Valuation of Ecosystem Services in Karnataka State, India

Report of the NCAVES Project

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System of Environmental Economic Accounting

Valuation of Ecosystem Services, Karnataka State, India

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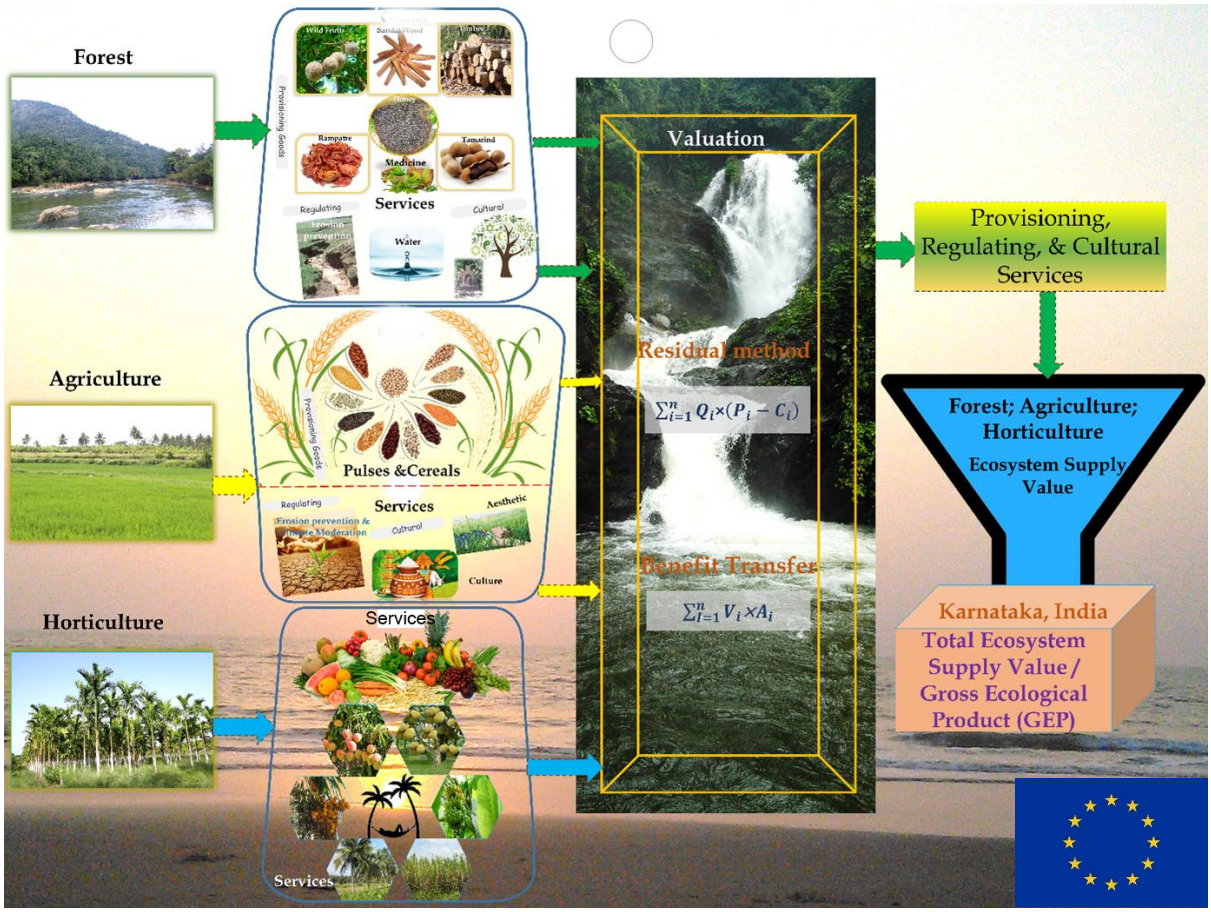

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PREFACE AND ACKNOWLEDGEMENTS

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VALUATION OF ECOSYSTEM SERVICES, KARNATAKA STATE, INDIA

SUMMARY

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. This report focuses on ecosystem services in forest and agricultural ecosystems in Karnataka for 2005 and 2019.

This report follows the SEEA Ecosystem Accounting (SEEA EA), which constitutes the statistical framework for natural capital accounting and organizes data on ecosystems and the services they provide. The UN Statistical Commission adopted the SEEA EA framework in 2021, and it forms the underlying conceptual framework of the accounts developed in this report. Ecosystem services in the SEEA EA are defined as the contributions of ecosystems to the benefits that are used in economic and other human activities. Within the SEEA EA, 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.

The value of all ecosystem services, including the degradation costs, needs to be understood for developing appropriate policies toward the conservation and sustainable use and 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. In order to accurately assess trade-offs, natural capital accounts are needed to incorporate the economic worth of natural capital found in ecosystems such as forests to measure the wealth of a region.

For this report, ecosystem services were quantified following the valuation principles of the SEEA. This means that only the contribution of the ecosystem to the benefit is measured, not the benefit itself. This can be achieved, for instance, 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 labor, produced assets, and intermediate inputs (as per the SEEA Central Framework).

This report 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 in 2019 with 2005 highlights 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, indicates 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 the 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 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. 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.

Based on the experiences gained in the current pilot, it is estimated that the exercise of natural capital accounting and valuation of ecosystem services could be replicated in any region (of 10000 to 12000 sq. km) as per the SEEA-EA framework in a period of 15 months, involving field data collection with a team consisting of multidiscipline expertise. It requires (i) all para-state agencies sharing the data of biophysical variables as the primary data collection is a time-consuming endeavor, (ii) organizing orientation programs and hands-on training to enhance the capability of the team to undertake spatial analyses, collecting biophysical variables from the government agencies and the field, data integration and validation, analyses of the data and interpretation, (iii) addressing the gaps in the existing biophysical models (adapting to local conditions)**. Thus, 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.**

VALUATION OF ECOSYSTEM 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 labor 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). 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). 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 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 and consider resources exploited for human settlement, food, and energy production.

In this regard, a statistical framing of data on ecosystems plays a vital role in incorporating at least some parts of the wider value of ecosystems as a regular component of decision-making. The SEEA Ecosystem Accounting (SEEA EA) provides such a framework. Adopted by the United Nations Statistical Commission in 2021, the SEEA EA constitutes an integrated and comprehensive statistical framework for organizing ecosystem data, measuring ecosystem services, and tracking ecosystem changes. In addition, the data on ecosystems is linked to information on economic and other activities, as the SEEA EA uses many of the same concepts, definitions, and classifications as the System of National Accounts (SNA). Finally, the SEEA EA enables high-quality and consistent measurement over time by using agreed concepts, definitions, and classifications. Providing relevant time series and trend data on the environment-economy nexus is crucial for effective policy design, decision-making, and evaluation.

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, and horticulture ecosystem types, district-wise for Karnataka State, India (ii) the computation of the total ecosystem supply value (TESV), and (iii) Net present value (NPV) of ecosystem assets. The report focuses on data for the years 2005 and 2019.

It should be noted that the SEEA EA focuses on values of anthropocentric origin – i.e., values that are centered on human beings. Further, the measurement focus of the SEEA EA 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).

The outline of this report is as follows: the following section (Section 1) defines ecosystem services and accounting for ecosystem services in the context of the SEEA EA. Section 2 describes the study region – Karnataka State, India and provides socio-economic context. Section 3 explains data sources, and Section 4 presents methods adopted for valuation. Section 5 describes the results: of ecosystem services accounting for forest ecosystems and agriculture ecosystems. Section 5 concludes with recommendations. Ecosystem-wise services (physical as well as monetary) computed district-wise are presented in Annexures 5.3 for forest ecosystems.

1.1. Ecosystem services

In the SEEA EA, ecosystem services are the contributions of ecosystems to the benefits that are used in economic and other human activities. In this definition, use incorporates 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. 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.

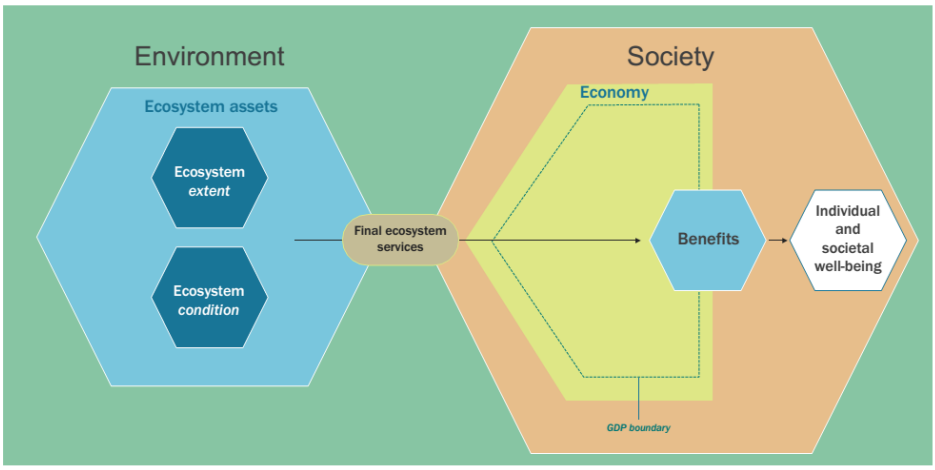
Most resource management decisions are influenced by ecosystem services (ESs) entering markets; thus, the non-marketed benefits often remain unaccounted. Both renewable resources (water supply, air quality, etc.) and non-renewable resources (mineral deposits, some soil nutrients, fossil fuels, etc.) 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, 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 for understanding 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. Recent efforts, especially the System of Environmental-Economic Accounting, Central Framework (SEEA CF), and Ecosystem Accounting (SEEA 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. In the SEEA EA, ecosystem services are broadly categorized 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.

Ecosystem services serve as the connecting concept between ecosystem assets (contiguous spaces of a specific ecosystem type, i.e., individual ecosystems) and the production and consumption activities as per the SEEA EA. The key concepts of the SEEA EA related to ecosystem services concern (i) the supply of ecosystem services to users; and (ii) the contribution of ecosystem services to benefits (i.e., the goods and services ultimately used and enjoyed by people and society). Further, ecosystem services encompass all forms of interaction between ecosystems and people, including both in situ and remote interactions. 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.

1.2 Ecosystem services accounting – Physical as well as monetary (based on residual value techniques)



Source: SEEA EA 2021

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. The SEEA EA emphasizes the need to consider the ecosystem as a whole and underlines those changes or impacts on one part of an ecosystem have consequences for the whole system. Therefore, considering the scale and scope of the services to be valued is vital to arrive at any meaningful values.

The key stages in the valuation of ecosystem services in the SEEA EA are: (i) setting a scope and baseline through ecosystem extent and condition accounts, (ii) physical quantification of services, and (iii) valuation of ecosystem services, including changes over time. Monetary accounts can further inform a qualitative assessment of the potential impacts of policy options on ecosystem services and quantification of the impacts of policy options on specific ecosystem services, and evaluation of the effects on human welfare.

There is a growing interest in ecosystem services (ESs), and ES 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) enhanced 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 take into account 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 United Nations Statistical Commission (UNSC) endorsed the SEEA-Experimental Ecosystem Accounting (SEEA-EEA in 2013 (System of Environmental-Economic Accounting-Experimental Ecosystem Accounting) as the basis for commencing testing and further development of a common statistical framework for ecosystem accounting. The UNSC also encouraged the use and experimentation of the SEEA-EEA by international and regional agencies (SEEA 2017; SEEA EA 2021). The various research publications from the scientific community on the valuation of ecosystem services have substantially grown to address the several challenges and for proposing common frameworks. 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).

The ecosystem accounts in this report have been developed for Karnataka State, India, as per the SEEA Ecosystem Accounting (SEEA EA) framework. Valuation of ecosystem services is the third report in a series of four, which follow Ecosystem Extent Accounts (Ramachandra et al. 2021a) and Ecosystem Condition (Ramachandra et al. 2021b)

The objective of the current analysis is to pilot 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 ecosystems (forests and agriculture) despite the constraints (time and also unfortunate situation with restrictions on travel due to lockdown with the global pandemic COVID19). 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 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).

Section 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 Reorganization 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).

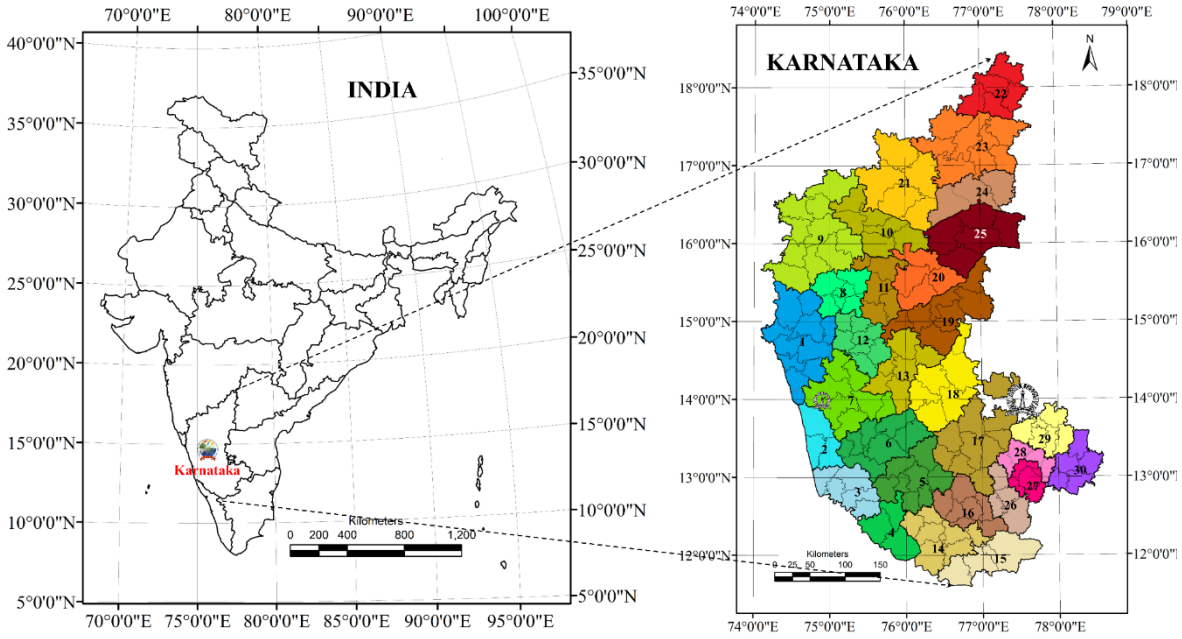


Figure 2.1. Karnataka State, India, with the administrative (district and taluk) boundaries

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. Administrative divisions (Census 2011) in Karnataka

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 harbors 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. 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 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.

