCS, 2011) which are comparable to tropical forests-global ecosystem service valuation database(ESVD). https://www.es-partnership.org/wp-content/uploads/2020/08/ESVD_Global-Update-FINAL-Report-June-2020.pdf were adjusted for GDP (PPP) per capita of the country for which values were estimated and corresponding currency exchange rate	Benefit Transfer method $\sum_{i=1}^{n} V_i \times A_i$ Where Vi represents the monetary values per hectare and Ai represents the area
	Local (micro and meso) climate regulation services	The spatial extent of forest ecosystems 17,933 INR/Ha/Yr (MDF) to 48,468 INR/Ha/Yr (VDF) based on published literature from India (Ghosh, 2020, Verma et al., 2007), which are comparable to values – global ecosystem service valuation database (ESVD). https://www.es-partnership.org/wp-	

		content/uploads/2020/08/ESVD_Global-Update-FINAL-Report-June-2020.pdf adjusted for GDP (PPP) per capita of the country for which values were estimated and corresponding currency exchange rate	
Cultural services	Aesthetic	Karnataka Forest Department (Uttara Kannada, Shimoga, Chikmagalur, Dakshina Kannada and Kodagu districts) (primary survey – entrance fees (park, recreation spots) x the average number of visitors to the park/recreation spots during 2018, 2019, and 2020), supplemented with the Indian case studies (Ray et al., 2010; Bharath et al., 2017; Ramachandra et al., 2018c) Districts at a Glance (KSRSAC 2018) https://des.karnataka.gov.in/english https://kgis.ksrsac.in/kag/ Based on these, the value ranges 1500±250 ₹/Ha/Yr, and an average value of Rs 1500 ₹/Ha/Yr was considered	Considering entrance fees (park, recreation spots) x the average number of visitors to the park/recreation spots during 2018, 2019, and 2020), supplemented with the Indian case studies, and travel expenses associated to the travel, based on the address of visitors and considering the connectivity. Collected additional details from the service providers of revenue during the past three years. The data collected from the service operators include (i) cost (labour, fuel and maintenance) and (ii) annual revenue.
	Spiritual and historic	Spiritual and historic services 1,200 ₹/Ha/Yr (MDF) to 7,200 ₹/Ha/Yr (VDF) based on the primary data. Distribution of sacred groves (relic forests protected under belief) across the state is considered and quantified on the per hectare value -travel cost basis. Data about the annual collection and expenses were	Residual method (annual collection for rituals and deducting costs – priest salary and ritual expenses) In groves, where annual collection details were not available, travel cost

		compiled from select groves' administrative / management committees in Shimoga, Uttara Kannada, and Kodagu districts. In groves, where annual collection details were not available, the travel cost method is used to quantify the number of visitors (visiting groves) for annual rituals, festivals, and other religious activities. This is done through primary surveys of select groves in Uttara Kannada, Shimoga, and Kodagu districts and supplemented with case-studies from India – benefit transfer method	method and supplemented with case-studies from India – benefit transfer method
	Tourism and recreational	Ranges from 28,944 ₹/Ha/Yr (MDF) to 2,88,000 ₹/Ha/Yr (VDF), based on a primary survey (Annexure 3.4)– entrance fees (park, recreation spots) x the average number of visitors to the park during 2018, 2019, and 2020), supplemented with the Indian case studies. Benefit transfer method - (Badola et al., 2017; Gunarekha and Binoy 2017; Ramachandra et al 2017. 2019b; Sinclair et al., 2020)	Travel cost method $\sum_{i=1}^{n} V_i \times A_i$ Where Vi represents the monetary values per hectare and Ai represents the spatial extent of the respective ecosystem and entrance fee with details of visitors
	Education, scientific and research	4800 ₹/Ha/Yr based on the primary data. Details of the (i) nature education programs organized by the Karnataka Forest Department jointly with the non-governmental organisations and universities, (ii) research	Based on funding – field research component

		funding (field research component) research, duration, the project budget (for field research), research team details were compiled from the Karnataka Forest Department This information is supplemented with the data compilation through discussion with researchers, and relevant literature of field-based research (ecology, medicinal plants, etc.) (Chandran et al., 2010; Ray and Ramachandra 2010; Gould et al., 2014; Ray et al., 2014a; Dorji et al., 2019; Kreye et al., 2019).	
Total ecosystem supply value (TESV)	TESV provides the total worth of ecosystem service and is calculated as the sum of provisioning services (*PS*), regulating services (*RS*) and cultural services (*CS*).		$TESV = \sum EVi$ i = 1,2,3 1: Provisioning, 2: Regulating and 3: Cultural
Source: Ramachandra et al., 1999, 2000a, 2000b, 2000b,2000d; 2010, 2012, 2015, 2016, 2017, 2018a,b,c, 2019a, b, 2020; Rao et al., 2014, 2015; Ramachandra and Bharath 2021; Bharath et al., 2017; Balachandran et al., 2017, Ray et al., 2015, Chandran et al., 2010; Ray et al., 2014b, 2015, Chandran et al., 2010; Ray and Ramachandra 2010; Gould et al., 2014; Ray et al., 2014a; Dorji et al., 2019; Kreye et al., 2019 ; Karnataka Biodiversity Board (kbb.karnataka.gov.in), Karnataka Forest Department (https://aranya.gov.in/; http://envis.frlht.org/mpcas) and the Medicinal Plants Conservation Authority (https://ayush.karnataka.gov.in/)			

4.2 Valuation of services from agriculture ecosystems

In order to determine the revenue due to the services from the agriculture ecosystems, i) production was calculated for each crop based on the crop area and crop yield per hectare at taluk level; ii) Minimum support price (MSP) specified by the Government of India (MSP 2020), followed by prices at mandi (local market yards, prices fixed by the Government of Karnataka) were used to determine the monetary value; iii) Regulatory services, cultural services, and other provisioning services were obtained based on the review of published literature (revenue per unit area is derived from the literature, based in India specific case studies), and for specific parameters where data was not available, international values were adopted (adjusting for GDP PPP per capita). The method for evaluating the services from the agriculture ecosystem is illustrated in Figure 4.2. Table 4.2 depicts the revenue of various services per hectare, iv) Total ecosystem supply value, and (v) NPV for each (provisioning, regulating, cultural) and cumulative service is derived.

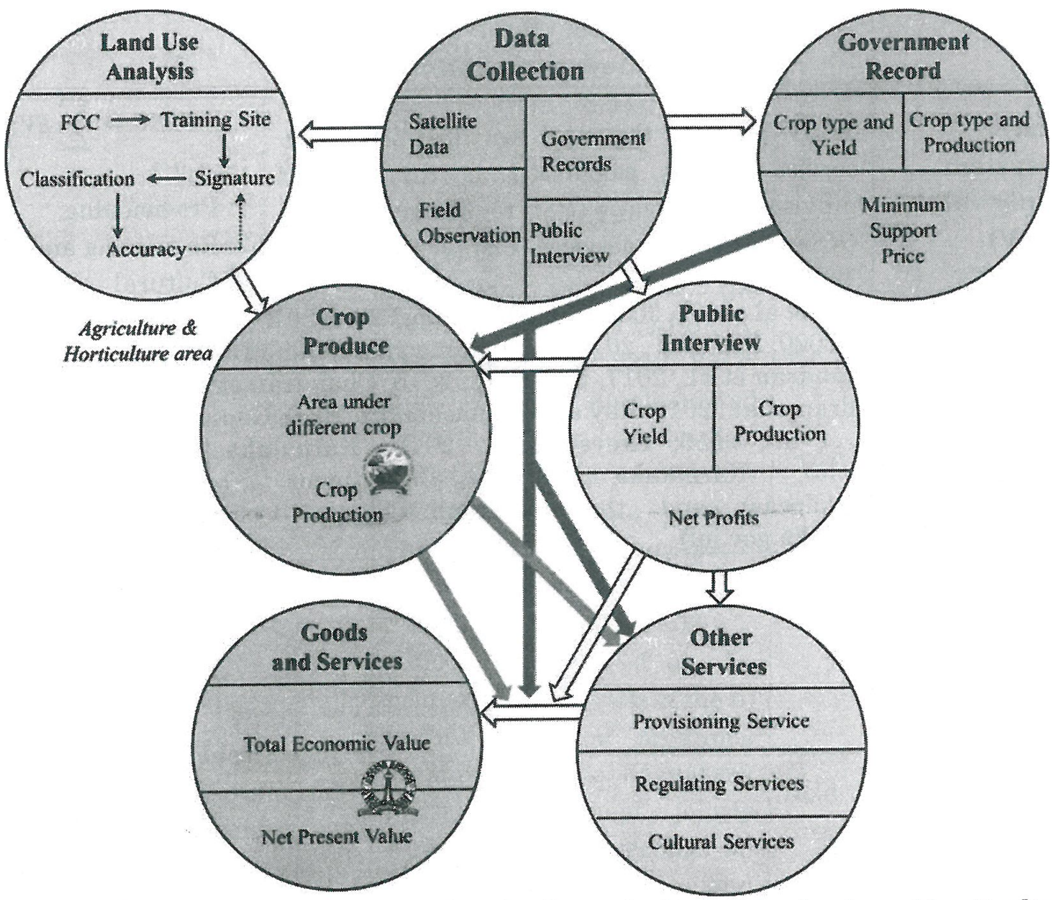


Figure 4.2. Method for accounting services in the agriculture (croplands and horticulture) ecosystem