[1] One lakh is equal to a hundred thousand.
[2] One crore is equal to ten million, or one hundred lakhs

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). 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 Mullayyana Giri (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.

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

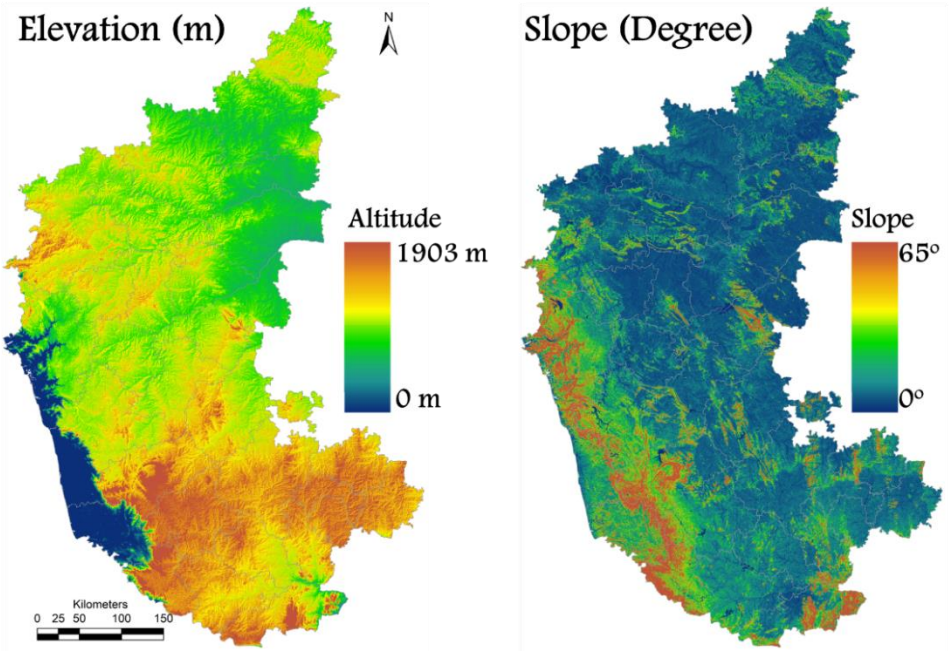


Figure 2.2. Karnataka – Topography

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; and
- The northern transition zone includes Belgaum and Dharwad.

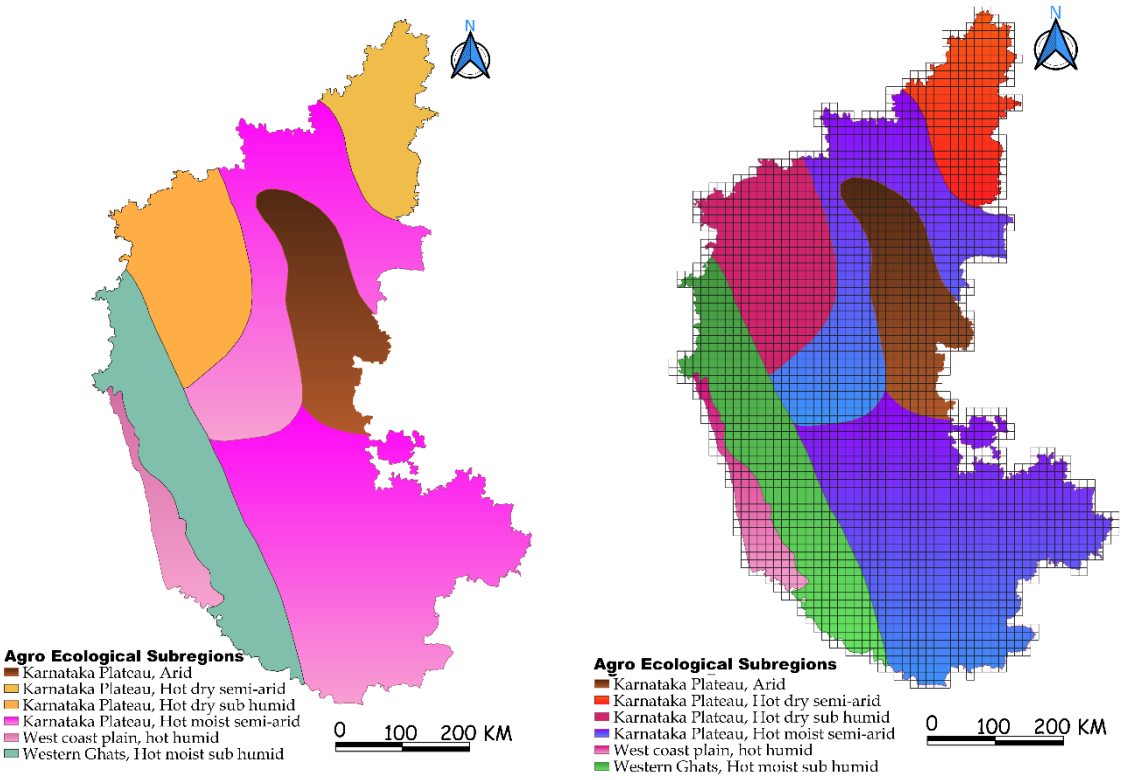


Figure 2.3. Agro ecological sub-regions in Karnataka

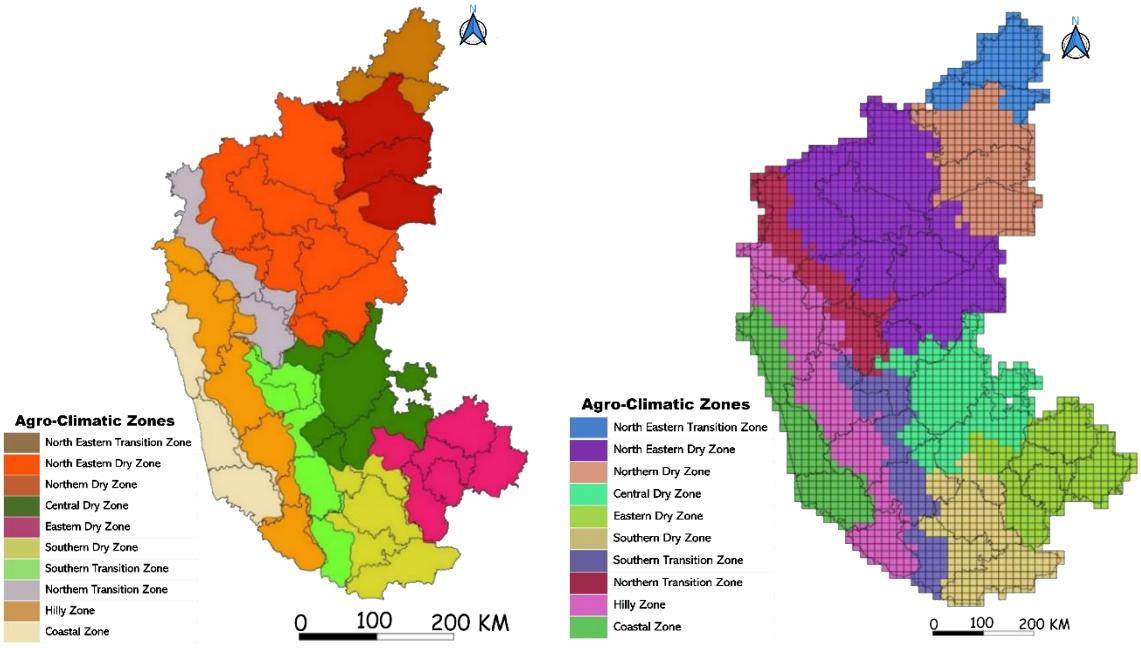


Figure 2.4. Agro-climatic zones in Karnataka

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.

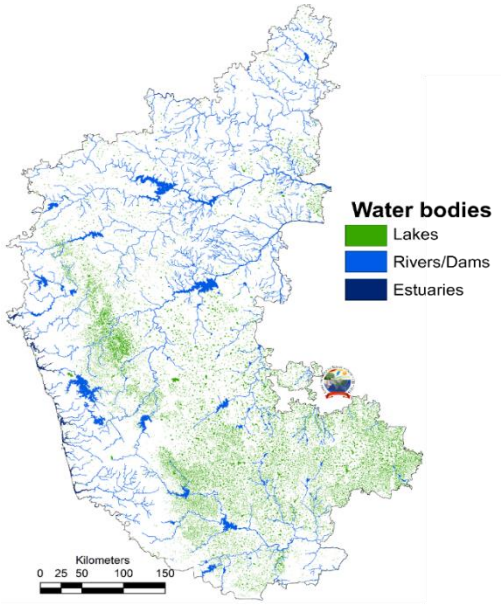


Figure 2.5. Water Resources and Agro-climatic Zones of Karnataka

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.

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.

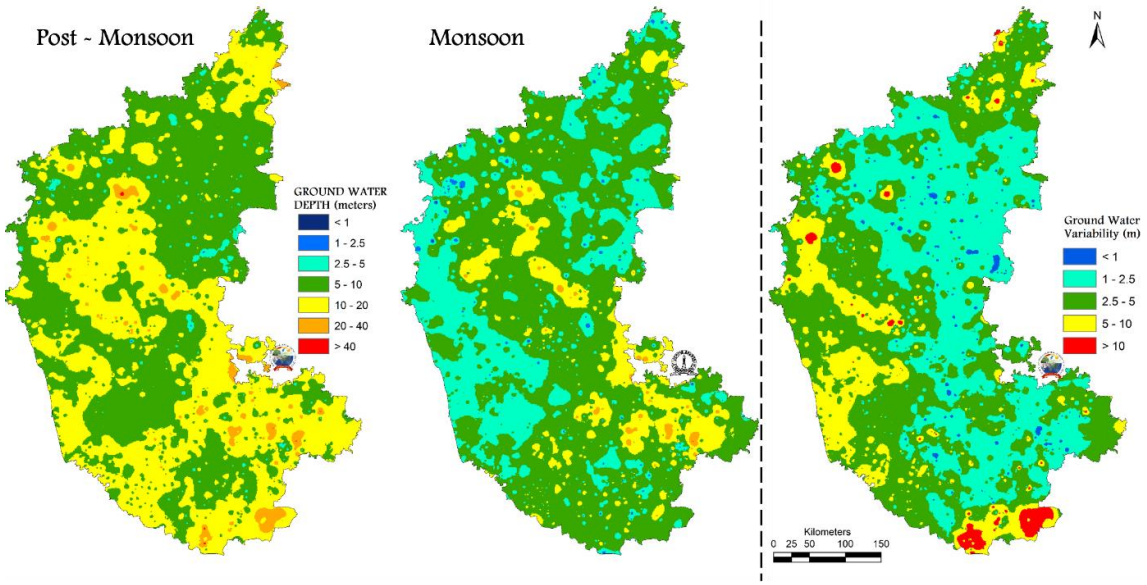


Figure 2.6. Ground Water dynamics

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 km². 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