Table 4.2. Revenue generated per unit area

Services	Variables	Data and source	Approach
Provisioning	Food	MSP – Cost of production government records and public interview	**Residual Method** $\sum_{i=1}^{n} Q_i \times (P_i - C_i)$ Where Qi represents quantity, Pi is the price, Ci is the cost involved in the harvest
	Fodder	**3000** – 5000 Rs/Acre, 7500-12500 Rs/Ha Public interview, the lowest value is used for accounting	
	Wood	**432** Rs /Ha to 4000 Rs/Ha, public interview, the lowest value is used for accounting	
Regulating	Air filtration services	3017 Rs per year (Pal 2018)	Benefit transfer method – based on Indian case studies
	Local (micro and meso) climate regulatio n	720 Rs/Ha/Year, Value is based on global studies based on published literature - global ecosystem service valuation database (ESVD). https://www.es-partnership.org/wp-content/ uploads/2020/08/ESVD_Global-Update-FINAL-Report-June-2020.pdf adjusted for GDP (PPP) per capita of the country and corresponding exchange rate	Benefit transfer method $\sum_{i=1}^{n} V_i \times A_i$ Where Vi represents the monetary values per hectare and Ai represents the area
	Global climate regulatio n - carbon sequestra tion	**Croplands** 36 Rs/Ha/Year Ecosystem extent through land-use analyses, area under crop and type, yield Comparison with the Indian case study (Nayak et al., 2019) Horticulture 5040 Rs/Ha, Ecosystem extent through land-use analyses, area under crop and type, AGB and BGB, Comparison with Indian case study (Murali 2010)	InVEST carbon model
	Soil carbon sequestra tion	**Agriculture** (croplands) 363.6 Rs/Ha/Year, ecosystem extent based on land use analyses, ecosystem condition (soil), Carbon and Nitrogen (C&N) analyses through elemental analyzer of soil samples (collected from plots	CHN elemental analyses of representative soil samples,

		representative of agro-climatic regions), Comparison with a case study from India (Nayak et al., 2019) **Horticulture** 14400 Rs/Ha, Comparison with a case study from India (Murali 2010)	Benefit transfer method InVEST carbon model
	Water flow (groundwater recharge)	**Agriculture (croplands)** 792 Rs/Ha/Year Ecosystem extent, rainfall, etc. Comparison with the study from India (Nayak et al., 2019) **Horticulture** 1224 Rs/Ha/Year Ecosystem extent, rainfall, etc. Comparison with global ecosystem service valuation database (ESVD). Adjusted for GDP (PPP) per capita of the country for which values were estimated and corresponding exchange rate	InVEST
	Nitrogen fixation	396 Rs/Ha/Year Ecosystem extent based on land use analyses, ecosystem condition (soil), CHN analyses through elemental analyzer of soil samples (collected from plots representative of agro-climatic regions) (Nayak et al., 2019)	C&N elemental analyses of representative soil samples
	Soil fertility (NIC 2020)	2448 Rs/Ha/Year (poor soils) Soil erosion, soil fertility estimated per hectare in terms of monetary values Comparison with (Nayak et al., 2019) 4991 Rs/Ha/Year (good soils) Soil erosion, soil fertility estimated per hectare in terms of monetary values, comparison with http://naasindia.org/Policy%20Papers/policy%2094.pdf	RUSLE, InVEST
	Remediation – Organic	5760 Rs/Ha/Year (Nayak et al., 2019)	Benefit transfer method

	and inorganic materials		(case studies from India)
	Pollination	391 Rs/Ha/Year agriculture (croplands and horticulture) http://naasindia.org/Policy%20Papers/policy%2094.pdf	
	Genetic diversity	12897 Rs/Ha/Year http://naasindia.org/Policy%20Papers/policy%2094.pdf	
	Biological control	115.2Rs/Ha/Year (Nayak et al., 2019)	
Cultural	Tourism & recreational	941 Rs/Ha/Year Travel cost method – Uttara Kannada district (based on number of visitors visiting farm houses per year, the amount paid and expenses, benefit to travel operators) and comparison with the case study http://naasindia.org/Policy%20Papers/policy%2094.pdf	Travel cost method
	Inspirational, culture, art	1152 Rs/Ha/Year Values based on global studies based on published literature - global ecosystem service valuation database (ESVD), adjusted for GDP (PPP) per capita of the country for which values were estimated and corresponding exchange rate	$\sum_{i=1}^{n} V_i \times A_i$ Where Vi represents the monetary values per hectare and Ai represents the area
Total ecosystem supply value (TESV) for agriculture (croplands, horticulture) ecosystem	TESV provides the total worth of ecosystem service and is calculated as the sum of provisioning services (*PS*), regulating services (*RS*), and cultural services (*CS*).		$TESV = \sum EVi$ i = 1,2,3 1: provisioning, 2: regulating and 3: Cultural

Source: Coffee Board 2020; Commodities Online 2020; Cost of Cultivation/Production and related data, no date; District Statistical Office 2019; Directorate of Economics and Statistics 2017; Economic Survey of Karnataka 2017 – 2018, 2018; Farmers Portal 2020; Krishi Marata Vahini 2020; Krishi Marata Vahini 2020; MSP for Rabi Crops 2019 – 2020, 2020

4.3 Total Ecosystem Supply Value [TESV]

The ecosystem services (provisioning, regulating and cultural) for forest and agriculture ecosystems were then summed across all benefit flows to estimate a total annual flow of value from the respective spatial units.

Temporal comparison of ecosystem services: Monetary values of ecosystem services (provisioning, regulating, cultural services, and TESV) of 2005 and 2019 are compared to understand the changes due to changes in the spatial extent and condition of the ecosystem. Monetary values of 2005 were adjusted at 2019 values by considering the GDP deflator (MoSPI 2020) of an inflation rate of 2.92 times (*Inflation Calculator - Indian Rupee*, 2019).

4.4 Net Present Value (NPV) of ecosystem assets:

The net present value (NPV) *is the value of an asset determined by estimating the stream of income expected to be earned in the future and then discounting the future income back to the present accounting period* (SEEA, 2021). In ecosystem accounting, it is applied by aggregating the NPV of expected future returns for each ecosystem service supplied by an ecosystem asset. The use of an NPV approach implies that their value will be related to the capacity to supply ecosystem services and how this capacity is expected to change in the future.

NPV is based on the measurement of (i) the ecosystem services supplied by the asset, and the monetary values of these services (ii) estimation of pattern of future flows of each ecosystem service, considering expected degradation/enhancement and demand (iii) expected future prices for each ecosystem service; (iv) expected institutional arrangements; and (v) expected asset life. In addition, NPV requires a discount rate, which adjusts the value of a stream of future flows to account for time preferences and attitudes to risk. Discount rates are required to convert the expected future ecosystem services flows into a current period estimate of overall value. In this report, a social discount rate (as opposed to individual discount rate) has been used, as most of the ecosystem services contribute to collective benefits.

Net present value is calculated using equation 4.1 and applied at the level of individual ecosystem services, and the resulting discounted values are aggregated to derive the monetary value of the ecosystem asset.

$$\mathrm{NPV} = \sum_{t=1}^{T} \frac{ES_t}{(1+r)^t} \qquad \text{-------------------- 4.1}$$

Where, t – Number of years ranging between 1 to T.

T - Number of years for which this annual benefit from the asset will accrue. This is closely linked to the length of time needed to regenerate the same type and quality of forests. The Hon'ble Supreme Court of India in the Judgement of 26th September 2005 (Page 10, Para 4) has suggested that the basis for calculation of NPV should be the economic value spread over a period of 50 years, which is the period for forest regeneration

ES_t –Ecosystem services at time t

r – Social rate of discount for capital returns. As per the norms in India and Hon'ble Supreme Court, a social discount rate of 4% is applied for renewables and 2% for non-renewable resources. Hence, for forest ecosystems, 3% is considered that is the weighted average of renewable and non-renewable.

NPV of ecosystems (forests, agriculture) in Karnataka is computed using TESV -the total value of ecosystem flow based on a social discount rate of 3% and a period of 50 years.

The ecosystem service values are determined based on government records, and prices were considered to remain the same with no inflations for 50 years (w.r.t 2019).

5.0 Results and Discussion

Valuation of ecosystem services entails the computation of spatial extent and conditions of the respective ecosystems, quantification of services in physical and monetary units The spatial extent was used for computing the value of the provisioning services per hectare. Forests have been reclassified as VDF (very dense forests), MDF (medium dense forests), and open forests (OF) based on the condition (computed through the fragmentation analyses), comparable to the classification approach adopted by the Karnataka Forest Department (based on the forest type and their canopy cover). A similar approach was adopted earlier to compute ecosystem services from forest ecosystems in India (Verma et al., 2013).

The following subsections presents (i) extent of ecosystems in Karnataka, (ii) valuation of ecosystem services, (iii) computation of TESV: Total ecosystem supply value and (iv) NPV of ecosystem assets

5.1 Assessment of ecosystem extent over time

An assessment of ecosystem extent was performed, using land use and land cover as proxies. The spatiotemporal land cover/use analysis was carried out from 1985 to

2019 using remote sensing data through a supervised classifier based on the Gaussian maximum likelihood algorithm.

The state witnessed large-scale land-use transitions post-1990s due to globalization and the consequent spurt in industrialization and urbanization, as well as an increase of horticulture crops and the conversion of croplands (cereals, pulses, etc.) to market-based cash crops (coffee, sugarcane, arecanut, etc. with higher economic values), etc.

Temporal land cover/use analyses reveal the decline of forest cover in Karnataka from 1985 to 2019 (Figure 5.1). Districts of the Western Ghats region have a higher forest cover than other districts, as depicted in Figure 5.1. Currently, 15% of the State's geographical area is forested, compared to 21% in 1985 (Table 5.1). Large-scale developmental activities such as constructing a series of reservoirs and dams, creating special economic zones, townships, and land conversion for built-up areas have led to the loss of large tracts of forests. The forest cover now is confined to major conservation reserves such as protected areas, national parks and wildlife sanctuaries. Natural forests show a decline of evergreen forests from 7.5% (1985) to 5.7% (by 2019), moist deciduous forests from 5.7% (1985) to 4.1% (by 2019), and dry deciduous forests from 4.0% (1985) to 2.2 % (2019).

The abrupt land-use conversion has also resulted in a loss of productive agricultural lands near the cities such as Bengaluru, Mysore, Hubli-Dharwad, Shimoga, etc. Districts such as Kodagu, Uttara Kannada, Bengaluru, Shimoga, Belgaum, Dakshina Kannada, and Chikmagalur have been experiencing large-scale land cover change due to unplanned development activities. The built-up cover has increased from 0.47% to 3% from 1985 to 2019, causing an impact on agriculture, forest, and lakes. This necessitates sustainable land-use policies to arrest deforestation and abrupt land conversions.

Horticultural areas have increased from 8.8% (1985) to 11.1% (2019), and category-wise land-use dynamics are presented in Table 5.1. Large-scale monoculture plantations of eucalyptus, rubber, acacia, teak, and arecanut have increased and now cover 12% of the state. In addition, new urban agglomerations were noticed across cities and major towns such as Bengaluru, Mangalore, Hubli, Hassan, Mysore, etc. These changes are abrupt and have resulted in a disruption in the provision of ecosystem services, affecting the hydrologic regime and natural resources availability. While horticultural areas have increased overall, coastal and Tier-1 cities (e.g. Bangalore) and Tier-2 cities (e.g. Mysore, Hubli-Dharwad, Belgaum) are experiencing loss of agricultural areas in the sub-urban regions with new layouts and satellite towns.

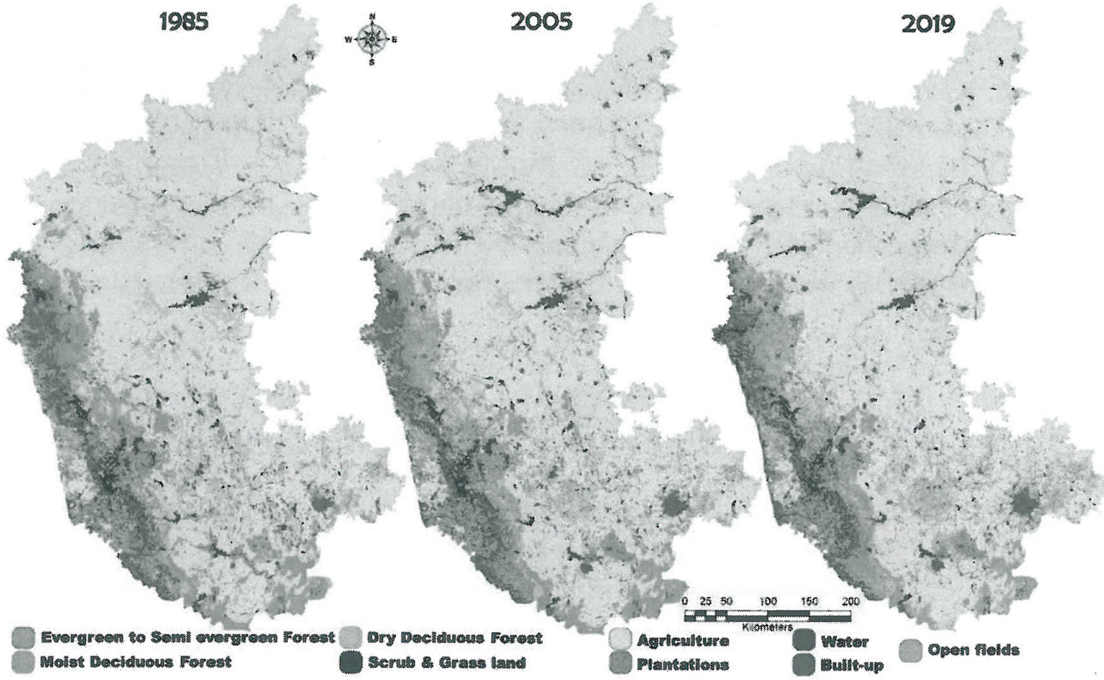


Figure 5.1. Land uses from 1985 to 2019 in Karnataka

Table 5.1 Ecosystem extent – Karnataka State (units in sq.km and %) – based on temporal remote sensing data analyses

Year (Ecosystem type)	Units	Built-up	Crop land	Horticulture	Fallow land	Evergreen forest	Moist deciduous	Dry deciduous forest	Scrub \Grass lands	Water	Total area
1985	sq. km	904	128468	16790	1678	14293	10960	7622	6733	4344	191791
	%	0.5	67.0	8.8	0.9	7.5	5.7	4.0	3.5	2.3	
2005	sq. km	2666	127196	20209	1185	12445	9900	7410	5604	5177	191791
	%	1.4	66.3	10.5	0.6	6.5	5.2	3.9	2.9	2.7	
2019	sq. km	5748	127962	21325	2854	10888	7892	4281	4907	5934	191791
	%	3.0	66.7	11.1	1.5	5.7	4.1	2.2	2.6	3.1	
Changes from 1985 to 2019											
1985	sq. km	904	128468	16790	1678	14293	10960	7622	6733	4344	191791
2019	sq. km	5748	127962	21325	2854	10888	7892	4281	4907	5934	191791
Net change in extent from1985 to 2019											
Extent	sq. km	4844	-505	4536	1175	-3405	-3068	-3341	-1826	1590	
	%	535.8	-0.4	27.0	70.0	-23.8	-28.0	-43.8	-27.1	36.6	

Forest ecosystem extent is further disaggregated into very density forests (VDF) and medium-density forests (MDF) based on the ecosystem condition (fragmentation of forests). Karnataka state has 11,334 km² area under VDF (2019), which accounts for 6% of the entire landscape, and MDF covers 12,869 km², which accounts for 7% of the state land area (Figure 5.2). Table 5.2 provides details of ecosystem types (VDF and MDF categories) for forest circles in Karnataka. Districts such as Uttara Kannada and Kodagu have good VDF cover as compared with other districts. On the other hand, during 2005 to 2019, districts such as Ballari, Bagalkot, Bidar, Kolar have witnessed a loss of major tracts of MDF.

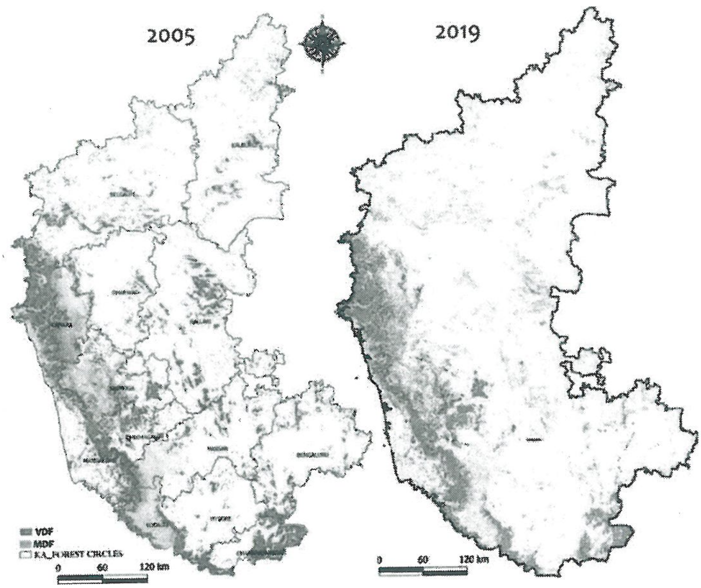


Figure 5.2. Very dense forest (VDF) and medium-density forests (MDF) in Karnataka

Table 5.2. Circle wise forest ecosystem reclassified as VDF and MDF

Sl.no.	Circle	VDF (Ha)		MDF (Ha)	
		2005	2019	2005	2019
1	Bengaluru	1,44,717	33,696	37,213	63,035
2	Belgaum	2,01,790	60,393	78,388	87,360
3	Ballari (Bellary)	2,49,789	13,514	64,122	92,697
4	Chamarajanagar	2,72,557	96,515	15,222	89,538
5	Chikmagalur	1,84,516	1,31,484	37,230	64,794
6	Dharwad	83,942	17,012	25,637	35,280
7	Kalaburagi (Gulbarga)	79,842	15,575	51,355	38,904
8	Hassan	1,04,205	44,309	88,492	72,695
9	Canara	3,78,655	2,56,730	3,10,345	3,32,741
10	Kodagu	93,764	59,239	1,25,832	1,12,642
11	Mangaluru	2,60,299	2,23,033	54,209	73,169
12	Mysore	1,16,604	68,775	19,081	33,795
13	Shivamogga	1,95,940	1,13,215	2,23,267	1,90,270
Total Area		23,66,620	11,33,490	11,30,393	12,86,920

5.2 Valuation of the ecosystem services

Ecosystem services and the natural capital stocks in Karnataka State make significant direct and indirect contributions to the district and state economies and human welfare. The evaluation of ecosystem services will aid in formulating policy and legislation that can provide protection and sustainable management of ecosystems to fully capitalize on the most significant ecosystem services. Accounting for ecosystem services in physical terms aims to record, in an accounting structure, the flows of ecosystem services over an accounting period in physical units such as cubic meters and tonnes. Physical quantification commonly focuses on the measurement of ecosystem structures, processes, and functions, i.e., the supply side of ecosystem service flows (SEEA EA) (SEEA EA 2021).

Ecosystem services were quantified through the residual value method by taking the gross value of the final marketed good to which the ecosystem service provides input and then deducting the cost of all other inputs, including labour, produced assets, and intermediate inputs (as per the SEEA Ecosystem Accounting). Ecosystem services were computed based on the ecosystem flows in 2005 and 2019. Values of 2005 were adjusted through the consumer price index or GDP deflator; these values reflect the real measures of ecosystem services, which could be compared with ecosystem services of 2019.

Comparison of values of services of 2019 with 2005 highlights there has been a considerable decline in the provisioning services evident from 42% decline in rosewood, 93% decline in bamboo, NTFP (honey reduced by 97%, tamarind reduced by 75%), 42% decline in fodder and 35% decline in medicine, which could be attributed to the degradation of forests (extent as well as conditions) in Karnataka during 2005 to 2019. Table 5.3 and Table 5.4 list services by ecosystem type (forest, agriculture, and horticulture) for 2005 (at 2019-2020 values) and 2019, respectively. There has been a reduction in ecosystem services – 28.4% reduction in provisioning services (51.6% reduction in forest ecosystem), 14 % reduction in regulatory services (mainly in forest ecosystem - 27.1% reduction), and 0.2% reduction in cultural services.

Table 5.3. Ecosystem wise – Provisioning, regulatory and cultural services – 2005 (Million ₹) at 2019-2020 values, 2005 values were adjusted to 2019 considering inflation

Ecosystem type / YearUnits	Built-up	Crop land	Horticulture	Fallow land	Evergreen forest	Moist deciduous forest	Dry deciduous forest	Scrub \ _grass lands	Water	Total
2005 sq.km	2,666	1,27,196	20,209	1,185	12,445	9,900	7,410	5,604	5,177	1,91,791
%	1.4	66.3	10.5	0.6	6.5	5.2	3.9	2.9	2.7	100
Provisioning, Regulating and cultural services (in Million ₹) for forest, agriculture and horticulture ecosystems										
Food (cereal, pulses..)		₹2,51,411	₹39,944	₹2,342						₹2,93,697
Timber					₹712	₹566	₹424	₹321		₹2,023
NTFP					₹50,167	₹39,908	₹29,871	₹22,590		₹1,42,537
Fish					₹2,409	₹1,916	₹1,434	₹1,085	₹1,002	₹7,845
Fuelwood		₹262	₹42	₹2	₹17,196	₹13,679	₹10,239	₹7,743		₹49,163
Fodder		₹1,00,865	₹16,026	₹940	₹23,550	₹18,734	₹14,022	₹10,605		₹1,84,742
Medicine					₹272	₹216	₹162	₹122		₹773
Water					₹1,89,899	₹1,51,064	₹1,13,069	₹85,512	₹78,996	₹6,18,540
Genetic					₹1,33,800	₹1,06,438	₹79,667	₹60,250		₹3,80,154
Total Provisioning (Million ₹)		₹3,52,538	₹56,011	₹3,284	₹4,18,004	₹3,32,522	₹2,48,888	₹1,88,228	₹79,998	₹16,79,473
Air filtration services		₹26,941	₹4,280	₹251	₹28,015	₹22,286	₹16,680	₹12,615		₹1,11,068
Local (micro and meso) climate regulation services		₹6,425	₹1,021	₹60	₹59,655	₹47,456	₹35,520	₹26,863		₹1,76,999
Global climate regulation service		₹310	₹49	₹3	₹2,79,793	₹2,22,576	₹1,66,595	₹1,25,991		₹7,95,318
Pollination		₹3,489	₹554	₹33	₹13,913	₹11,068	₹8,284	₹6,265		₹43,605
Soil erosion					₹19,919	₹15,846	₹11,860	₹8,970		₹56,595
Soil fertility		₹47,784	₹7,592	₹445	₹33,393	₹26,564	₹19,883	₹15,037		₹1,46,907
Water purification					₹3,167	₹2,519	₹1,886	₹1,426	₹1,318	₹10,316
Waste treatment					₹4,483	₹3,567	₹2,670	₹2,019	₹1,865	₹14,604
Groundwater					₹3,289	₹2,616	₹1,958	₹1,481	₹1,368	₹10,713
Water flow regulation		₹7,068	₹1,123	₹66						₹8,256
Nitrogen fixation		₹35,731	₹5,677	₹333						₹41,741
Remediation – organic and inorganic materials		₹51,402	₹8,167	₹479						₹60,047
Genetic diversity		₹1,15,091	₹18,286	₹1,072						₹1,34,449
Biological control		₹1,028	₹163	₹10						₹1,201
Total Regulating (Million ₹)		₹2,95,270	₹46,913	₹2,751	₹4,45,628	₹3,54,497	₹2,65,336	₹2,00,667	₹4,551	₹16,15,611
Aesthetic					₹1,249	₹994	₹744	₹563		₹3,550
Tourism & recreational		₹8,397	₹1,334	₹78	₹98,840	₹78,627	₹58,851	₹44,508		₹2,90,635
Spiritual					₹70	₹56	₹42	₹32		₹199
Artistic		₹10,280	₹1,633	₹96	₹591	₹470	₹352	₹266		₹13,688
Education, scientific and research					₹5,153	₹4,100	₹3,068	₹2,321	₹2,144	₹16,786
Total Cultural (Million ₹)		₹18,678	₹2,968	₹174	₹1,05,903	₹84,246	₹63,057	₹47,688	₹2,144	**₹3,24,858**
TESV (Million ₹)		₹6,66,485	₹1,05,892	₹6,209	₹9,69,535	₹7,71,265	₹5,77,280	₹4,36,583	₹86,692	**₹36,19,942**
TESV (Million ₹)		Agriculture, Horticulture		**₹7,78,58**	Forest Ecosystem				**₹28,41,355**	**₹36,19,942**