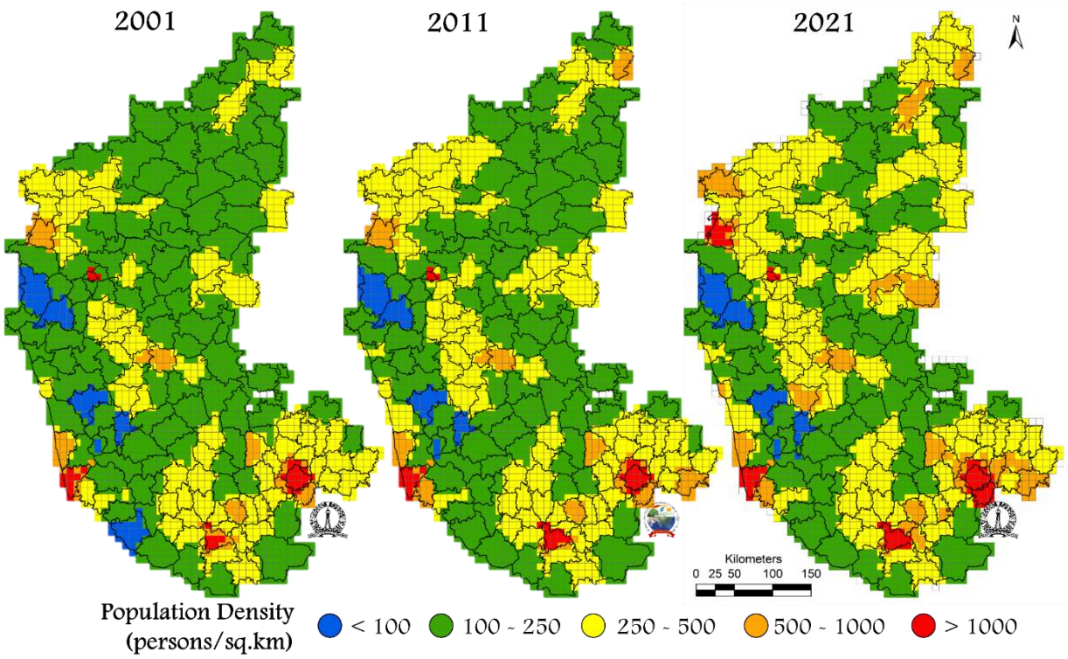
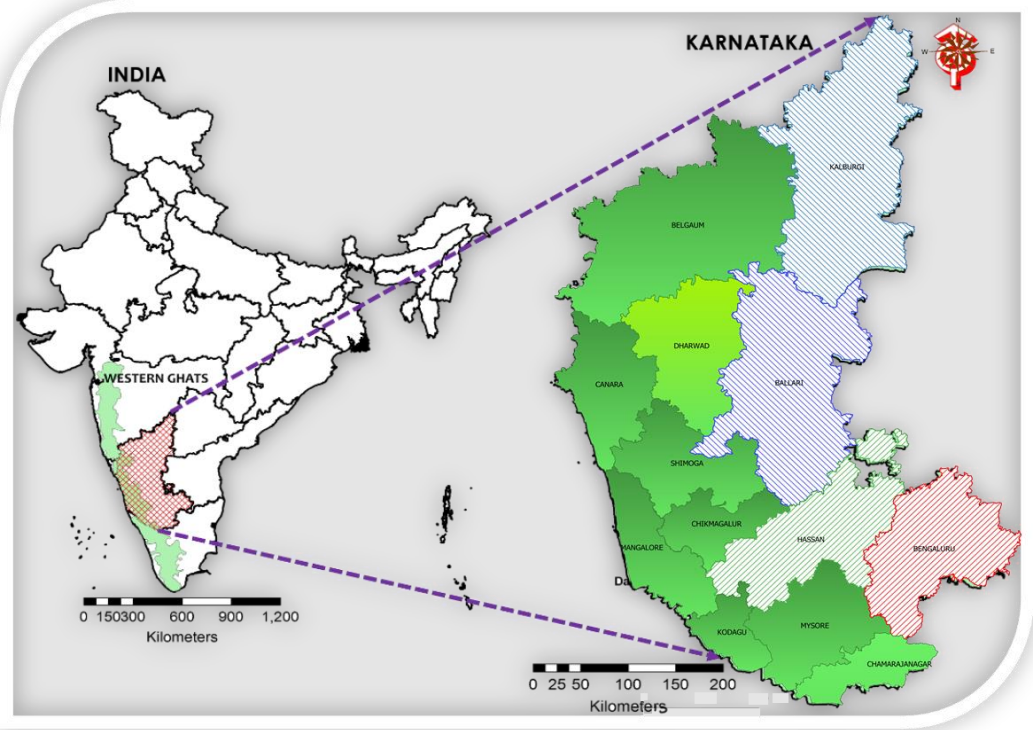


Figure 2.7. Population dynamics

Section 3.0 Data

Ecosystem extent account: An important foundation for estimating ecosystem services is the ecosystem extent account (Ramachandra et al., 2021a). Table 3.1 lists the spatial data 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 decentralized 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 3.2.



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. Details of remote sensing (RS) data for Karnataka State (2019) with respective path and row

Sno	District	Satellite Data Path & Row
1	Bagalkot	146048, 146049, 145049
2	Belgaum	146048, 146049
3	Ballari	145049, 145050, 144049, 144050
4	Bengaluru Rural	144051
5	Bengaluru Urban	144051
6	Bidar	145057, 145058
7	Chamarajnagar	144052, 144051
8	Chikballapur	144050, 144051
9	Chikmagalur	145050, 145051
10	Chitradurga	145050, 145051, 144050, 144051
11	Dakshina Kannada	146051, 145051
12	Davanagere	145050
13	Dharwad	146049, 146050
14	Gadag	145049, 145050, 146049, 146050
15	Hassan	145051, 144051
16	Haveri	146050, 145050
17	Kalaburagi	145048, 144048
18	Kodagu	145051, 145052
19	Kolar	143051
20	Koppal	145051
21	Mandya	144051, 144052
22	Mysuru	144051, 144052, 145051, 145052
23	Raichur	145049, 144049
24	Ramanagara	144051
25	Shivamogga	146050, 146051, 145050, 145051
26	Tumakuru	144050, 144051, 145051
7	Udupi	146050, 146051, 145051
28	Uttara Kannada	146049, 146050
29	Vijayapura	146048, 146049, 145048, 145049
30	Yadgir	145048, 145049, 144048, 144049

17 scenes of RS data cover Karnataka state

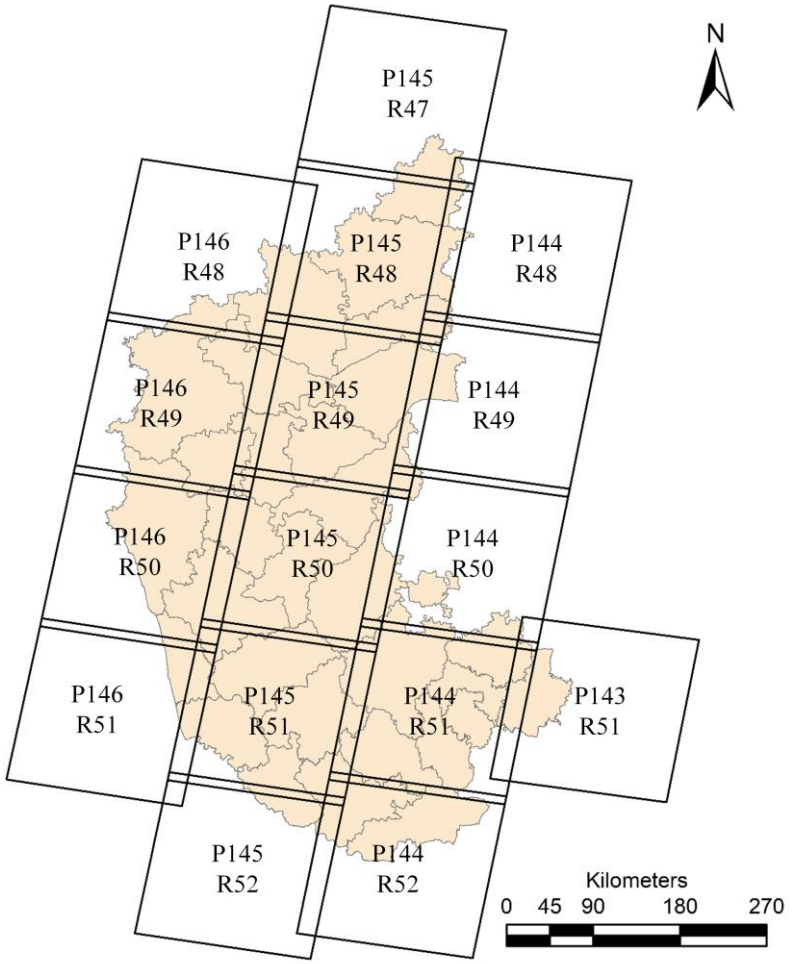


Table 3.2. The districts covered in each forest circle of Karnataka State

	Circle Name	District	Protected 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

Table 3.3 lists the data pertaining to the forest ecosystems (with the seigniorage values / residual value of goods used) for computing ecosystem services. Seigniorage value (Haslag 2020) is the revenue received by the government after deducting expenses (costs of labor, produced assets, and intermediate inputs) from the auction price of outputs (benefits). Table 3.4 lists the data (with source details) used for valuing agriculture ecosystem services.

Table 3.3. Data used for computing ecosystem services with the details of data sources.

Services	Services and monetary benefits	Source
Ecosystems type: Forest ecosystems		
Provisioning services	Provisioning services: The data included (i) service-wise (timber, bamboo, non-timber forest produce, fodder) quantity extracted for the two time periods (2014-2019 and 2001-2005) years and (ii) seigniorage rate as per forest department records for respective provisioning services (timber and other forest goods) for corresponding years	Data pertaining to the provisioning services at the circle level of the supply in physical terms and their benefits in monetary terms were collected for the respective circles from The Karnataka Forest Department offices at respective circles.
	Fuelwood	Fuelwood required per person is estimated based on the socio-economic survey carried out in select taluks

	Fish and other aquatic products provisioning services (in streams, reservoir, etc. - which are inseparable parts of the district's forest area)	District wise inland fish catch from districts, Department of Inland Fisheries, GoK https://fisheries.karnataka.gov.in/english Directorate of Economics and statistics, GoK https://des.karnataka.gov.in/english;
	Water Supply (domestic, irrigation, industries, hydro-electricity generation)	Land use data (Ramachandra et al. 2021a).Long term meteorological data such as temperature, rainfall, solar radiation were collected from online portals(Worldclim http://*www.worldclim.org/),* FAO (http://www.fao.org), Climate Research Unit, University of East Anglia http://www.cru.uea.ac.uk, NASA – Climate change and global warming http:// *climate.nasa.gov/, http://data.giss.nasa.gov/gistemp/,* KSNDMC Karnataka (https://www.ksndmc.org/), the Directorate of Economics and Statistics Karnataka (http://*des.kar.nic.in/)*, India Meteorological Department (https://mausam.imd.gov.in/), Food and Agriculture Organisation (http://www.fao.org). Population census for the years 2011 and 2001 was collected from the Census of India (https://censusindia.gov.in/). Livestock data such as Census (http://www.ahvs.kar.nic.in/), water requirements were collected from the Directorate of Economics and Statistics (http://*des.kar.nic.in/*), District at a Glance, and through public interviews. Agriculture data such as various crops grown, cropping pattern, water requirement at different growth phases were collected from District at a Glance, public interviews, online portals such as Raitamitra (http://*raitamitra.**kar**.nic.in/)*, iKisan *(http://www.**ikisan**.com),* National Food Security Mission *(http://www.**nfsm**.gov.in*, Tamil Nadu Agriculture University, etc. and other published literature. Field investigations in select stream catchments were carried out for ten months to understand the intra and inter variability of the hydrologic regime in the Central Western Ghats. The information for ungauged streams

		was compiled from published literature (Ramachandra et al. 2020). Water demand: Field survey, review of published literature, daily per capita water requirement (domestic), water use in agriculture – crop-wise, season-wise, and discussion with subject experts, Domestic and irrigation water supply – economic values were compiled from farmers and residents. Industrial water uses were compiled from publications – Annual reports of Karnataka Power Corporation Ltd, District at a Glance (allocation of water to industries, revenue, and cost)
	Medicine Various medicinal plants used by the local people were identified, and the value of medicinal plants per unit area of forest area was extrapolated to different types of forests	Public interview and literature review (Ramachandra et al. 2017; De Groot et al. 2020). Benefits are estimated per hectare as per the access and benefit-sharing data (royalty payments from the Karnataka Biodiversity Board and the Medicinal plant conservation authority)
	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	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 a case study from India (Verma et al. 2013)
Regulating services	Global climate regulation services /Carbon sequestration Data – Ecosystem extent and type of above-ground biomass (AGB), below ground biomass (BGB), soil carbon and net primary productivity (NPP)	(i) Land use information, (ii) quantification of AGB through field measurements of girth and height and sampling of the locations through transect-based quadrat – a survey carried out across forest types (evergreen, deciduous, scrub forests, etc.) in 10 districts.

	Soil conservation and soil fertility – Data: soil characteristics, land use characteristics, vegetation characteristics, farming practices, topographic effects, etc Annual rainfall, monthly rainfall, quick flows, historical climate data bioclimatic variables, long term weather data, daily rainfall data	Ecosystem entent assessment (Ramachandra et al. 2021a), Ecosystem condition -soil (Ramachandra et al. 2021b; Ma et al. 2019), IMD, GoI (https://mausam.imd.gov.in/), NASA Portal (https://gpm.nasa.gov/data), Worldclim (https://www.worldclim.org/), KSNDMC (www.ksndmc.org)
	Ground water recharge Precipitation, overland flow, infiltration, evapotranspiration, maximum and minimum temperature along with the solar radiation	Overland flow (runoff) – field measurements – four river basins in Uttara Kannada and two river basins in Shimoga districts using a current meter (water velocity measurement – three consecutive days, monthly), IMD, GoI (https://mausam.imd.gov.in/), NASA Portal (https://gpm.nasa.gov/data), Worldclim (https://www.worldclim.org/), KSNDMC (www.ksndmc.org)
	Water purification	Economic values of water purification and waste treatment are estimated per hectare as per a case study from India (Verma et al. 2013, Ramachandra et al. 2017)
	Pollination service Ecosystem extent, and type. Natural forest regeneration and afforestation (replacement) cost	Ecosystem extent based on land use analyses and literature (Ramachandra et al. 2021a). Comparative assessment of natural regeneration of forest patches (with fencing protection from external pressures (Ray et al. 2015) and afforestation cost. The estimates of natural forest regeneration in all forest types are adjusted according to the forest regeneration in plantations (NAP 2009; Ollerton et al. 2011; Hipólito et al. 2019)
	Air filtration services – extent of forest ecosystem Air filtration regulation service values per hectare is based on published literature from India (Ninan and Kontoleon, 2016, Joshi G and Negi GCS, 2011)	Ecosystem extent based on land use analyses (Ramachandra et al. 2021a) and Air filtration regulation service values per hectare based on published literature from India (Ninan and Kontoleon, 2016, Joshi G and Negi GCS, 2011) which are comparable to global studies -– global ecosystem service valuation database (ESVD) for tropical forests, and mangroves.

	Compared with values of global studies, adjusted for GDP (PPP) per capita and corresponding currency exchange rate	https://www.es-partnership.org/wp-content/uploads/2020/08/ESVD_Global-Update-FINAL-Report-June-2020.pdf GDP(PPP) per capita for India - https://data.worldbank.org/indicator/ NY.GDP.PCAP.PP.CD?locations=IN Currency exchange rate https://www.xe.com/currencyconverter/ convert/?Amount=1&From=USD&To=INR
	Local (micro and meso) climate regulation services – extent of forest ecosystem Per hectare local climate regulation service values based on published literature from India (Ghosh, 2020, Verma et al., 2007), Compared with global studies adjusted for GDP (PPP) per capita of the country for which values were estimated and corresponding currency exchange rate	Ecosystem extent based on land use analyses (Ramachandra et al. 2021a), per hectare local climate regulation service values based on published literature from India (Ghosh, 2020, Verma et al., 2007), which are comparable to values in global ecosystem (tropical forests, mangroves) service valuation database(ESVD). https://www.es-partnership.org/wp-content/uploads/2020/08/ESVD_Global-Update-FINAL-Report-June-2020.pdf GDP(PPP) per capita for India - https://data.worldbank.org/indicator/ NY.GDP.PCAP.PP.CD?locations=IN Currency exchange rate https://www.xe.com/currencyconverter/ convert/?Amount=1&From=USD&To=INR
Cultural Services	Aesthetic - National parks, sanctuaries, waterfalls	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), and supplemented with the Indian case studies (Ray et al. 2010; Bharath et al. 2017; Ramachandra et al. 2018c), publications - Districts at glance https://des.karnataka.gov.in/english https://kgis.ksrsac.in/kag/

	Spiritual and Historic - Distribution of sacred groves (relic forests - protected due to belief and customs)	Rituals are performed by devotees and the amount is paid for performing rituals (either visiting the grove or in absentia). Also, there is a practice of donating money during birthday celebrations or in the name of elders (or departed soul). Data pertaining to the annual collection and expenses were compiled from the administrative / management committees of select groves in Shimoga, Uttara Kannada, and Kodagu districts. Residual method was used (annual collection for rituals and deducting costs – priest salary and ritual expenses). In groves, where annual collection details were not available, the travel cost method is used for valuation, considering 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 using the benefit transfer method (Ramachandra et al. 2012; Ray et al. 2014b, 2015; Ramachandra et al. 2016, 2017, 2019a)
	Tourism and recreational services	Travel cost method (primary survey – benefits to travel operators, entrance fees (park, recreation spots) x the average number of visitors to the park during 2020) is used, supplemented with the Indian case studies. Benefit transfer method -(Ramachandra et al. 2019b; Badola et al. 2017; Gunarekha and Binoy 2017; Sinclair et al. 2020)
	Education, science, and research	Researchers need to obtain prior permission from the Forest Department to undertake research (and long-term monitoring). Details of the research, duration, project budget (for field research) and research team 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).

Table 3.4. Data used for valuing services from agriculture ecosystems

Agriculture – croplands, horticulture			
Services		Variables	**Source**
Provisioning services -	Cereals, pulses, oilseeds, vegetables, and commercial crops (coconut, areca nut, rubber, etc.)	Administrative boundaries (Ecosystem services are evaluated at taluk and district level),	(KSRSAC 2018)
		Crop yield (crop wise yield per unit agriculture area)	(DSO 2019) Public interviews
		Crop area (integrating with land use data, to derive actual crop area at taluk level)	
		Crop production (crop wise produce at taluk level for valuation of provisioning service)	
		Moderate-resolution satellite data (land use analysis)	(NRSC 2020)
		Virtual earth (Bhuvan and Google earth for land use analysis)	(NRSC 2016; Google 2020)
		Ecosystem extent	Ecosystem extent based on land use analyses (Ramachandra et al. 2021a)
		Data pertaining to crop yield, produce, net revenue generated fodder production (cattle feed) per unit area, cost of production	Primary survey: public interaction during 2019 – 2020, data pertaining to revenue, cost, etc.

		Minimum support price (specified by Government of India), and implemented at Mandi (local market) by the Government of Karnataka) was used to determine the monetary value).	(HOPCOMS 2019; AGRICOOP 2020; Coffee Board 2020; Commodities Online 2020; DMI 2020; KMV 2020; MSP 2020)
		Production cost (to determine net revenue from food crops, used for computing residual value of provisioning services)	(EANDS 2020)
		Agriculture revenue (the contribution of agriculture sector with state gross district domestic product (GDDP))	(DPPMS 2018)
		Government records and Published literature (Economic values for services - Provisioning, Regulating, Cultural)	(Murali 2010; Nayak et al. 2019; De Groot et al. 2020; NAAS 2020)
	Fodder	Type, quantity, likely uses, revenue, costs	Public interviews
	Wood	Type (horticulture crop), quantity, likely uses, revenue, cost of harvesting	Public interviews
Regulating Services	Air filtration services	Extent of ecosystem, per hectare air filtration services from India	Literature review – case studies from India – ICAR Indian Council of Agriculture Research (http://naasindia.org)

	Local (micro and meso) climate regulation services	The extent of an ecosystem, climate control services value per hectare based on published literature from India (Ghosh, 2020, Verma et al., 2007), compared with based on global studies. These estimates were adjusted for GDP (PPP) per capita of the country for which values were estimated and the corresponding currency exchange rate	Literature review Per hectare local climate regulation service values based on published literature from India (Ghosh, 2020, Verma et al., 2007), Compared with global studies adjusted for GDP (PPP) per capita of the country for which values were estimated and corresponding currency exchange rate – global ecosystem service valuation database (ESVD). https://www.es-partnership.org/wp-content/uploads/2020/08/ESVD_Global-Update-FINAL-Report-June-2020.pdf
	Global climate regulation services /Carbon Sequestration	The extent of an ecosystem, per hectare carbon sequestration services in agriculture and horticulture	Literature review – case studies from India (Nayak et al. 2019)
	Soil carbon	The extent of an ecosystem, per hectare – soil carbon storage service values	Literature review – case studies from India (Nayak et al. 2019)
	Water flow (ground water recharge)	The extent of an ecosystem, per hectare – groundwater recharge service values	Literature review – case studies from India (Nayak et al. 2019)
	Nitrogen fixation	The extent of an ecosystem,	Literature review – case studies from India (Nayak et al. 2019)

		per hectare – nitrogen fixation services values	
	Soil fertility (NIC 2020)	The extent of an ecosystem, per hectare – soil fertility services values	Literature review – case studies from India (Nayak et al. 2019)
	Remediation – organic and inorganic materials	The extent of an ecosystem, per hectare – remediation services values	Literature review – case studies from India (Nayak et al. 2019)
	Pollination	The extent of an ecosystem, per hectare – pollination services value	Literature review – case studies from India http://naasindia.org/Policy%20 Papers/policy%2094.pdf
	Genetic Diversity	The extent of an ecosystem, per hectare – genetic diversity services value	Literature review – case studies from India http://naasindia.org/Policy%20 Papers/policy%2094.pdf
	Biological Control	The extent of an ecosystem, per hectare – biological control services values	Literature review – case studies from India (Nayak et al. 2019)
Cultural Services	Tourism & Recreational	The extent of an ecosystem, per hectare recreation and tourism services	Literature review – case studies from India http://naasindia.org/Policy%20 Papers/policy%2094.pdf
	Inspirational, Culture, Art	The extent of an ecosystem, Per hectare inspirational, culture and art services value	Literature review (Van Berkel and Verburg 2014; Hirons et al. 2016; Moreno et al. 2018; Cheng et al. 2019) review; Global ecosystem service valuation database (ESVD).

		based on global studies. These estimates were adjusted for GDP (PPP) per capita of the country for which values were estimated and the corresponding currency exchange rate	https://www.es-partnership.org/wp-content/uploads/2020/08/ESVD_Global-Update-FINAL-Report-June-2020.pdf GDP(PPP) per capita for India - https://data.worldbank.org/indicator/ NY.GDP.PCAP.PP.CD?locations=IN Currency exchange rate https://www.xe.com/currencyconverter/ convert/?Amount=1&From=USD&To=INR

Note: Annexures 3.1, and 3.2 provide the questionnaires used for data compilation (crop yield, cost, revenue) through public interviews for agriculture (cropland and horticulture) ecosystems.

Annexures 3.3 and 3.4 provide the details of the data collected from the surveyed sacred groves and tourism locations.

Section 4.0 Method

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

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

Provisioning services from forest ecosystem: The provisioning services derived from the forests in this report include:

- **Timber*:*** Forests are the prime source of timber for the local people. Timber includes wood for making furniture, agricultural implements, fencing wood and wood poles, and planks for roofs. Timber provides revenue and constitutes an essential component of value on forest land properties. Timber is a readily available goods, which has a marketable value from the forests. However, strict rules and regulations are in operation from the State Government to extract timber from the protected forests.

  In many cases, the value of the timber can be several times the value of the land. Timber includes rosewood, teak wood, jungle wood, etc. Timber is mainly prominent in deciduous forests, while it is found in less amount in evergreen forest patches. Plantation forests primarily consist of timber-producing trees like acacia, teak, etc. Forest-based industries depend on the produce from the forest, which includes round wood, softwood, matchwood, etc. The data regarding the quantity of timber harvested and seigniorage values (residual value) were obtained from the Karnataka Forest Department. As per the Karnataka Forest Department records, the seigniorage values remain the same for all provisioning services for 2005 and 2019.
    - 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.
    - Teakwood 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.
    - Other kinds of timber are 4,644 and 4,297 Rs/Ha/yr for 2005, 2019.
    - Pulpwood is 3,369 Rs/Ha/yr (2005) and 3381Rs/Ha/yr (2019).
    - Round poles wood is assessed as 4,434, and 4,261 Rs/Ha/yr for 2005, and 2019.
    - Sandalwood is accounted as 4,573, and 4,652 Rs/Ha/yr for 2005, and 2019 respectively.
    - Bamboo for the Karnataka state is assessed as 3,938, and 4,402 Rs/Ha/yr for 2005 and 2019.

- **Fuelwood:** Fuelwood is the most important forest product in Karnataka. Fuelwood is the energy source for cooking in most parts of rural India, and 50% of the total fuelwood consumed comes from the forests. The yield of fuelwood depends on the

ease of access to the forests. The total value of fuelwood includes the value of fuelwood used for domestic purposes, i.e., for cooking and water heating, and also the fuelwood used for various industrial and commercial purposes like jaggery making, areca processing, cashew processing, restaurants, and bakery, parboiling, cremation, etc. Local people collect fallen wood/dry tree branches from the forests. An exploratory survey focusing on fuelwood requirements was initially conducted in various taluks of the agro-climatic zones and through a review of literature based on our earlier work (Ramachandra et al. 2000d). Socio-economic and energy data was collected from randomly selected samples in the Sirsi, Siddapur, Kumta, and Ankola taluks of Uttara Kannada district. The fuelwood required for various other purposes (large scale jaggery making, drying of agro products such as cardamom, etc.) were based on field experiments (Ramachandra et al. 2000c, 2017; Ramachandra and Bharath 2019a). The preliminary results of the survey in households using fuel-efficient stoves in the Sirsi and Kumta taluks showed fuelwood requirements for cooking (kg/person/day) to be 1.80 and 1.78 (summer) and 2.25 and 1.98 (monsoon), respectively. Villagers are permitted to collect fuelwood from the nearby forests, and the collection fee is collected by the forest department. Based on these data, the forest circle-wise fuelwood requirement is assessed and quantified in physical (tons) and monetary values (million INR). 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.

- **Non-timber forest products:** Non-timber forest products play a significant role in the livelihoods of the local communities and often contribute significantly towards the family income of the forest-dependent communities. The Forest Department gains significant revenue (over 50%) from NTFP extractions, and 75-80% of forest export income comes from NTFP exports. Over 275 million of the rural population (27% of India total) are engaged in collecting NTFP (Bhattacharya and Hayat 2009), resulting in a revenue of 6000 crores to rural communities (Planning Commission 2011). Traditional, non-destructive methods of extraction of NTFPs are practiced by the villagers. In many places, due to the commercial players, traditional harvesting has been replaced by destructive/excessive harvesting. The data on the harvesting of NTFP was obtained from the Forest Department. The total value of NTFP includes the value of a) NTFPs extracted by Forest Department, b) NTFPs collected by households, and c) bamboo extracted by the Karnataka Forest Department. Twenty-two varieties of food products derived from the forest were identified, and the value of food extracted per unit area of forest was obtained from literature was extrapolated to the total forest area. Household honey collection, which is a critical provisioning service from forests, was quantified based on the earlier field studies (Ramachandra et al. 2012, 2018a)) for all talukas and valued based on the quantity and benefits.

- **Fodder:** Fodder is the most important source of nutrients for livestock. A significant proportion of cattle reared grazes from the forested landscapes. Tree leaves and ground herbage (grass) are collected from the forests to feed the livestock, and fallen leaves are used to prepare compost and mulching in gardens. Leaf litter from the

forest floor is collected by the local people and used as cattle beds for some time and is then transferred to compost pits; once turned into compost, it is then transported to crop fields to replenish soil fertility. The livestock dependent on forests for fodder requirements is estimated, and the cost-adjusted price of fodder is also evaluated considering the unit market price of the fodder and the cost for collecting fodder. The total value of fodder supplied from the forest was quantified using field data and data from the earlier studies (Prasad et al. 1987; Ramachandra et al. 2000d) on herb layer productivity in different types of forests and the extent of different types of forest. Based on these inputs, per hectare value for fodder was assessed, and total values were computed based on market prices, assuming 10% cost factor, with a standard daily fodder requirement of 22 kg/CU/day and the existing livestock. The ecosystem supply value of fodder is 7,736 and 15,476 Rs/Ha/yr for 2005 and 2019, respectively.