Table 5.4. Ecosystem wise – Provisioning, regulatory and cultural services (Million ₹) – 2019

Ecosystem type		Built-up	Crop land	Horticulture	Fallow land	Evergreen forest	Moist deciduous forest	Dry deciduous forest	Scrub \ grass lands	Water	Total
Year	Units										
2,019	sq.km	5,748	1,27,962	21,325	2,854	10,888	7,892	4,281	4,907	5,934	1,91,791
	%	3	67	11	2	6	4	2	3	3	100
Provisioning, Regulating and cultural services (Million ₹) for forest, agriculture and horticulture ecosystems											
Food (cereal, pulses..)			₹3,87,216	₹64,530	₹8,636						
Timber						₹565	₹409	₹222	₹254		₹1,450
NTFP						₹5,414	₹3,924	₹2,129	₹2,440		₹13,906
Fish						₹3,897	₹2,824	₹1,532	₹1,756	₹2,124	₹12,133
Fuelwood			₹298	₹50	₹7	₹22,313	₹16,173	₹8,773	₹10,056		₹57,668
Fodder			₹1,05,472	₹17,577	₹2,352	₹15,207	₹11,023	₹5,979	₹6,854		₹1,64,464
Medicine						₹202	₹146	₹79	₹91		₹519
Water						₹90,179	₹65,365	₹35,457	₹40,642	₹49,148	₹2,80,792
Genetic						₹81,257	₹58,898	₹31,949	₹36,621		₹2,08,726
Total Provisioning (Million ₹)			₹4,92,986	₹82,157	₹10,995	₹2,19,034	₹1,58,763	₹86,121	₹98,714	₹51,272	₹12,00,041
Air filtration services			₹28,618	₹4,769	₹638	₹20,807	₹15,082	₹8,181	₹9,377		₹87,474
Local (micro and meso) climate regulation services			₹6,825	₹1,137	₹152	₹44,308	₹32,116	₹17,421	₹19,969		₹1,21,929
Global climate regulation service			₹3,788	₹631	₹84	₹2,22,348	₹1,61,165	₹87,424	₹1,00,208		₹5,75,648
Pollination			₹3,706	₹618	₹83	₹10,491	₹7,604	₹4,125	₹4,728		₹31,356
Soil erosion						₹14,003	₹10,150	₹5,506	₹6,311		₹35,969
Soil fertility			₹60,426	₹10,070	₹1,348	₹39,408	₹28,564	₹15,495	₹17,760		₹1,73,071
Water purification						₹2,225	₹1,613	₹875	₹1,003	₹1,213	₹6,927
Waste treatment						₹3,149	₹2,283	₹1,238	₹1,419	₹1,716	₹9,806
Groundwater						₹2,285	₹1,656	₹898	₹1,030	₹1,245	₹7,115
Water flow regulation			₹7,805	₹1,301	₹174						₹9,280
Nitrogen fixation			₹3,754	₹626	₹84						₹4,463
Remediation – organic and inorganic materials			₹54,601	₹9,099	₹1,218						₹64,918
Genetic diversity			₹1,22,255	₹20,374	₹2,727						₹1,45,355
Biological control			₹1,092	₹182	₹24						₹1,298
Total Regulating (Million ₹)			₹2,92,870	₹48,807	₹6,532	₹3,59,024	₹2,60,233	₹1,41,163	₹1,61,805	₹4,174	₹12,74,610
Aesthetic						₹627	₹455	₹247	₹283		₹1,612
Tourism & recreational			₹8,920	₹1,487	₹199	₹1,09,309	₹79,231	₹42,979	₹49,263		₹2,91,388
Spiritual						₹71	₹51	₹28	₹32		₹181
Artistic			₹10,920	₹1,820	₹244	₹439	₹318	₹173	₹198		₹14,111
Education, scientific and research						₹3,620	₹2,624	₹1,423	₹1,631	₹1,973	₹11,271
Total Cultural (Million ₹)			₹19,840	₹3,306	₹443	₹1,14,066	₹82,679	₹44,849	₹51,407	₹1,973	₹3,18,563
TESV (Million ₹)			₹8,05,696	₹1,34,270	₹17,970	₹6,92,124	₹5,01,675	₹2,72,133	₹3,11,926	₹57,419	₹27,93,213
TESV (Million ₹)		Agriculture, Horticulture			₹9,57,936	Forest Ecosystems				₹18,35,277	₹27,93,213

5.3 Valuation of the forest ecosystem services – forest circle wise, Karnataka

The forest provisioning services (physical values), area of extraction, and seigniorage value (revenue) for two five-year periods (2001-2005 and 2015-2019) were compiled from the respective forest circles of the Karnataka Forest Department. Averages of five years of goods were used to quantify goods in physical terms for 2005 and 2019. Forests are managed by the Karnataka Forest Department, Government of Karnataka (KFD 2020). Decentralized administration and management of forests in Karnataka state are through forest circles, and there are 13 forest circles. Temporal data of 5 years period helped in accounting for variability across the study period (years). The seigniorage represents the residual value of the respective goods after deducting the cost involved (harvesting, transportation, etc.). Seigniorage is expressed as revenue received by the government (Haslag 2020) after deducting all expenses from the auction amount of the respective provisioning services.

Provisioning services of forest ecosystems in Karnataka

Timber: Timber includes rosewood, teak wood, eucalyptus, softwood, round pole, etc. The total provisioning value of timber extracted from Karnataka state is 2,023, and 1,445 billion rupees respectively for the years 2005 and 2019. The rosewood is available only in specific circles, which are part of the Western Ghats. Shimoga, Kodagu, and Canara circles have higher ecosystem supply value as compared with other circles. The ecosystem supply value of rosewood is 140,017 Rs/Ha/yr (2005) and 140,998 Rs/Ha/yr (2019). The maximum value is observed as 240,571 Rs/Ha/yr in the Canara circle, and the minimum value is observed in Dharwad as 60,909 Rs/Ha/yr for the year 2005. In 2019 maximum value is observed from the Canara circle as 240,656 Rs/Ha/yr and the minimum value as 60,909 Rs/Ha/yr from the Dharwad circle.

Teakwood: Teakwood is extracted in large quantities from Canara, Shimoga, Kodagu, and Chikmagalur circles. The ecosystem supply value of teak wood shows 79,881 Rs/Ha/yr (2005) and 79,961 Rs/Ha/yr (2019) as per the collected data. Maximum and minimum values are observed as 157,744, 41,302 Rs/Ha/yr (2005) for the circles Kodagu, Dharwad respectively, whereas for the year 2019, maximum and minimum values accounted as 158,134, 41,231 Rs/Ha/yr for the circles Kodagu, Dharwad respectively. The average teak wood values are observed as 79,881, 79,961 Rs/Ha/yr for the years 2005, and 2019 respectively.

Eucalyptus: The revenue from eucalyptus is high in Bengaluru, Mysore circles. Sandalwood is extracted in large quantities from Dharwad, Hassan circles. Overall, the circles such as Belgaum, Mysore, Ballari (Bellary) have lower timber services for 2019 compared to 2005. The ecosystem supply value of Eucalyptus wood is 4,304 and 4,265 Rs/Ha/yr for the data collected for the years 2005, 2019 respectively. The maximum value is observed as 9,246 Rs/Ha/yr in Hassan, and the minimum value is observed in the Canara circle as 1,302 Rs/Ha/yr for the year 2005. In 2019 maximum value is observed from the Hassan circle as 9235 Rs/Ha/yr and the minimum value as 1,302 Rs/Ha/yr from the Kodagu circle.

Softwood: The ecosystem supply value of softwood is 2,692 Rs/Ha/yr as per the collected data for 2005, and 2019. Maximum and minimum values are 3,864 and 1,303 Rs/Ha/yr (2005) for Mangalore, Canara circles, respectively, whereas for the year 2019, maximum and minimum values accounted as 158,134, 41,231 Rs/Ha/yr for the circles Kodagu, Dharwad respectively. *Other timber:* The ecosystem supply value of other kinds of timber is 4,644 and 4,297 Rs/Ha/yr for the data collected for the years 2005, 2019 respectively. The maximum value is 9,276 Rs/Ha/yr in Hassan, and the minimum value is in Canara, Kodagu circles as 1,302 Rs/Ha/yr for the year 2005. In 2019 maximum value is from the Mysore circle as 9,241 Rs/Ha/yr and the minimum value as 1,302 Rs/Ha/yr from Canara and Kodagu circles.

Pulpwood: The ecosystem supply value of pulpwood is 3,369 Rs/Ha/yr (2005) and 3,381Rs/Ha/yr (2019) based on the data collected across the circles from Karnataka Forest Department. The maximum value is 4,272 Rs/Ha/yr in the Bangalore circle, and the minimum value is in Chikmagalur as 3,830 Rs/Ha/yr for the year 2005. In 2019 maximum value is from the Bangalore circle as 4,295 Rs/Ha/yr and the minimum value as 3,829 Rs/Ha/yr from the Chikmagalur circle.

Round poles: The ecosystem supply value of round poles wood is assessed as 4,434 and 4,261 Rs/Ha/yr for 2005, and 2019, respectively. The maximum value is 10,788 Rs/Ha/yr in Hassan, and the minimum value is in the Canara circle as 1,303 Rs/Ha/yr for the year 2005. In 2019 maximum value is from the Mysore circle as 9,224 Rs/Ha/yr and the minimum value as 1,304 Rs/Ha/yr from the Canara circle.

Sandalwood: The ecosystem supply value of sandalwood is accounted as 4,573, and 4,652 Rs/Ha/yr for 2005, and 2019 respectively. The maximum value is 9,237 Rs/Ha/yr in Hassan, and the minimum value is in Canara circles as 1,302 Rs/Ha/yr for the year 2005. In 2019 maximum value is from Hassan circle as 9,240 Rs/Ha/yr and the minimum value as 1,302 Rs/Ha/yr from the Canara circle.

Bamboo and Cane Production: Timber and biomass of bamboo and cane production have been assessed from forest inventory. Circles such as Canara and Mangalore are getting higher revenue from bamboo, and Bengaluru, Canara Dharwad, Mangalore are getting from high revenue from canes. The ecosystem supply value of bamboo has reduced for the year 2019 might be attributed to the degradation in the forest ecosystem with the reduced bamboo cover. The ecosystem supply value of Bamboo for the Karnataka state is assessed as 3,938 and 4,402 Rs/Ha/yr for the years 2005 and 2019, respectively. The maximum value is 9,283 Rs/Ha/yr in Mysore, and the minimum value is observed in Canara circles as 1,302 Rs/Ha/yr for the year 2005. In 2019 maximum value is from the Hassan circle as 8,911 Rs/Ha/yr and the minimum value as 1,303 Rs/Ha/yr from the Canara circle.

Fodder Production: fodder values are 66,911 and 39,063 million rupees for 2005 and 2019, respectively. The reduction in fodder availability could be attributed to the degradation of forest ecosystems in the State. Canara, Shimoga, Mangalore, and Chamarajanagar contribute higher compared to the Dharwad circle (least). Ecosystem supply value from fodder for Karnataka state is assessed 7,736, and 15,476 Rs/Ha/yr for the years 2005 and 2019. The maximum value is 8,988 Rs/Ha/yr in Chamarajanagar, and the minimum value is in the Kodagu circle as 6,583 Rs/Ha/yr for the year 2005. In 2019 maximum value is witnessed from the Chamarajanaga circle as 20,050 Rs/Ha/yr and the minimum value as 12,779 Rs/Ha/yr from the Ballari circle.

Non-Timber Forest Produce / Non-Wood Forest Produce: Ecosystem value from NTFP is estimated as 13,906 million rupees, in which Mysore, Shimoga, circles show higher values, and Mangalore, Chikmagalur show lower values. The quantity of NTFP extraction is higher in 2005 compared with 2019. The reduction is due to the degradation of the forest cover and the non-availability of labor (discussion with farmers during field investigations) for the sustainable extraction of NTFP.

- The ecosystem supply value of honey is 13,177 Rs/Ha/yr (2005) and 13,186 Rs/Ha/yr (2019) based on the data collected across the circles from Karnataka Forest Department. The maximum value is 13,411 Rs/Ha/yr in the Chamarajanagar circle and the minimum value is 13,059 Rs/Ha/yr for the year 2005 in the Shimoga circle. In 2019, maximum value of 13,413 Rs/Ha/yr is in the Chamarajanagar circle, and the minimum value is 13,060 Rs/Ha/yr in the Shimoga circle.
- Soapnut is 12,724 and 12,977 Rs/Ha/yr for the years 2005 and 2019, respectively. The maximum value of 16,757 Rs/Ha/yr is in the Chamarajanagar circle for 2005 and 2019. The minimum value of 11,714 Rs/Ha/yr is in Kodagu, Mangalore, and Shimoga circles for 2005 and Kodagu circle in 2019.
- Cashew nut is 13,812 Rs/Ha/yr (2005) and 13,945 Rs/Ha/yr (2019). The maximum value is 17,029 Rs/Ha/yr in the Bangalore circle, and the minimum is in Belgaum of 11,714 Rs/Ha/yr for 2005. In 2019, the maximum value of 17,048 Rs/Ha/yr in the Bangalore circle and the minimum value of 11,715 Rs/Ha/yr was from the Belgaum circle.
- Tamarind is 14,315 and14,346 Rs/Ha/yr for 2005 and 2019, respectively. The maximum values of 17,044 and 17,049 Rs/Ha/yr are in the Ballari circle for 2005 and 2019. Minimum values of 11,423, and 11,575 Rs/Ha/yr are in the Kalaburagi circle for 2005 and 2019.
- Rampatri (nutmeg - *Myristica malabarica*) is 12,997 Rs/ Ha /yr (2005) and 14,436 Rs/ Ha /yr (2019). The maximum value of 16,891 Rs/ Ha /yr is in the Hassan circle, and the minimum value is in Canara with 11,667 Rs/ Ha /yr for

the year 2005. In 2019, the maximum value of 16,842 Rs/ Ha /yr is in the Hassan circle, and the minimum value is 12,030 Rs/Ha/yr from the Canara circle.

- Dalchini (Cinnamon) is 13,333 Rs/Ha/yr (2005) and 13,478 Rs/Ha/yr (2019), based on the data collected across the circles from Karnataka Forest Department.
- Murugalu (Kokkum) is 11,717 Rs/Ha/yr (2005) and 11,740 Rs/Ha/yr (2019). The maximum value is 11,722 Rs/Ha/yr in the Shimoga circle, and the minimum value of 11,714 Rs/Ha/yr for the year 2005 is in the Canara circle. In 2019 maximum value is observed from the Chikmagalur circle as 11,765 Rs/Ha/yr and the minimum value of 11,715 Rs/Ha/yr is in the Canara circle.

Overall, Canara, Shimoga, Kodagu, and Chamarajanagar circles provide provisioning services in significant quantities, while Chikmagalur, Belgaum, Hassan, Mangalore, Ballari, Dharwad, Bengaluru provide moderate amounts, and the least amount is provided by Gulbarga circle.

Fuelwood: The ecosystem supply value from fuelwood amounts to 48,856 (2005) and 57,308 (2019) million rupees. The ecosystem supply value of fuelwood is assessed as 5,097 and 23,623 Rs/Ha/yr for 2005 and 2019 based on the fuelwood consumption data collected for the Karnataka state. The maximum value is observed as 9,366 Rs/Ha/yr in the Canara circle, and the minimum value is observed in Dharwad circles as 1,492 Rs/Ha/yr for the year 2005. In 2019 maximum value is in the Canara circle as 11,499 Rs/Ha/yr and the minimum value of 1,072 Rs/Ha/yr from the Kalaburagi circle.

Fish and other aquatic products provisioning services: The annual revenue from fish accounts for 7,837 (2005) and 12,126 (2019) million rupees. The harvested fish quantity has increased due to improved management and the construction of reservoirs.

Water supply: The ecosystem supply value of water for the State from various circles accounts for 618,534 (2005) and 280,785 (2019) million rupees. Circles such as Canara, Mangalore, and Chikmagalur have higher values compared to other circles due to the relatively higher amount of rainfall and better forest cover. Greater losses in the service value depict the direct relationship between deforestation and water supply. Assessment of overland flow (runoff) and local water recharge reveals of increase in the run-off with the decline in local water recharge with land degradation. Local water recharge ensures the water availability of water in streams and wells during the post-monsoon period. Circles such as Hassan, Ballari, Dharwad indicate a greater loss (-86.3%, -94.6% and -79.7%) in the ecosystem supply value compared to 2005.

Medicine: Ecosystem value from forest medicine is 766 million rupees and 514 million rupees for 2005 and 2019, respectively.

Genetic material service: The ecosystem values of genetic material services vary with forest type and are accounted through benefit transfer technique based on case studies from India (Verma et al., 2013) considering the spatial extent of forest patches (with the distribution of endemic species and species of conservation importance). The loss in economic values between 2005 (380149 million Rs.) and 2019 (208725) points to the change in forest cover in forests circles such as Bengaluru, Belgaum, Ballari and Shimoga, Hassan, and Mysore.

Regulating services of forest ecosystems in Karnataka

Global climate regulation services/ Carbon sequestration: The ecosystem supply value of carbon sequestration is calculated by considering the social cost of carbon per ton. The social cost of a tonne of CO_2 is taken as US$ 80 using the GDP deflator (MoSPI 2020). Carbon sequestration in forest ecosystems of Karnataka declined from 124153 Gg/Yr (2005) to 89194 Gg/Yr (2019) due to a decline in ecosystem extent and condition. The ecosystem supply value of carbon sequestration is 794949 and 571138 million rupees for 2005 and 2019, respectively. Canara, Mangalore, and Chikmagalur forest circles are contributing larger quantities.

Soil Conservation and Soil Fertility: The forests of Karnataka protect close to 756.4 million tons of sediment (sediment retention). Considering Rs 48.8 per ton of sediment retained retention, about 36,912 million rupees worth of sediment are retained by forest ecosystems across the state. The ability of forest ecosystems to prevent erosion and maintain high fertility is high in Canara, Shimoga, and Mangalore circles due to rich forest cover. With the degradation in the forest cover, soil fertility and erosion prevention has decreased across the circles. Ballari, Belgaum, Kalaburagi, Kodagu, and Hassan were highly impacted due to deforestation.

Water regulation and groundwater recharge: The forests of Karnataka locally recharge about 27.2 billion cubic meters of water to the ground per year, which later flow as base flows. The ecosystem supply values amounts to 7,109 million INR/Yr (2019).

***Water Purification*:** The ecosystem service of water purification ranges from 10,310 INR/Ha/Yr (2005) to 6,921 INR/Ha/Yr

***Waste treatment*:** waste treatment (remediation) amounts to 14,597 million INR/Yr (2005) to 9,799 million INR/Yr (2019).

***Pollination service*:** The ecosystem supply value of pollination services depicts higher values in Canara, Shimoga, Mangalore circles, and the State aggregate value is 26,942 million rupees per year.

***Air filtration services*:** The total ecosystem supply value of air quality regulation service is estimated as 79,590 (2005) and 53,440 (2019) million rupees, with Canara, Shimoga, Mangalore, Kodagu circles contributing a higher share. The degradation in the forest cover from 2005 to 2019 has resulted in the decline of air filtration services.

***Local (micro and meso) climate regulation services*:** The ecosystem value of moderating climate accounts for 169,487 (2005) and 113,807 (2019) million rupees. Canara, Shimoga, Mangalore, and Kodagu circles contribute a higher share due to good forest cover, which is responsible for moderating the climate. All forest circles show a decline in local climate regulation ecosystem value due to the loss of forest cover.

Cultural services from forest ecosystems: The ecosystem values of various cultural services - Aesthetic values are 3541 Million Rs (2005) and 1605 million Rs (2019), Tourism and recreational services ranges from 280821(2005) to 280777 million Rs (2019) Spiritual and historic ranges from 198 million Rs 92005) to 179 million Rs (2019) Artistic and culture ranges from 1679 million Rs (2005) to 1127 million Rs (2019), Education, scientific and research is about 16786 million Rs (2005) to 11271 million Rs (2019)

Total provisioning, regulating, and cultural services of forest ecosystems in Karnataka

Provisioning services: The forest circles in the Western Ghats indicate high values for timber, bamboo, fodder, NTWP, genetic resources, medicine, and fuelwood, which are aggregated to compute the total provisional service of forests. Relatively higher provisioning services in the few forest circles can be attributed to the presence of rich, intact evergreen forest cover, followed by the transition zones to the east (Deccan plains) and west (Coast) of the Western Ghats. The provisional services of forest ecosystems in Karnataka amount to 517 (2005) and 531 (2019) billion rupees per year.