- **Fish and other aquatic products provisioning services:** Fish is one of the primary sources of animal protein globally, and inland fishing is an important economic activity in the forest ecosystem. Inland fishing happens in rivers, rivulets, streams, reservoirs, lakes, etc., which are inseparable parts of the district's forest area. Fish are harvested by locals and for commercial purposes in the streams, lakes, and reservoirs of Karnataka. The inland fish quantity harvested for the years 2005 and 2019 has been compiled from the published reports of the Karnataka Inland Fisheries Department, Government of Karnataka. The revenue generated is quantified by using fishermen's share value per ton. The fishermen's share in consumers' rupee (%) is estimated from the net price received by the fishermen over the price paid by consumers (Aswathy et al. 2014). The fishermen generally receive 56% of the share from the consumers' end price (Piumsombun 2001; Kumar et al. 2008; Aswathy et al. 2014). Economic values for the ecosystem's contribution were determined (65,000 Rs/Ha/yr for 2005 and 2019) based on the residual value considering revenue and cost of harvesting.

- **Water supply service*:*** The accessibility and quality of water are intensely influenced by forests, which regulate water flows and control the availability of water resources (Ramachandra et al., 2020). The misconception of evapotranspiration, misinterpretations, and misinformation about vegetation in catchments has resulted in ad-hoc policies (Calder et al. 2008).

  Most of the water resources come from forested catchments. Hydrological services are quantified by the quantity of domestic water utilization, water for irrigation purposes (Ramachandra et al. 2001), water for industrial use, and water used for power generation (hydropower stations and nuclear power stations). Point-based daily rainfall data from various rain gauge stations in and around the study area between 1901 and 2019 were considered for the analyses of spatial and temporal patterns of rainfall (Ramachandra et al. 1999, 2020). Run-off (surface flow and sub-surface flow), infiltration, and groundwater recharge were quantified based on field measurement (Ramachandra et al. 1999, 2020). The field data reveal a correlation between water supply and the quality of forests as follows: (i) moderate overland flow with the substantial local recharge in catchments dominated by native vegetation, (ii) higher

overland flow, and reduced local water recharge in catchments with vegetation cover < 30%. Local water recharge helps in sustaining water in streams and wells during the post-monsoon season. Societal demand depends on the availability of water in streams and wells in the region. Streams are perennial (with 12 months flow) when their catchment is dominated by vegetation (> 60%) of native species. This is mainly due to infiltration or percolation in the catchment as the soil is porous with the presence of native species. Diverse microorganisms interact with plant roots, and soil helps in the transfer of nutrients from the soil to plants, and the soil is porous. Analyses of soil samples from the catchments of perennial, intermittent streams reveal that soils in perennial streams catchment have the highest moisture content (61.47 to 61.57%), higher nutrients (C, N, and K), lower bulk density (0.50 to 0.57 g/cc). Compared to this, a catchment of intermittent and seasonal streams had higher bulk density (0.87 – 1.53 g/cc) and relatively lower nutrients. Due to this, water infiltrates and fills the underlying zones, namely saturated zone, and vadose zones, which is crucial for the sustenance of water in the streams during lean seasons. This emphasizes that forest vegetation helps in retarding the water flow in the catchment by allowing infiltration. Contiguous forests of native species moderate the local climate (through transpiration) and also act as a sponge by retaining the water, which is slowly released to the streams during the lean seasons, thereby sustaining the water availability in the catchment to meet biotic needs throughout the year. Water availability for four months is observed in the streams of the degraded catchment, with vegetation cover less than 30%.

Domestic water demand is assessed as the function of water requirement per person per day, population, and season. Water required per person includes water required for bathing, washing, drinking, and other basic needs. Household surveys were conducted with structured questionnaires to understand the agricultural cropping pattern and water needed for various crops in the catchment. Livestock population details were obtained from the district statistics office, and water requirements for different animals were quantified based on the interviews. The crop water requirement for various crops was estimated considering their growth phase and details of the cropping pattern in the catchment (based on the data compiled from household surveys and discussion with the subject experts, review of published publications. Water used for electricity generation are compiled from the Annual reports of Karnataka Power Corporation Ltd and the District at a Glance (allocation of water to industries, revenue, and cost). Water supply services are accounted sector wise (domestic, croplands, horticulture, industries, and electricity generation) considering the quantum of water and residual value (revenue and cost details as per the Water Resources Development Organisation, Government of Karnataka (http://waterresources.kar.nic.in), Department of Minor Irrigation (https://minorirrigation.karnataka.gov.in/english), Karnataka Power Corporation (http://karnatakapower.com/), districts at a glance (kgis.ksrsac.in/kag/), Directorate of Economics and Statistics Karnataka (http://*des.kar.nic.in/)*, etc. The water supply services accounts to 2,61,360 ₹/Ha/Yr (medium density forests: MDF) to 4,80,315

₹/Ha/Yr (very dense forests: VDF), which is comparable to the earlier reports (values are within ±10% as per Ravindranath and Ostwald 2008, de Groot et al. 2020b).

- **Medicine**: Medicinal plants act as a prime source for healing in forest areas, with widespread usage in recent times, even in urban areas. The people of India have an ancient history of using medicinal plants as codified and non-codified healing systems. As per the Botanical Survey of India, about 255 modern medicines are derived from forest medicinal plants. Forest ecosystems in Karnataka are endowed with 1838 species of medicinal plants (http://envis.frlht.org/checklist/karna.pdf). The demand for medicinal plant-based raw materials is growing at the rate of 15 to 25 percent annually. According to the World Health Organisation (WHO) estimate, the demand for medicinal plants is likely to increase from the current $14 billion a year to $5 trillion in 2050.

  A sampling of medicinal plants has been done through (i) field-based measurements collected across the forests of Karnataka using transect-based quadrat sampling techniques (see below) and (ii) published literature on an inventory of medicinal plants. The study region (Karnataka State) was divided into 2597 grids of 5' × 5' (or 9 km x 9 km) grids corresponding to grids of 1:50000 topographic maps of the Survey of India. Select grids corresponding to agro-climatic zones were chosen for field investigations. The field estimations were done across the varied forest types covering around 424 transects in Uttara Kannada, Shimoga, Chikmagalur, Kodagu, Dakshina Kannada, Udupi, Dharwad, etc. The number of quadrats per transects varied between 3 and 5 depending on species occurrence in the sampling locality. The opportunistic survey was also carried out to list out species not recorded in transect studies to get the total medicinal plant species count. Per hectare population was also calculated for important medicinal plant (trees, shrubs, and herbs) species. The medicinal plants in the region were identified based on the available secondary literature (Rao et al. 2014, 2015; Ramachandra et al. 2015). Medicinal plants used by the local people were identified (Ramachandra et al. 2017), and the value of these medicinal plants per unit area of forest area was computed, based on public interviews, discussion with the local experts (with the knowledge of traditional uses of plants) and the review of literature review (Ramachandra et al. 2017; Chanda and Ramachandra 2019a, b). Highly traded medicinal plants such as *Salacia chinensis, Nothapodytes foetida, Embelia ribes, Coscinium fenestratum, Cinnamomum malabathrum, Myristica malabarica, Costus speciosus* and *Garcinia* spp. were found to be well represented in the study area.

  Medicinal plants being used at local levels and details of plants, details of use for treating ailments, and likely market value were compiled through the public interviews, discussion with the experts, and literature review (Ramachandra et al. 2017; De Groot et al. 2020). Medicinal plants have commercial value (in addition to local uses), and as per the norms (Biodiversity Act, 2002, Government of India (http://nbaindia.org/) and norms of access and benefit-sharing as per Article 15 of the Convention on Biological Diversity (CBD)), industries are required to pay the royalty to the government on an

annual basis. Medicinal plants harvested (type/species, quantity extracted per season, and royalty/revenue) with the access and benefit-sharing details are obtained from (from Karnataka Biodiversity Board (https://kbbwebportal.karnataka.gov.in/default.aspx), Karnataka Forest Department (https://aranya.gov.in/; http://envis.frlht.org/mpcas) and Medicinal Plants Conservation Authority (https://ayush.karnataka.gov.in/). Medicine services of forest ecosystems were quantified based on the spatial extent of forests, quantity of medicinal plants harvested, and residual value (revenue and costs). The medicinal plants' services of forest ecosystems ranging from 221 Rs/Ha/Year (MDF) to 445 Rs/Ha/Year (VDF) and are comparable to studies from India (Verma et al. 2013) and international (De Groot et al. 2020) studies (adjusted for GDP (PPP) per capita and the currency exchange rate).

- **Genetic material service:** Forests aid as gene pools and play a significant role in conserving biodiversity, which is being explored for various purposes (medicine, conservation, species richness, biodiversity, etc.) and is increasingly recognized. The economic value of gene-pool conservation in terms of bioprospecting is based on i) the number of medicinal plants found in each district, (ii) the number of species of conservation importance in each district, and (iii) all species. The estimate is based on all species in the district and ecosystem extent. Species details were obtained from the 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/). The genetic material services of forest ecosystems in Karnataka is estimated considering the spatial extent of forest patches (with the distribution of endemic species and species of conservation importance) through benefit transfer technique (Verma et al. 2013), which ranges from 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) and 67,852 Rs/Ha/Year (dry deciduous) based on studies from India.

Regulating services from forest ecosystems: Forests provide several intangible benefits such as regulating local and global climate, protecting watersheds, controlling soil erosion, nutrient cycling, etc., that are often ignored in policy contexts since these values do not register in conventional markets or are challenging to measure. 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, 2020; Amirnejad et al. 2006; Costanza et al. 2014; Zarandian et al. 2016). However, regulating services, unlike provisioning services, pose much more significant challenges in valuation as they are seldomly marketed. In the present study, regulating services were quantified through the benefit transfer method (Ramachandra et al. 2000b, 2010, 2017, 2018b; Ramachandra and Bharath 2021). Regulating services considered are:

- **Global climate regulation services/ Carbon sequestration**: Forests sequester CO_2, which aids in mitigating climate change impacts. However, degradation of forest ecosystems

leading to deforestation would lead to loss of carbon sequestration potential. The carbon sequestration potential of Karnataka state's forests was estimated by integrating temporal land-use data with field investigations at the grid level. The study region (Karnataka State) was divided into 2597 grids of 5' × 5' (or 9 km x 9 km) grids corresponding to 5' × 5' grids of 1:50000 topographic maps of the Survey of India. Carbon sequestration is assessed across the various forest cover types by accounting for the annual increment in above-ground biomass (AGB), below-ground biomass (BGB), soil organic carbon (SOC) and deadwood content. The biomass, annual increment in biomass of various forest types, sequestered carbon, and productivity has been computed using field data integrated with information compiled from various literature listed in Table 4.1.1. Carbon sequestration (CO_2 equivalent) is computed by multiplying the carbon sequestration values with the factor 3.67 as per the protocol of The Intergovernmental Panel on Climate Change (IPCC 2003).

Table 4.1.1. Carbon sequestration based on forest cover types

Index	Forest type	Equation	Quantification
Annual Increment in biomass (T/Ha)	Evergreen	(Forest cover) × 10.48	Incremental growth in biomass (Ramachandra et al. 2000a; Pandey et al. 2011; Devagiri et al. 2013; Do et al. 2018)
	Deciduous	(Forest cover) × 13.82	
	Scrub	(Forest cover) × 5.4	
	Plantations	(Extent) × 1.4	
Annual increment in carbon (T/Ha)	All	(Annual increment in biomass) × 0.5	Incremental growth in carbon storage
NPP (net primary productivity) or Net annual biomass productivity (T/Ha)	Evergreen	(Forest cover) × 3.6	Used to compute the annual availability of woody biomass in the region. (Ramachandra et al. 2000d)
	Deciduous	(Forest cover) × 3.9	
	Scrub	(Forest cover) × 0.5	
	Plantations	(Extent) × 3.6	
Annual increment of soil carbon (T/Ha)	All	(Cover) × 2.5	Annual increment of carbon stored in the soil(Ravindranath et al. 1997; Rajan et al. 2010)

InVEST carbon sequestration model: The InVEST carbon sequestration model estimates the quantity of carbon sequestered from a landscape and values the amount of sequestered carbon over time. It aggregates the biophysical amount of carbon stored in four carbon pools (aboveground living biomass, belowground

living biomass, soil, and dead organic matter) based on land use/land cover (LULC) maps. The InVEST 3.9 Carbon model was used to validate the results of 2005 and 2019 field-based estimates. The model considers inputs as land use maps and a CSV file containing the values of carbon above ground, carbon below ground, soil carbon, and dead carbon concerning each land-use class. Invest also tries to quantify projected sequestration with the input for future land use. The model output summarizes results into raster outputs for sequestration and value as aggregate totals.

Additionally, a REDD (reducing emissions from deforestation and forest degradation) scenario can also be included to evaluate the additional future scenario, calculate storage and sequestration, and summarize results. Outputs of the model are expressed as Mg of carbon per pixel. The valuation model estimates the economic value of sequestration as a function of the amount of carbon sequestered, the monetary value of each unit of carbon, a monetary discount rate, and the change in the value of carbon sequestration over time. Thus, valuation can be done in the carbon model for future scenarios.