Regulating services of forest ecosystems in Karnataka: The total regulating services of forest ecosystems in Karnataka amounts to 1270 (2005) and 926 (2019) billion rupees per year. Circles such as Canara, Shimoga, Kodagu, and Mangalore show relatively higher values, emphasizing their forest cover status. The least regulating services were provided in Kalaburagi and Dharwad circles due to the absence of interior / intact forest cover.

Cultural services of forest ecosystems in Karnataka: The total cultural services amount to 303 (2005) and 295 (2019) billion rupees per year. The circles of the Western Ghats showed higher values in terms of cultural services, primarily spiritual, recreation, and artistic services, emphasizing the intrinsic relation between forests and the culture of the people.

5.4 Total Ecosystem Supply Value (TESV) of forest ecosystems in Karnataka

The total ecosystem supply value (TESV) of the forest ecosystem is computed by aggregating all the ecosystem services as given in equation 5.1 below:

Total ecosystem supply value (TESV) = Provisioning services + regulating services+ cultural services

The total ecosystem supply value (TESV) of forest ecosystems in Karnataka amounts to 2,894 billion INR/year (2005) and 1,835 billion rupees/year (2019). Provisioning services constitute 44%, regulating services 45%, and cultural services 11% of TESV for 2005 (Figure 5.3). Similarly, provisioning services constitute 34%, regulating services 51%, and cultural services 16% of total TESV for the year 2019 (Figure 5.3).

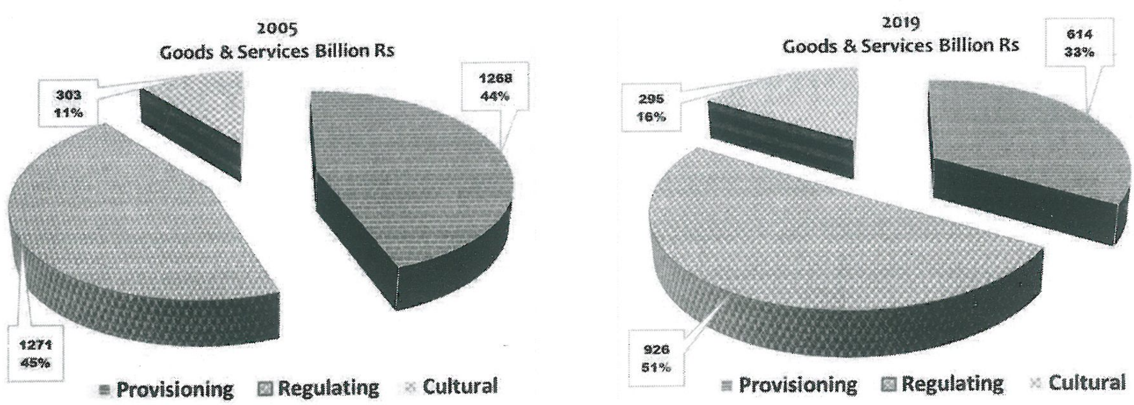


Figure 5.3. Share of individual services in TESV

The reduction in TESV and provisioning services is due to the degradation of forests (extent and condition - fragmentation of forests, decline of contiguous intact native forests) from 2005 to 2019 (Table 5.5). Forest circles such as Canara, Shimoga, Mangalore, Chamarajanagar, Chikmagalur, and Kodagu contribute more to TESV. However, the forest ecosystems in circles such as Ballari, Belgaum, Kalaburagi (Gulbarga), Hassan and Bangalore have significantly reduced provisioning and regulating services due to deforestation and forest degradation.

Table 5.5. Total ecosystem supply value (TESV) of forest ecosystem (circle wise) in Karnataka

Sl.no	Circle name	Provisioning Billion ₹		Regulating Billion ₹		Cultural Billion ₹		TESV Billion ₹	
		2005	2019	2005	2019	2005	2019	2005	2019
1	Bengaluru	56	16	59	35	2	1	116	52
2	Belgaum	102	38	88	53	2	1	192	91
3	Ballari	91	9	77	30	3	2	172	41
4	Chamarajanagar	115	48	122	87	81	80	318	215
5	Chikmagalur	99	72	90	82	15	14	204	168
6	Dharwad	35	9	35	18	0.9	0.5	71	28
7	Kalaburagi	31	6	35	13	0.8	0.2	67	19
8	Hassan	47	13	59	30	1.2	0.5	108	44
9	Canara	207	146	280	239	55	54	542	439
10	Kodagu	82	33	87	63	33	33	202	129
11	Mangalore	150	117	127	122	51	51	328	290
12	Mysore	114	30	53	41	31	31	199	101
13	Shimoga	138	78	158	113	27	26	323	217
Total		**1268**	**614**	**1271**	**926**	**603**	**295**	**2841**	**1835**

5.5 Valuation of agriculture (croplands and horticulture) ecosystem services

Karnataka has diverse cropping patterns across the six major agroecological zones. In addition to this, numerous irrigation projects have supported growing food crops, commercial/horticulture crops across the State. Various crops grown in the State are cereals, pulses, oilseeds, fruits, vegetables, commercial crops, horticulture, etc.).

Agriculture (cropland, horticulture) ecosystem services at the district level are compiled considering i) spatial extent – crop-wise, (ii) production as per the statistics from the agriculture department and verified for each crop based on the crop area and crop yield per hectare iii) Minimum support price fixed by the Ministry of Agriculture, Government of India, and crop-wise cultivation costs and prices at Mandi (crop market set up by the Government of Karnataka) were used to determine the monetary value, iv) regulating services and cultural services were based on the benefit transfer method through the relevant literature. The spatial extent under each crop with production details at the district level were collated from the government records at the district level (DSO 2019; DPPMS 2018; HOPCOMS 2020; KMV 2020). The area under cultivation of crops (cereals, pulses, fruits, vegetables, oil seeds, commercial crops - sugarcane, coffee and tobacco,) in the State was about 11.5 million hectares, and horticulture is cultivated in 8,03,000 hectares.

Cereals: Paddy is cultivated extensively over 1000 sq. km in the coastal districts and districts such as Shimoga, Mysore, Raichur, and Davanagere. Jowar is grown in about 2250 sq. km in Vijayapura (Bijapur), Belgaum, etc. Maize is grown in 1200 sq. km in the districts of Davangere, Haveri and Belgaum. Ragi is grown extensively in the districts of Tumkur and Hassan, encompassing an area over 1000 sq. km. Among the districts, Belgaum has the most significant spatial extent under cultivation of cereals, covering 5237 sq. km area, followed by Vijayapura (Bijapur) covering 4110 sq. km, Davanagere 3347 sq. km and Raichur with 3232 sq. km.

Pulses are grown widely in the arid zones, particularly in the northern belt of Karnataka. Kalaburagi (Gulbarga) leads in cultivation of pulses with 4215 sq. km area under cultivation, followed by Bidar and Yadgir with more than 2000 sq. km area under cultivation. Similar trends are observed in oilseeds. Vijayapura (Bijapur) has the highest extent under cultivation, i.e., 4008 sq. km, followed by Raichur, Belgaum and Chitradurga with areas ranging between 2131 sq. km to 2517 sq. km.

Commercial crops (sugarcane, cotton rubber and tobacco) dominate in Belgaum (1742 sq. km), followed by Mysore (1409 sq. km). Fruits dominate in Kolar and Chikkaballapura districts, followed by Vijayapura (Bijapur), with areas ranging between 200 sq. km to 250 sq. km. Vegetable cultivation dominates the districts of Hassan and Dharwad, with the spatial extent over 400 sq. km.

Horticulture crops (arecanut, coconut, coffee, mango, pomegranate, banana) dominate in the Western Ghats districts (Uttara Kannada, Shimoga, Chikmagalur, Kodagu and Dakshina Kannada).

The area under cropland – cereal cultivation (single cropping and multi-cropping in croplands) in Karnataka in 2005 was about 115.5 thousand sq. km. Belgaum and Vijayapura (Bijapur) encompass the highest extent, i.e., more than ten thousand sq. km, followed by Kalaburagi (Gulbarga) with 9481 sq. km. Horticulture in the State during 2005 was 8031 sq. km, of which Tumkur constituted about 1272 sq. km, followed by Chickmagalur and Hassan with 1182 and 1028 sq. km, respectively.

From 2005 to 2019, there has been an 11% decline in the area under croplands, from 115 thousand sq. km to 103 thousand sq. km (cereals, pulses, oilseeds, fruits, vegetables, commercial crops). There has been a decline of 18% in the spatial extent of cereals and a 55% decline in area under oilseeds, while the area under pulses has increased by 55%, commercial crops by 27%, fruits by 89%, and vegetables by 24%. The area under horticulture has risen by 2%, i.e., from 8.0 sq. km to 8.18 sq. km. Both these, i.e., change in area under horticulture as well as croplands, have a direct influence on revenue. There has been an increase in the spatial extent of cereal crops in Chikkaballapura (33%), Chitradurga (18%), Bellary (16%), Chickmagalur, Dharwad, and Haveri districts. In contrast, the other districts showed a reduction in area under agriculture between 2005 and 2020. Bengaluru Urban district showed a 60% reduction due to urbanization. Similarly, the spatial extent of pulses shows an upward trend from 170% to 272% in Raichur, Vijayapura (Bijapur), and Bagalkot.

Crop production: The State has produced 11.0 million tonnes of cereals, 1.4 million tonnes of pulses, 1.9 million tonnes of oilseeds, 16.4 million tonnes of commercial crops, 1.7 million tonnes of fruits and 1.4 million tonnes of vegetables, summing up to 33.3 million tonnes of agricultural produce in 2005. In addition to this, 1.4 million tonnes of horticulture produce.

The monetary value of ecosystem goods was evaluated based on the minimum support price (MSP) and relative crop produce cost. The minimum support price for crops was obtained from the Price Policy Reports for rabi crops and kharif crops, respectively, along with other published literature.

The cost of production for different crops was derived based on public interviews in the districts of Belgaum, Dharwad, Uttara Kannada, Mysore, Mandya, Shimoga, Chitradurga, Davanagere, Tumkur, etc. from December 2019 to April 2020, and on published data by the Department of Agriculture, Farmer Welfare and Directorate of Economics and Statistics, Government of India (EANDS 2020).

Ecosystem services of agriculture ecosystem: Table 5.6 provide details of various ecosystem goods and services and their monetary value across different major crop types.

Table 5.6. Agriculture ecosystem goods and services (INR/hectare/Yr) 2005*

	Croplands**	Horticulture	Fruits	Vegetables
Provisioning services				
Food	MSP – cost of production			
Fodder/Fiber	3742		2245	2245
Wood		131		
Regulating services				

Air quality	915	915	915	915
Climate	218	218	218	218
Carbon fixation atmosphere	11	1527	3	1
Soil carbon	110	4364	110	110
Water flow regulation	240	371	240	240
Nitrogen fixation	1213	1213	1213	1213
Soil fertility	1512	1512	1512	1512
Remediation – organic and inorganic materials	1745	1745	1745	1745
Pollination	118	118	118	118
Genetic diversity	3908	3908	3908	3908
Biological control	35	35	35	35
Cultural services				
Opportunities for recreation and tourism	285	285	285	285
Inspiration for culture, art and design	349	349	349	349

**services of croplands include all crops except fruits and vegetables

*Source: Public interviews, government records (CACP 2005a, b; Nayak et al., 2019; CRED 2020; De Groot et al., 2020; DMI 2020; EANDS 2020; NAAS 2020; TNAU Agriculture Portal 2020)

Croplands services amount to 223 billion rupees per year (provisioning services: 106.6 billion rupees, regulating: 110 billion rupees, and cultural service: 6.9 billion rupees).

Similar to cropland, the ecosystem services of the horticulture ecosystem amount to 42.9 billion rupees (provisioning services: 34.4 billion rupees, regulating services: 8.0 billion rupees, cultural services: 0.5 billion rupees).

Valuation of agriculture ecosystem services (2019): Services of agriculture ecosystem in Karnataka state in 2019 with diverse cropping patterns amounts to 1,077.6 billion rupees, with 55% from provisioning services, 42% from regulating services, and 3% from cultural services (Figure 5.4). The net present value (NPV) of the agriculture ecosystem is 27.72 trillion rupees.

The annual provisioning services amounts to 589 billion rupees (food: 462 billion, fodder:125 billion, and wood 1.5 billion rupees), regulating services amounts to 459 billion rupees (air quality: 42 billion, climate regulation: 10 billion, carbon fixation: 18 billion, soil carbon: 54 billion, water flow: 12 billion, nitrogen fixation: 5 billion, soil fertility: 47 billion, remediation – organic and inorganic materials (mineralization of soil nutrients): 80 billion rupees and pollination: 5 billion rupees) and cultural services 29 billion rupees (recreation: 123 billion rupees, culture: 16 billion). TESV of the agriculture ecosystem is 1077 billion rupees per year. Based on the annual flow, the net present value (NPV) of the agriculture ecosystem in Karnataka is about 27,727 billion rupees.

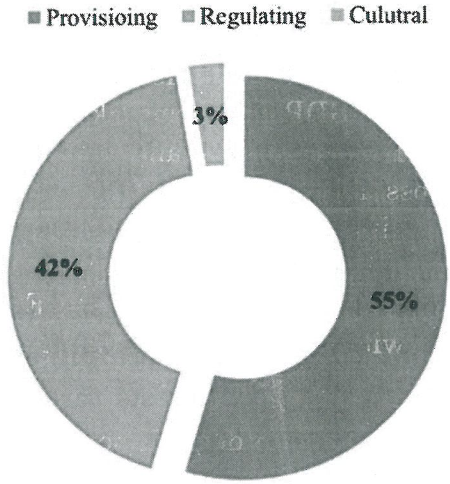


Figure 5.4. Agriculture ecosystem services distribution – Karnataka State, 2019

5.6 TESV - TOTAL ECOSYSTEM SUPPLY VALUE, GEP- GROSS ECOSYSTEM PRODUCT, KARNATAKA STATE, INDIA

Ecosystem services (provisioning, regulating, and cultural services) were aggregated to compute total ecosystem supply value (TESV). The aggregate measure is also referred to as ***gross ecosystem product (GEP), which is equal to the sum of all final ecosystem services (i.e., by economic units) from ecosystem assets***. The ecosystem monetary asset account also records the changes in the monetary value of ecosystem assets from 2005 to 2019 (accounting period).

TESV of terrestrial (forest and agricultural) ecosystems in Karnataka state is about 3,620 billion rupees (2005) contributed by provisioning services (1,679 billion rupees, 46%), regulating services (1,615 billion rupees, 45%), and cultural services (324 billion rupees, 9%). Forest ecosystems contribute 2,841 billion rupees (78.5%), while croplands and horticulture contribute 778 billion rupees (21.5%) in TESV.

TESV or GEP for Karnataka state is about 2913 billion rupees (in 2019) contributed by provisioning services (1,203 billion rupees, 41%), regulating services (1,385 billion rupees, 48%), and cultural services (324 billion rupees, 11%). Forest ecosystems contribute 1,835 billion rupees (63%), while agriculture (croplands and horticulture) contribute 1,077 billion rupees (37%) in TESV. Figure 5.5 depicts the district-wise share and share of provisioning, regulating, and cultural services in TESV of 2019.

Higher NPV values in the Western Ghats districts – Uttara Kannada (NPV: 11,885 billion), Chikmagalur (5,875), Chamarjanagar (5,858), Dakshina Kannada (5,205), Shimoga (5,062), Udupi (3,787), Kodagu (3,721), Belagavi (3,445), and Mysore (2,527) highlight the role of a forest ecosystem with native species of vegetation in supporting rich endemic biodiversity, sustaining water availability during all seasons to meet biotic demands, and supporting the livelihood of people. Understanding these linkages would help the planners/decision-makers with valuable knowledge for integrated ecosystem management. The study highlights the vital ecological function of the Western Ghats, one among 36 global biodiversity hotspots, in sustaining the hydrologic regime and livelihood of local people. Hence, the premium should be towards conserving the forests with native species to sustain water and biotic diversity, which are vital for food security. There still exists a chance to restore the lost natural evergreen to semi-evergreen forests through appropriate conservation and management practices in Karnataka State.

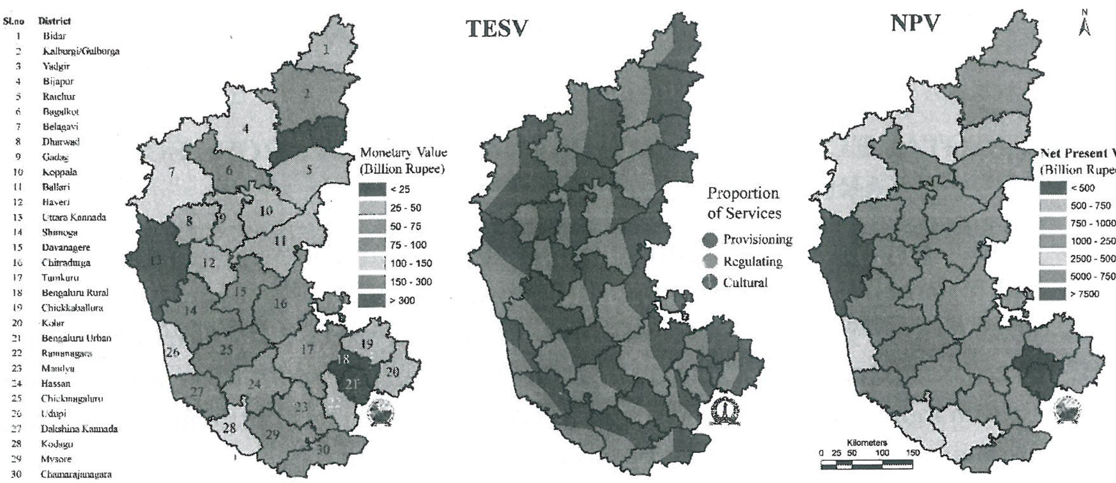


Figure 5.5. TESV with the proportion of services (provisioning, regulating and cultural), and NPV 2019-20

Figure 5.6 depicts the district-wise share of TESV in GDDP. The district-wise assessment indicates TESV of Bengaluru urban and rural districts are the lowest, amounting to <10% of GDDP. In contrast, forest-rich Western Ghats districts (mainly Uttara Kannada of Canara forest circle, Kodagu of Kodagu forest circle, and Chamarajanagar and Chamarajanagar circle) provide TESV that is about 200% of the respective district GDDP. The presence of rich forests in these districts contributes to higher TESV, highlighting that TESV share in GDDP (Gross District Domestic Product) is correlated with the extent and conditions of forest ecosystems in the respective districts.

Table 5.7 lists TESV or GEP for Karnataka considering forest, and agriculture (croplands and horticulture) ecosystems. The TESV of these ecosystems is 3620 billion rupees in 2005 (forest ecosystem: 2,841 billion rupees and agriculture (croplands and horticulture) ecosystem: 779 billion rupees). Similarly, TESV computed for 2019 indicates 2,912 billion rupees (forest ecosystem: 1,835 billion rupees and agriculture 1,077: billion rupees). There has been a 35.4% reduction in TESV of forest ecosystems from 2005 to 2019, mainly due to the degradation of ecosystems.

The decline of TESV highlights the degradation of forest ecosystem assets from 2005 to 2019 due to the reduction of ecosystem extent and condition. The decrease in value is also demonstrated by a fall in the net present value of expected future returns of the ecosystem services supplied by forest ecosystem assets, as shown through the ecosystem monetary asset account.

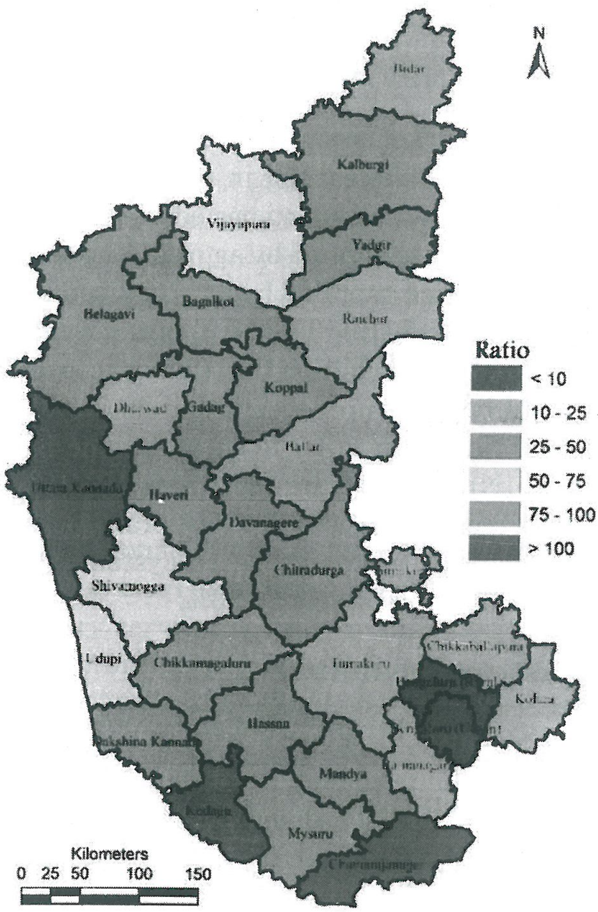


Figure 5.6: TESV to GDDP ratio

Table 5.7. Comparison of provisioning, regulating, and cultural services and TESV during 2005 (in 2019 rupees) and 2019