The land use maps of 2005 and 2019 have been provided as input in the InVEST carbon model to quantify the carbon sequestration across the Karnataka region. InVEST provides values of carbon sequestration, which were converted to carbon dioxide (CO_2) equivalent as suggested by IPCC. The value of CO_2 sequestration is 1,17,660 Gg (Giga gram) and 87946 Gg using InVEST for the years 2005 and 2019, compared to the field-based estimates of 1,24,153 Gg; 89,194 Gg. The model's accuracy is around 95%, and 98%, respectively, which depicts good consistency compared with field measurements. The carbon sequestration service value (social cost of CO_2) is computed as a function of the amount of carbon sequestered per year (based on field measurements), the monetary value of each unit of carbon as US$ 80 using the GDP deflator, as per MoSPI (MoSPI 2020).

Note: Annexure 4.1 provides the details of the protocol adopted for assessing carbon storage in the forest ecosystems of Karnataka (which is not considered in the valuation of ecosystem services).

- **Soil conservation and soil fertility**: Forests also help increase soil fertility through the decomposition of leaves and humus formation. Forests play a key role in tempering droughts as well as floods and protecting against the incidence of landslides. Forests also limit soil/splash erosion, help retain rainwater, maintain soil moisture, intercept and delay high-pressure precipitation, disperse and delay runoff, intercept sediment and protect the surface (Ma et al. 2019). In addition, forests regulate soil fertility through the underground root system, improving soil physical and chemical properties.

The InVEST Sediment Retention model estimates the capacity of a land parcel to retain sediment by using details of geomorphology, climate, vegetative coverage, and management practices. Estimated soil loss and sediment transport of a land parcel are the input to InVEST model, which produces avoided sedimentation as output. The model can also value the landscape in terms of water quality maintenance or avoided reservoir sedimentation and determines how land-use changes may impact the cost of sediment removal. A region's sediment yield and retention characteristics are computed using Revised Universal Soil Loss Equation (RUSLE) based on the knowledge of soil characteristics, land use characteristics, vegetation characteristics, farming practices, topographic effects, etc. Figure 4.1.1 depicts the method involved in deriving local sediment retention using RUSLE method. Various factors defining Sedimentation in RUSLE are R Factor, K factor, L Factor, S Factor, P Factor, and C Factor. R factor is defined as Rainfall Erosivity Factor. There are numerous methods that incorporate annual rainfall, monthly rainfall, quick flows, etc., to derive R factor. R Factor is defined based on Quick/Surface flow conditions in the current study and was estimated as R = 81.5+0.375*Quick flow. Quick flows were estimated using the Natural Resources Conservation Service (NRCS) method (Seasonal Water Yield Model) in InVEST 3.9.0. Soil erodibility factor varies based on soil texture and depth. Table 4.1.2 describe the K factor considered based on published literature. Root zone depth of various vegetation type, Conservation practice factor (CPF), and Land cover factor (LCF) were derived based on land use data and published literature. DEM was used to estimate Length and Slope Factors.

Table 4.1.2: K Factor – Soil Erodibility Factor

Texture	**K**	**Texture**	**K**
Clayey	0.22	Loamy	0.3
Clayey over Loamy	0.3	Loamy over Sandy	0.11
Clayey over Sandy	0.07	Loamy Skeletal	0.11
Clayey Skeletal	0.22	Rocky Outcrops	0.01
Coarse Loamy	0.3	Sandy	0.02
Fine	0.08	Sandy Skeletal	0.02
Fine Loamy	0.39	Very Fine	0.08
Built-up	0.01	Water	0.00

InVEST sediment yield model integrates various data sets as described in Table 4.1.3 lists the data used in deriving the local sediment retention using RUSLE method. There are various outcomes[3] with regards to soil retention, but in the current study, sediment

[3] Various outcomes with regards to soil retention are (i) total soil loss per pixel in the absence of land-use features equivalent to bare earth, (ii) total amount of sediment exported from each pixel that reaches the drainages/streams, (iii) amount of sediment deposited on the pixels due to retention in upstream resources, (iv) potential soil loss per pixel with original land cover features and (v) sediment retention map at pixel level by comparing soil loss at the pixel level for bare earth and due to land cover features.

retention potential at pixel level was used to derive sediment loss at various land surface features.

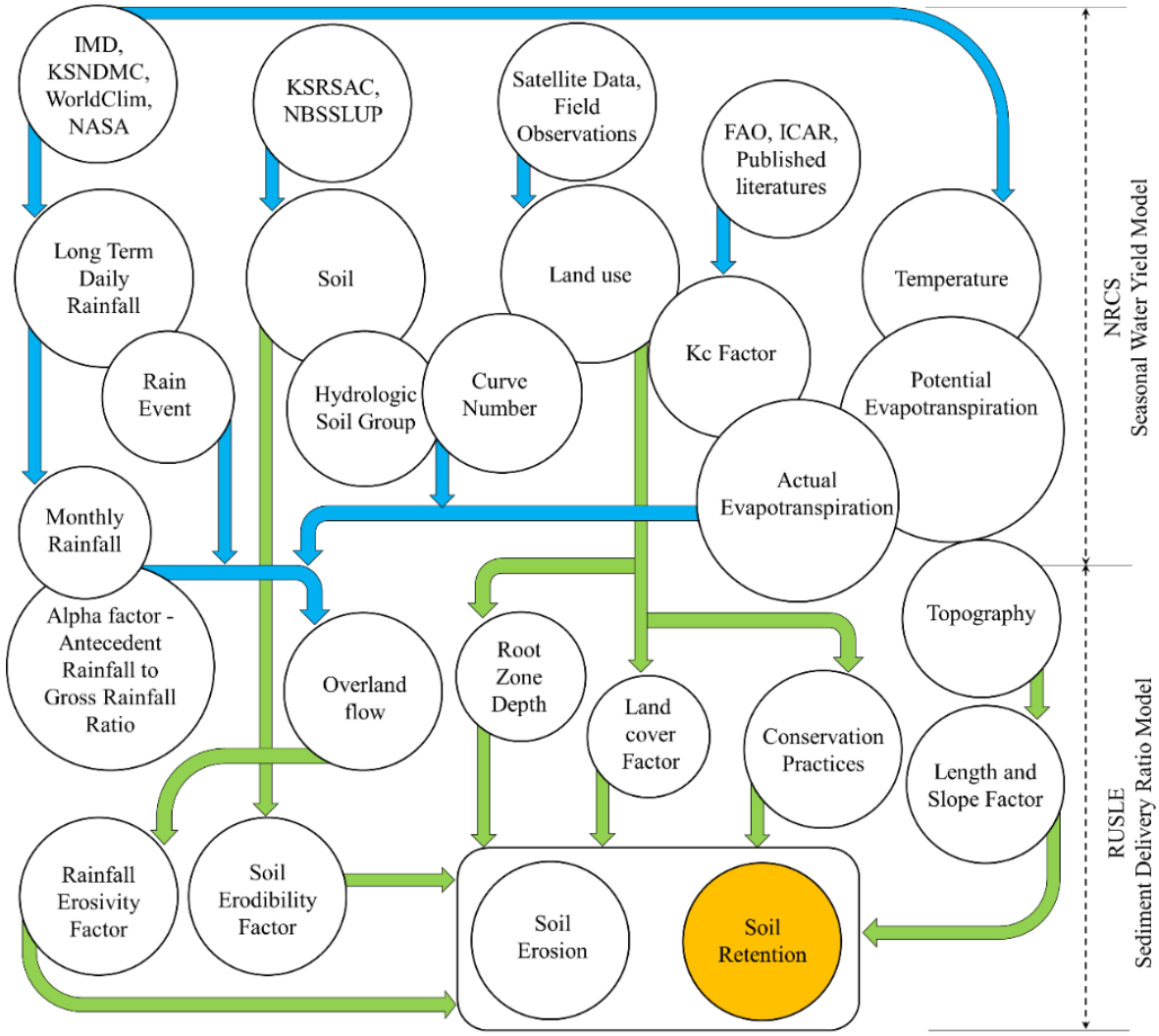


Figure 4.1.1: procedure for estimating soil retention through RUSLE module of InVEST with details of input data

Sedimentation outcomes of the model were compared with field experiments carried out at Aghanashini river (https://linkinghub.elsevier.com/retrieve/pii/S0301479717307429) located in Uttara Kannada district, Central Western Ghats. The analysis carried out using InVEST tool showed average sediment yield in the catchment is about 4232 tons per hectare per year i.e., about 1627 cum/ha/year with an average density of 2.6 tons/cum (http://isslup.in/wp-content/uploads/2018/09/Characterisation-Of-Soils-Of-Western-Ghats-In-Dakshina.pdf), whereas observed yield in Aghanashini river was in the range of 1367 to 1567 cum/ha/year. InVEST model was able to predict with an accuracy of 85 to 96% compared to select field measurements. This calibrated model was used to investigate sediment retention for the year 2020. Prevention of soil erosion varies according to forest types (evergreen, deciduous, scrub) and the quantity varies based on the extent and condition of forests.

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), soil retention services values range from 9064 INR/Ha/yr (dry deciduous, medium-density forests) to 19436 INR/Ha/Yr (evergreen, very dense forests). Analyses of sediment yield based on vegetation type and canopy cover reveal that sediment retention in evergreen forests ranges from 150 tons per hectare (MDF) to 1000 tons per hectare per year (VDF), and soil retention services range from 7320 Rs/ha/year (Open canopy forests) to more than 48800 Rs/Ha/year (VDF) in evergreen forests. Similarly, in deciduous forests, sediment retention ranges between 15 tons per hectare per year to 350 tons per hectare per year (VDF), and soil retention services range from 732 Rs/ha/year (open forests) to 17080 Rs/Ha/year (VDF).

Table 4.1.3 Data used for assessing soil conservation services

Data and type	Source	Purpose	InVEST	File type
Daily rainfall	• India Meteorological Department • Karnataka State Natural Disaster Monitoring Cell • Tropical Rainfall Measuring Mission • NASA POWER • NOAA – Climate Data Online • Terrestrial Hydrology Research Group – Princeton University Database	Quantification of number of rainy days in a month (long term average)	Monthly climate zone factor table – Varies across each month, and across agro-climatic zones. Rainy days are associated with agro-climatic zones across each month.	*.csv
		Quantification of antecedent monthly rainfall to annual rainfall	Monthly alpha table -Varies across each month, common values, does not differentiate between agro-climatic zone	*.csv
Monthly rainfall		Quantification of overland flows	Monthly precipitation data stored in directory	*.tif
Monthly evapotranspiration	• NASA POWER • Terrestrial Hydrology Research Group – Princeton University Database • Food and Agriculture Organisation • Indian Meteorological Department	Quantification of actual evapotranspiration based on land use type and potential (reference) evapotranspiration ET_0 [mm day^{-1}]	Monthly ET_0 data stored in directory	*.tif
Land use	• Indian Remote Sensing (IRS) satellite data • United States Geological Survey	Quantifications of overland flows, actual evapotranspiration, root zone depth, P factor and C factor	Land use identified with integer number and titled within the biophysical table	*.tif
Soil	• Karnataka Remote Sensing Application Centre • National Bureau of Soil Studies and Land Use Planning	Assigning HSG (Hydrological Soil Group) based on soil texture and patterns, and based on land use, defining curve numbers.	Soil texture HSG identified as number (HSG A = 1, HSG B =2, HSG C = 3 and HSG D = 4)	*.tif

	• ICRISAT – Soil Fertility Atlas of Karnataka • Soil Health Card - Department of Agriculture, Cooperation & Farmers Welfare Ministry of Agriculture and Farmers Welfare Government of India • European Soil Data Centre	Assigning K factor based on soil texture	K Factor (Table 1) as defined as an image with float values defining soil erodibility factor	
Kc	• Food and Agriculture Organisation • Published Journal Articles • ICAR -KRISHI • Published literature	Crop coefficient defining the evaporation coefficient for each month	Month wise crop coefficients for each land use type, stored within the biophysical table	*.csv
Watershed	• NRSC Bhuvan • Karnataka State Remote Sensing Application Centre	Used to define the boundary condition for analysis	Defined with a shape file consisting a single polygon	*.shp
Agroclimatic zones	• University of Agriculture Sciences	Climatic patterns and cropping vary with agroclimatic zones. The number of rainfall days is minimum at arid zones while the coast and ghats have a higher number of rainy days. According to the number of rainy days, the rainfall is spread across the month to define the likely flow patterns.	Agroclimatic zones are identified with numbers for each of the raster pixels. The number of rainy days is defined based on agro climatic zone for each month.	*.img
R factor	• Published literature	Defines the rainfall erosivity factor, derived based on quick flow conditions	R factor is identified as float values in an image	*.img
K factor	• Published literature	Soil erodibility factor, defined by soil texture	K factor is based on soil texture, and defined as float values	*.img
Bio physical table	• ORNL DAAC • NRCS USDA • Published literature		QUICK FLOW:	*.csv

			Stores data such as month wise Kc values with respect to land use, curve numbers with respect to soil type and land use. Relates Pixel numbers to land use classes SEDIMENT Retention: According to the various land use types, stores the sedimentation cover management factor (C Factor), Practice (P Factor), Root Zone depth, Kc factor	
Topography	• Shuttle Radar Topographic Mission (SRTM)	Defines the flow direction, slope characteristics of terrain. Used to derive L (length) and S (Slope) factors.	DEM is directly taken into InVEST tool which automates the calculation of slope and length factors using Moore neighbourhood and pixel dimensions	*.img
Root zone depth	• Published literature	Vegetation roots		
Max SDR, Borselli k Parameter, Borselli IC0 Parameter			Default values (SDR, k, IC0) provided in InVEST tool has been considered	

- **Water regulation and groundwater recharge:** Forests in the watershed help retain water supplied from precipitation in underground aquifers just as water is stored in human-made reservoirs. They simplify in increasing the efficient water available, improving water quality, and decreasing water runoff. The quantity of water conserved depends on several parameters: evaporation and runoff rates, interception ratios, tree and forest characteristics, nature and intensity of rainfall, geographic and soil conditions, etc. (Ramachandra et al. 2020). Forests help regulate the hydrological regime locally and sustain water flow in the streams due to their sponge-like effect. Vegetation in the catchment helps in retarding the water flow in the catchment by allowing infiltration.