Ecosystems	Year	Units	Provisioning	Regulating	Cultural	TESV
Forests	2005	Million ₹	12,67,528	12,70,583	3,03,034	28,41,145
		%	44.6	44.7	10.7	100
Agriculture (Croplands and horticulture)		Million ₹	4,11,834	3,44,933	21,819	778,586
		%	52.9	44.3	2.8	100
Total		Million ₹	16,79,361	16,15,516	3,24,854	**36,19,731**
		%	46.4	44.6	9.0	100
Forests	2019	Million ₹	6,13,883	9,26,346	2,94,955	18,35,184
		%	33.5	50.5	16.1	100
Agriculture		Million ₹	5,89,283	4,59,037	29,305	10,77,625
		%	61.2	36.3	2.5	100
Total		Million ₹	12,03,166	13,85,383	3,24,260	**29,12,809**
		%	41.3	47.6	11.1	100

5.7 NET PRESENT VALUE (NPV) OF ECOSYSTEM ASSETS

The ***net present value (NPV)*** of ecosystem assets was determined by considering the stream of income expected to be earned in the future and then discounting the future income back to the present accounting period (SEEA Central Framework, para. 5.11). In ecosystem accounting, it is applied by aggregating the NPV of expected future returns for each ecosystem service supplied by an ecosystem asset. Table 5.8 provides a monetary asset account (2005-2019). The NPV of accounted ecosystems based on 2005 ecosystem flows is about 93,130 billion INR (forest ecosystem: 73,099 billion INR; agriculture (croplands and horticulture) ecosystem: 20,031 billion INR). The NPV of ecosystems in Karnataka based on 2019 flows indicate 74,938 billion INR (forest ecosystem: 47,214 billion INR; agriculture ecosystem: 27,724 billion INR). A decline of 35.4% in NPV of forest ecosystems is due to the transition of forest ecosystems to either croplands or horticulture (agriculture ecosystems), which correlates to an increase in NPV of agriculture ecosystems by 23%.

Table 5.8. Monetary asset account (2005-2019)

	Units	Forest ecosystem	Agriculture ecosystem	Total NPV
Opening stock – 2005 (at 2019 values)	Billion ₹	**73,099**	**20,031**	**93,130**
Changes (absolute)	Billion ₹	-25,885	7,693	-18,192
Changes	%	-35.4	38.4	-19.5
Provisioning	%	-51.6	43.1	-28.4
Regulating	%	-27.1	33.1	-14.2
Cultural	%	-2.7	34.3	-0.2
Closing stock - 2019	Billion ₹	**47,214**	**27,724**	**74,938**

NPV of forest and agriculture ecosystems based on the 2019 TESV, which totals to about **74,938** billion rupees for Karnataka as a whole. This shows a declline of 19.5% from 2005, when the NPV of ecosystem assets in Karnataka was **93,130** billion rupees based on 2005 ecosystem service values (in 2019 rupees).

The study reveals that about 63% of TESV and NPV is contributed by the districts of central Western Ghats (Uttara Kannada (11,885 billion rupees), Chickmagalur (5,875 billion rupees), Chamarajnagar (5,858 billion rupees), Dakshina Kannada (5,205 billion rupees), Shimoga (5,062 billion rupees), Udupi (3,787 billion rupees), Kodagu (3,721 billion rupees), Belagavi (3,445 billion rupees), and Mysore (2,527 billion rupees), again reinforcing the critical role of a forest ecosystem with native species of vegetation in providing critical ecosystem services.

6.0 Conclusion

Ecosystem services were quantified through the residual value method by taking the gross value of the final marketed good to which the ecosystem service provides input and then deducting the cost of all other inputs, including labour, produced assets, and intermediate inputs). Ecosystem services were computed based on the ecosystem flows in 2005 and 2019. Values of 2005 were adjusted through consumer price index or GDP deflector, these values reflect the real measures of ecosystem services, which could be compared with ecosystem services of 2019.

The compilation of ecosystem extent, service and asset accounts has enabled thorough analysis of the changes in the provision of ecosystem services in Karnataka between 2005 and 2019. The comparison of the values of goods of 2019 with 2005 highlights there has been a considerable reduction in ecosystem services – a 28.5% reduction in provisioning services (including a 51.6% reduction in forest ecosystem), a 21 % reduction in regulatory services (mainly in forest ecosystem - 27.1% reduction), and a 1.9% reduction in cultural services. In terms of the reductions in provisioning services, these included a 93% decline in bamboo, a decline in NTFP (honey reduced by 97%, tamarind reduced by 75%), a 42% decline in fodder and a 35% decline in medicine. The large decreases in provisioning and regulatory services can be attributed to the degradation of forests (extent and conditions) in Karnataka from 2005 to 2019.

Ecosystem services were aggregated to compute TESV. This aggregate measure is also referred to as gross ecosystem product (GEP), ***equal to the sum of all final ecosystem services (i.e., used by economic units) from ecosystem assets.*** The TESV of ecosystems was 3620 billion INR in 2005 (forest ecosystem: 2,841 billion INR and agriculture ecosystem: 779 billion INR). However, the TESV computed for 2019 indicates 2,793 billion INR (forest ecosystem: 1,835 billion INR and agriculture 958 billion INR). While the TESV for agricultural ecosystems increased by 179 billion INR between 2005 and 2019, there was a much larger decrease in TESV for forest ecosystems, which amounted to 1,006 billion INR. This 35.4% reduction in TESV of forest ecosystems can again be attributed to the degradation of ecosystems.

The GDP of Karnataka is about 10,128 billion rupees. Therefore, the TESV of the forest ecosystem is equivalent to 18.1% of the GDP, and TESV from agriculture is equivalent to about 10.6% of GDP in Karnataka. The district-wise assessment indicates that the TESV of Bengaluru's urban and rural districts are the smallest, with <10% of GDDP (Gross District Domestic Product). In contrast, forest-rich Western Ghats districts (mainly Uttara Kannada, Kodagu, and Chamarajanagar) provide TESV that is about 200% of the respective district GDDP. The presence of rich forests in these districts contributes to higher TESV, highlighting that TESV share in GDDP is correlated with the extent and conditions of forest ecosystems in the respective districts.

The decline of TESV highlights the degradation of forest ecosystem assets from 2005 to 2019 due to the deterioration of ecosystem extent and ecosystem condition. The decrease in value is also reflected in a fall in the NPV of expected future returns of the ecosystem services supplied by forest ecosystem assets. The NPV of forest and agriculture ecosystems based on 2005 ecosystem flows is about 93,130 billion INR (forest ecosystem: 73,099 billion INR; agriculture ecosystem: 20,031 billion INR). Similarly, the NPV of ecosystems in Karnataka based on 2019 flows indicates 74,938 billion INR (forest ecosystem: 47,214 billion INR, agriculture ecosystem: 27,724 billion INR). This indicates a decline of 35.4% in NPV of forest ecosystems, largely due to the transition of forest ecosystems to either croplands or horticulture (agriculture ecosystems). These ecosystem conversions have led to an increase in the NPV of agriculture ecosystems by 23% between 2005 and 2019.

The drivers behind the land-use change and the decline of forest resources in Karnataka are mainly the expansion of agricultural activities coupled with industrialization and rapid urbanization. However, the increase in the values of agricultural TESV and NPV at the expense of a decrease in the values of forest TESV and NPV points to the need for an adequate assessment of trade-offs in land use policy. Hence, the current study emphasizes the need for the valuation of services of all ecosystems, capitalizing on the advances in geoinformatics, availability of spatial data at regular intervals to estimate the economic value of ecosystems forests, and, in particular, reflect the value of forests in policy decisions.

The overall assessment of the ecological services provides information for prioritizing ecosystems for sustainable land-use practices, promoting off-farm incomes to the dependent communities, restoration of degraded sites, biodiversity conservation, water resources, etc., while promoting community-based prudent management of natural resources. There is a need to enhance awareness for the protection of the environment, especially the maintenance of native forest cover, which is crucial for balanced economic and the social progress in the country. Over the last few decades, though India has evolved legislation, policies, and programs for environmental protection and conservation of natural resources, there is uneven implementation of these policies and programs. Thus, ecosystem accounting can play a role in two ways. First, ecosystem accounts can help policy makers factor in ecosystem service benefits when making economic policies which impact natural resources and ecosystems. Second, ecosystem accounts which are regularly compiled can be used to help monitor the impact of these policies over time and ensure that they are being implemented properly.

Finally, it should be noted that the ecosystem accounts compiled for Karnataka have large potential to be used for payment for ecosystem services schemes. The Supreme Court of India (2006) directed the national government to set up compensatory payments for the conversion of different types of forested land to non-forest uses and use these payments to improve India's forest cover. These accounts can provide important information on the values of ecosystems and their services which can help in creating transparent criteria with which to reward states. Afforestation in the degraded landscape would aid in mitigating changes in the climate due to global warming while sustaining people's livelihood through (i) provision of ecosystem services, (ii) improvements in the crop yield, ii) sustenance of water in the landscape, etc.

7.0 Recommendations

The ecosystem services computed for Karnataka State support the viability of markets for particular ecosystem services. The development of such markets requires additional institutional reforms such as changes with respect to property rights and reforms in land and labor markets. Hence, ecosystem services need to be internalized in decision-making, strengthening the economic case for conserving forests in all states in India and developing countries, as there is great pressure to relax forest laws and divert forests to non-forest uses with the illusion of boosting long-term economic growth. The main policy challenge is to promote conservation and develop such markets so that those bearing the cost of conservation are adequately compensated. **The valuation of ecosystem services done in Karnataka State and replication of this exercise in other states will undoubtedly play a vital role in conservation planning and ecosystem-based management in India.** This requires:

i) Strengthening biophysical research on ecosystem services, with a focus on those that would seem to have the highest economic value potential (e.g., changes in the climatic, hydrologic regime, etc.);
ii) Inventorying, mapping, and monitoring ecosystems' spatial extent and conditions through the use of advanced spatial technologies with temporal remote sensing data;
iii) Promoting valuation studies reveals current incentives i.e., the existing distribution of net ecosystem benefits/opportunity costs across stakeholders, which will aid for internalizing in the regional policies,; and
iv) Developing land-use policies which take into account the provision of ecosystem services across different ecosystem types.

Extending this exercise in Karnataka or other states could help evolve strategies to conserve ecosystems to support people's livelihood. As shown in this report, ecosystem accounts can provide insights into the social, economic, and environmental benefits of various levels of biodiversity that might be achieved under different ecosystem management options at various scales. The economic valuation of forest ecosystem services and biodiversity can help clarify trade-offs among conflicting environmental, social, and economic goals in the development and implementation of policies and to improve management in order to sustain biodiversity.

At the same time, there is a need to communicate more effectively the research results on these issues to decision-makers and other stakeholders.

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The Karnataka Science and Technology Academy, Bengaluru, a unit of the Department of Science and Technology, Government of Karnataka, among its programs, has the activity of formulating Policy and Strategy papers. The latest policy paper focusses on "**Valuation of Terrestrial Ecosystem Services**", and this paper was deliberated in a discussion meeting, organized on an online mode on Friday, 28 January, 2022 at 3 pm https://ksta.webex.com/ksta/j.php?MTID =m91ed27e7495902b4e575f8b26e8a2ab8

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