  Water regulation services are the ecosystem contributions to the regulation of river flows and groundwater and lake water tables. They are derived from the ability of ecosystems to absorb and store water, and gradually release water during dry seasons or periods through evapotranspiration and hence secure a regular flow of water. This is recorded as a final or intermediate ecosystem service. Peak flow mitigation services will be supplied together with river flood mitigation services to provide the benefit of flood protection, a final ecosystem service. Field investigations in four river basins of Uttara Kannada district reveal that water infiltrates and fills the underlying zones, namely saturated zone, and vadose zones, in the catchments of streams. The region receives rain for about four months, and the surface run-off during the monsoon is due to the precipitation (after saturation of underlying regions). After the monsoon recedes, the water stored in the vadose regions, and saturated zones flow laterally towards the streams for about 6-8 months (as pipe flow in the post-monsoon period of 4 months and base flow during summer). Water infiltration allows water storage in the saturated and vadose zones, which is crucial for water sustenance in the streams during lean seasons. Catchments with > 65% vegetation of native species have perennial streams, higher soil moisture, and groundwater than the catchment dominated by degradation.

  InVEST Seasonal Water Yield Model: the model integrates various data sets as described in Table 4.1.4. A Natural Resource Conservation Series (NRCS) model or SCS model uses the curve number functions-based soil characteristics, land use characteristics, climate characteristics, etc. Figure 4.1.3 depicts the method involved in deriving local water recharge using NRCS curve number method. The method uses the water balance equation to derive the unknown parameter (Precipitation = Overland Flow + Infiltration + Evapotranspiration). The local infiltration parameter defines local water recharge. The NRCS curve number model utilizes various parameters to derive the overland flow; FAO recommends the Penman Monteith / Modified Hargreaves method to derive the potential evapotranspiration (ET_0). In the

current study, the Modified Hargreaves method is used for deriving the ET_0, and this method uses the maximum and minimum temperature along with the solar radiation. Based on the crop evapotranspiration coefficient (Kc), actual evapotranspiration is derived for land use.

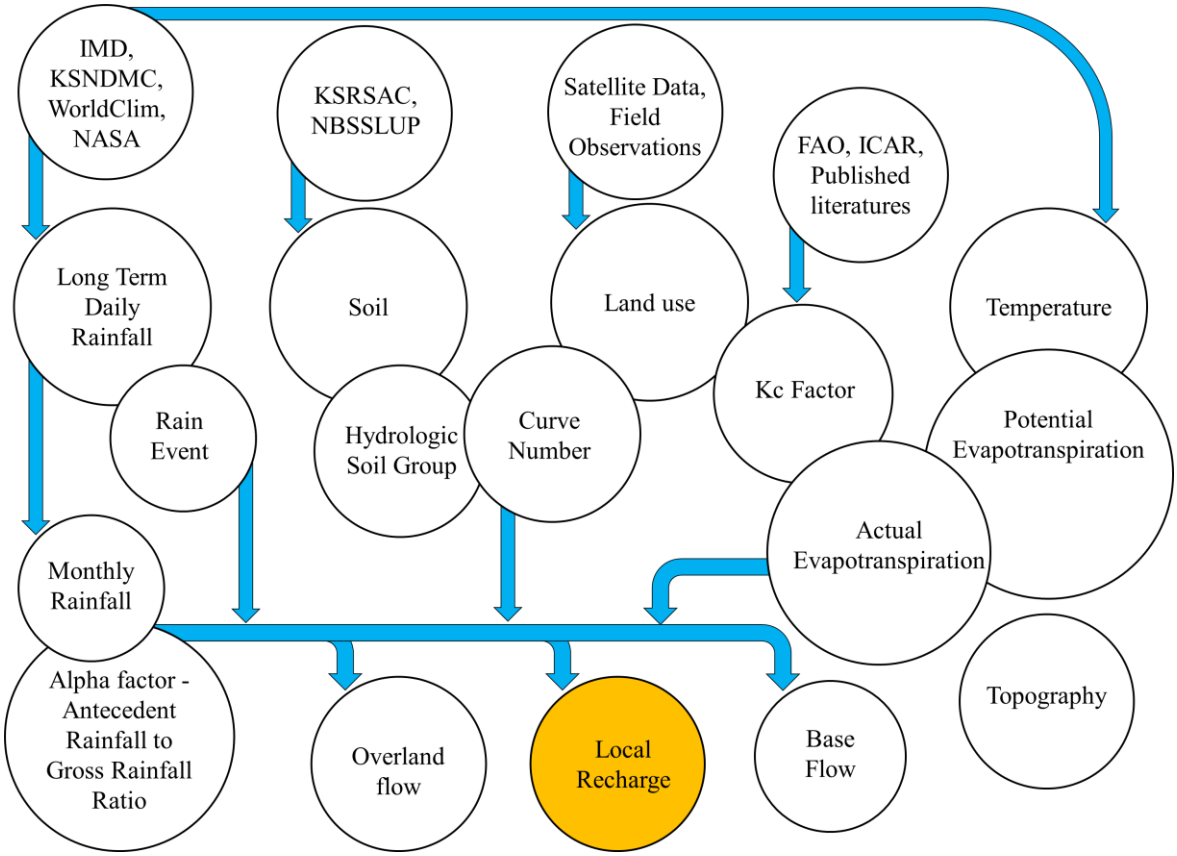


Figure 4.1.3. Procedure to assess groundwater recharge through InVEST

The model uses the NRCS (curve number) method to derive various outcomes with regard to water conservation, which includes (i) base flow per pixel level and upstream contribution, (ii) local recharge at pixel level and upstream contribution, and (iii) quick flow at pixel level and upstream contribution. In the current study, water retention was considered a function of local recharge. Local data sets and field-based observations were used to calibrate flow patterns. The InVEST model was able to predict with an accuracy of over 80%. This calibrated model was used to investigate water retention for 2019 and 2020 (note there is no variation between 2019 and 2020).

Table 4.1.4. Data used in InVEST Seasonal Water Yield Model for estimating local water recharge services of forest ecosystems

Data and type	**Source**	**Purpose**	**InVEST**	File type
Daily rainfall	• India Meteorological Department • Karnataka State Natural Disaster Monitoring Cell • Tropical Rainfall Measuring Mission • NASA POWER • NOAA – Climate Data Online • Terrestrial Hydrology Research Group – Princeton University Database	Quantification of number of rainy days in a month (long term average)	Monthly climate zone factor table – Varies across each month, and across agroclimatic zones. Rainy days are associated with agroclimatic zones across each month.	*.csv
		Quantification of antecedent monthly rainfall to annual rainfall	Monthly alpha table -Varies across each month, common values, does not differentiate between agroclimatic zone	*.csv
Monthly rainfall		Quantification of overland flows and local recharge	Monthly precipitation data stored in directory	*.tif
Monthly evapotranspiration	• NASA POWER • Terrestrial Hydrology Research Group – Princeton University Database • Food and Agriculture Organisation • Indian Meteorological Department	Quantification of actual evapotranspiration based on land-use type and ET_0	Monthly ET_0 data stored in directory	*.tif
Land use	• Indian Remote Sensing Satellite Data • United State Geological Survey	Quantifications of overland flows, local recharge, baseflow, and actual evapotranspiration	Land use identified with integer number and titled within biophysical table	*.tif
Soil	• Karnataka Remote Sensing Application Centre • National Bureau of Soil Studies and Land Use Planning	Assigning HSG (hydrological soil group) based on soil texture and patterns, and	Soil texture HSG identified as number (HSG A = 1, HSG B =2, HSG C = 3 and HSG D = 4)	*.tif

	• ICRISAT – Soil Fertility Atlas of Karnataka • Soil Health Card - Department of Agriculture, Cooperation & Farmers Welfare Ministry of Agriculture and Farmers Welfare Government of India • European Soil Data Centre	based on land use, defining curve numbers		
Kc	• Food and Agriculture Organisation • Published Journal Articles • ICAR -KRISHI • Published literature	Crop coefficient defining the evaporation coefficient for each month	Month wise crop coefficients for each land use type, stored within the biophysical table	*.csv
Watershed	• NRSC Bhuvan • Karnataka State Remote Sensing Application Centre	Used to define the boundary condition for analysis	Defined with a shape file consisting a single polygon	*.shp
Agroclimatic zones	• University of Agriculture Sciences	Climatic patterns and cropping vary with agro-climatic zones. The number of rainfall days are minimum at Arid Zones while the Coast, Ghats have a higher number of rainy days. According to the number of rainy days, the rainfall is spread across the month to define the likely flow patterns.	Agro-climatic zones are identified with numbers for each of the raster pixels. The number of rainy days is defined based on the agro climatic zone for each month	*.img
Biophysical table	• ORNL DAAC • NRCS USDA • Published literature		Stores data such as month wise KC values with respect to land use Curve numbers with respect to soil type and land use. Relates pixel numbers to land use classes	*.csv

Groundwater was the major source for irrigation apart from the canal irrigation system. Water contained in the voids of the geologic materials supports needs of irrigation, both domestic and from industries. The groundwater storage available annually is estimated based on area and depth of fluctuation in the groundwater table and specific yield factors. The groundwater storage in the aquifer depends on the input components such as precipitation; seepage, and return flow (Chatterjee 2011).

InVEST provides the quantum of water recharge within the natural forested areas. The forest of Karnataka locally recharges about 27.2 billion cubic meters of water to the ground, which later flows as base flows. The economic value of groundwater (after deducting costs) is about 262.5 Rs/kilo cum of water. Based on this, local recharge in evergreen forests ranges between 1000 mm (medium-density forests: MDF) to more than 4000 mm (very dense forests: VDF), and the economic value of groundwater recharge services for evergreen forests ranges from 2600 Rs/ha/year (MDF) to more than 5000 Rs/ha/year (VDF). Similarly, local recharge in deciduous forests ranges from 25 mm (MDF) to 1500 mm (VDF). The economic value of groundwater recharge services for deciduous forests ranges from 663 Rs/Ha/year to more than 3700 Rs/ha/year.

- **Water purification and waste treatment:** Forests, their diversity, and native vegetation, control all hydrological events such as flow, recharge, and precipitation, etc. Forest soils and root systems, and microorganisms present in soil and water help filter and absorb contaminants and bacteria from the water received from precipitation. In fact, the water obtained from rainfall in forest areas that drips through streams and springs is rich in mineral nutrients and highly valued for its purity and medicinal value (Chatterjee 2011; Terrado et al. 2014; Zawadzka et al. 2019; Ramachandra et al. 2020). Diverse microorganisms interact with plant roots, and soil helps in the transfer of nutrients from the soil to plants which aids in the remediation of water. Soil and water conservation and water purification are interrelated, as these are different services provided by forest ecosystems.

  Forest ecosystems have multifunctional potential in terms of water and wastewater treatment, thereby supporting natural processes of ecosystem services supply. Forests aid as sink and support treatment (bioremediation), which depend on the spatial extent, and condition of ecosystems (Zawadzka et al. 2019). Economic values of water purification and waste treatment by forest ecosystems in Karnataka are estimated through the benefit transfer method based on case studies from India. An average of 2,950 Rs/ha/yr was considered as a water purification service from forests (Verma et al. 2013).

Waste treatment is estimated at 4,716 Rs/ha/yr (Ramachandra et al. 2017, Verma et al. 2013), and 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.

- **Pollination service:** The natural processes of regeneration of the forest, fruiting, and food production from landscapes are due to pollination and seed dispersal from various agents. Pollination is a key service that governs biological production, and the maintenance of biodiversity. Most flowering plants (approximately 78%) depend on pollinators to reproduce and survive (Ollerton et al., 2011). Pollinator abundance will increase the ecosystem supply value through enhanced production levels by improving qualitative aspects of fruit and seed yields, nutritional content, and general appearance, including fruit size (Potts et al. 2016; Balachandran et al., 2017; Porto et al., 2020). This contribution can be well assessed through services such as pollination and seed dispersal (Hipólito et al., 2019), which directly affects the food security of human populations (Potts et al., 2016).

  Pollination services are accounted for through the comparative assessment of natural regeneration of forest patches (with fencing protection from external pressures: (Balachandran et al., 2017; Ray et al., 2015) and afforestation cost. The estimates of natural forest regeneration in all forest types are adjusted according to the forest regeneration in plantations (NAP 2009; Ollerton et al., 2011; Hipólito et al., 2019). The economic value of pollination has been estimated in the current study based on benefit transfer method considering 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). The pollination services vary with forest type, and canopy cover and values range from 10167 INR/Ha/Yr (MDF) to 11907 INR/Ha/Yr (VDF) (Verma et al. 2013) with regard to forest regeneration, excluding the contribution to agricultural production. The estimates of natural forest regeneration in all forest types are further adjusted according to the forest regeneration in plantations. The economic value so estimated is limited only to the value of artificially replacing the process of natural forest regeneration and covers partly the economic value of forest succession.

- **Air filtration services**: Forests moderate air quality and reduce pollution that affects human health and well-being, ecosystem health, crops, climate, etc. Forests remove gaseous air pollutants and improve the quality primarily by uptake via leaf stomata (Nowak et al. 2014) and provide clean air by capturing

the dust. Densely forested regions can remove air pollution, accounting for around 16%; moderately dense forests can remove up to 4.5%; and sparse cover can remove up to 1%, depending on the meteorological conditions (Nowak et al. 2006). The air quality service value of forest ecosystems ranges from 8,368 INR/Ha/Yr (MDF) to 22,617 INR/Ha/Yr (VDF) based on published literature from case studies in India (Ninan and Kontoleon, 2016, Joshi G and Negi GCS, 2011) which are comparable to tropical forest ecosystems in the global ecosystem service valuation database (ESVD) adjusted for GDP (PPP) per capita for India and the prevailing currency exchange rate (March 2020).

- **Local (micro and meso) climate regulation services**: Forest vegetation plays a crucial role in moderating the local climate. The presence of native vegetation improves the living conditions, regulates ambient atmospheric conditions for the people, and supports economic production. Forests also contribute to local atmospheric climatic moderation, humidity, and rainfall. Local climate regulation services value ranges from 17,933 INR/Ha/Yr (MDF) to 48,468 INR/Ha/Yr (VDF) quantified through benefit transfer method based on published literature from case studies in India (Ghosh, 2020, Verma et al., 2007), which are comparable to values for tropical forests in global ecosystem service valuation database (ESVD) adjusted for GDP (PPP) and currency exchange rate as on March 2020 (USD to INR).

Cultural ecosystem services from forest ecosystem: Cultural ecosystem services are the contributions to benefits and wellbeing people gain from their interactions with different environmental areas, which can be valued in terms of monetary, qualitative, quantitative methods. Cultural services generally reflect social connections, sensory experiences, symbolic importance, and identity. The forest has a high cultural value; the main reason can be attributed to the aesthetic beauty, recreational benefit, spiritual and historic (*Kan* forests, which are the sacred groves present in the district) values. Sacred groves are communally protected forest fragments with significant religious connotations (Ramachandra et al. 2010, 2017; Ray et al. 2010). Protected areas in Karnataka are Bannerghatta National Park, Anshi National Park, Bandipur National park, Kudremukh National Park, Arabithittu Wildlife Sanctuary, Bhadra Wildlife Sanctuary, Bhimgad Wildlife Sanctuary, Biligiri Rangaswamy Temple (BRT) Wildlife Sanctuary.

Further, recreational benefits provided by the forest include gaming, trekking, swimming, walking, hunting, etc. The aesthetic beauty of the forest is valuable; the presence of waterfalls and caves adds to the aesthetic value of the district. Education, scientific, and research value provided by the forest are indispensable as many long-term ecological monitoring research stations are set up by the major science and research institutes and organizations.

- **Aesthetic** - National parks, sanctuaries, waterfalls: Data pertaining to the entry fees (park, recreation spots), and details of visitors were compiled from the forest divisions (Uttara Kannada, Shimoga, Chikmagalur Dakshina Kannada, and Kodagu districts) of the Karnataka Forest Department. Valuation of aesthetic services is computed 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 (Ray et al. 2010; Bharath et al. 2017; Ramachandra et al. 2018c) and travel expenses associated to the travel, based on the address of visitors and considering the connectivity (road/train) and additional details collected from the service providers on revenue during the past three years. The data collected from the service operators include (i) cost (labor, fuel, and maintenance) and (ii) annual revenue. The aesthetic value is computed based on these (travel expenses, entrance fee, maintenance cost and benefits to service operators), which accounts for 1500±250 ₹/Ha/Yr and an average value of Rs 1500 ₹/Ha/Yr was considered for accounting for the aesthetic cultural services from forest ecosystems in Karnataka.

- **Spiritual and historic** - Distribution of sacred groves (relic forests - protected due to belief and customs): Sacred groves or *kan* forests of Central Western Ghats of Karnataka are climax evergreen forests, preserved through generations as sacred forests by the village communities of Malnadu regions. Patches of forests are dedicated to deities and used for worship and cultural activities by the local communities. In the past, *kans* numbered in the thousands, each *kan* measuring originally from a few hectares to several hundred hectares in area. They were characteristic of the traditional land use of Shimoga, Uttara Kannada, and Chikmagalur districts especially, and were equivalent to the devarakadus of Kodagu region. *Kan* forests functioned as important sources of perennial streams and springs used for irrigation crops and domestic needs. However, the curtailment of community rights in the *kans*, in districts of the central Western Ghats, including heavier taxation for collection of forest produce, resulted in the abandonment of many of them, causing various hardships to the villagers (Chandran et al. 2010; Ramachandra et al. 2012, 2016, 2017, 2019a; Ray et al. 2014b, 2015).

  Sacred groves or *devarakadu* in Kodagu district, Karnataka: Sacred groves or *devarakadu* or *kan* forests are culturally protected patches of forests that continue to thrive as a living tradition in Kodagu district. The district has the highest density of groves in the world. The extent of sacred groves in Kodagu is 2,500 hectares, i.e., around 2% of the land area in the district, with at least one grove for every 300-hectares. The groves are owned by the Forest Department and declared as Protected Forests, but are managed by local

communities as common property resources. Twenty-four villages in the district have more than ten sacred groves supporting diverse and unique flora and fauna. Overall, Kodagu has 1214 sacred groves (Figure 4.1.4) under three taluks. These are community-managed forests protected due to traditional practices, and they serve as crucial habitats for the conservation of endangered taxa. These groves also act as islands for protecting the biodiversity of rare species in high human-dominated landscapes (Garcia and Pascal 2006; Ormsby and Bhagwat 2010).

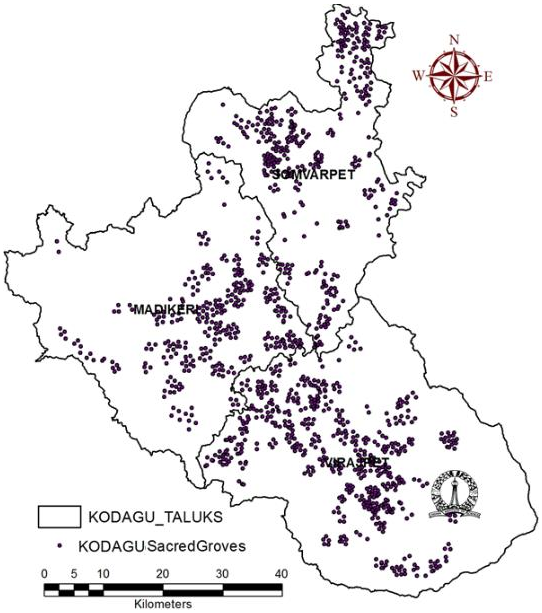


Figure 4.1.4. Distribution of Sacred groves/ *kans* in Kodagu district.

The cultural services from the forest ecosystem can be aesthetic, recreational and tourism, spiritual, education, scientific, and research. The spiritual value of the Uttara Kannada district is also high due to the presence of sacred groves, many temples, and pilgrimage centers like Gokarna, Murdeshwar, Dhareshwar, Idagunji, Banavasi, etc. There are 121 deities and unique forms of worship (Figure 4.1.5) practiced by 18 local communities, including Muslims, symbolizing communal unity (Ramachandra et al. 2019a).

The presence of sacred groves is important for the cultural services as there are many cultural beliefs associated with the sacred groves in India. Some groves have valuable timber in them but are not harvested for timber due to sacred beliefs. The taluks of Siddapur and Sirsi in Uttara Kannada district have higher cultural values as the region is rich in sacred grooves. The presence of wildlife sanctuaries, national parks, and groves, in turn, increases the science and educational value of the forest ecosystem.

The valuation of spiritual and historic services is done by collecting primary data (Annexure 3.3) pertaining to the amount collected for performing rituals

and expenses during 2018, 2019, and 2020. Rituals are performed at the sacred groves, and the amount paid is for performing rituals by devotees (either visiting the grove or in absentia). Every family (irrespective of religion/faith) from the region (resident and those who migrated to cities / abroad) makes donations every year. Also, there is the practice of donating money during birthday celebrations or in the name of elders. Data pertaining to the annual collection and expenses were compiled from the administrative / management committees of select groves in Shimoga, Uttara Kannada, and Kodagu districts. Valuation of spiritual and historical services of sacred groves is done by the residual method (annual collection for rituals and deducting costs – priest salary and ritual expenses).

Figure 4.1.4. Various deities in sacred groves

In groves where annual collection details were not available, the travel cost method is used to quantify the service, considering the number of visitors visiting groves for annual rituals, festivals, and other religious activities. This was done through primary surveys of select groves in Uttara Kannada, Shimoga, and Kodagu districts and supplemented with case-studies from India which used the benefit transfer method (Ramachandra et al., 2012, 2017; Ray et al. 2014b, 2015; Ramachandra et al. 2016, 2017, 2019a). Based on the field data supplemented with the information from published literature and consultation with the subject experts, the spiritual and historic services provided by forest ecosystems in Karnataka range from 1,200 ₹/Ha/Yr (MDF) to 7,200 ₹/Ha/Yr (VDF).

- **Tourism & recreational services** comprise travel to natural ecosystems for eco-tourism, outdoor sports, etc. The recreational sites include the Anashi-Dandeli Tiger Reserve, Attiveri Bird Sanctuary, and caves in Yana, Kavala, Uluvi, Sintheri,

etc. Recreation services are accounted for by considering (i) benefits to travel operators (revenue, costs – labor, fuel, and maintenance of vehicles) and (ii) fees (recreation spots) x the average number of visitors to the park during 2020 – park maintenance charges), (iii) supplemented with the Indian case studies - benefit transfer method (Badola et al. 2017; Gunarekha and Binoy 2017; Ramachandra et al. 2019b; Sinclair et al. 2020). Data are compiled from the select recreation spots as per Annexure 3.4. Recreation services ranges from 28,944 ₹/Ha/Yr (MDF) to 2,88,000 (VDF) ₹/Ha/Yr

- **Education, scientific, and research services** of forest ecosystems: Researchers need to take prior permission from the forest department (Forest and Wildlife Research Advisory Committee) to undertake research and monitoring in forests. Details of the research, duration, budget (for field research), and research team details were compiled from the Karnataka Forest Department. This information is supplemented with the data through discussion with researchers and relevant literature on 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). Based on the data, the education, scientific, and research services provided by forest ecosystems account for 4800 ₹/Ha/Yr.

Figure 4.1.6 and Table 4.1.5 summarize the method adopted to compute services from forest ecosystems.

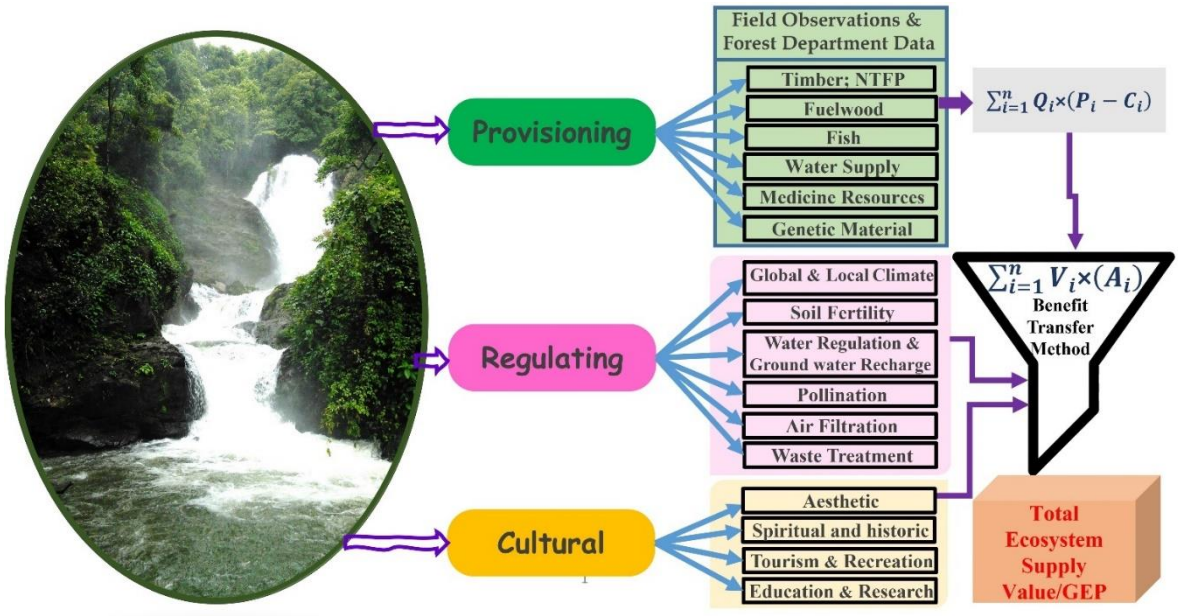


Figure 4.1.6 Method adopted for the valuation of ecosystem services

Table 4.1.5. 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/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 ▪ The ecosystem supply value of rosewood is 140017 Rs/Ha/yr (2005) and 140998 Rs/Ha/yr (2019) based on the data collected across the circles from Karnataka Forest Department. ▪ Teak wood is 79881 Rs/Ha/yr (2005) and 79961 Rs/Ha/yr (2019). ▪ Eucalyptus wood is 4304, and 4265 Rs/Ha/yr for 2005, 2019 respectively. ▪ Softwood is 2692 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.	**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
	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 Produce (NTFP)	▪ The ecosystem supply value of honey is 13177 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.	**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

		▪ 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).	
	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 5097, and 23623 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 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 7736 and 15476 Rs/Ha/yr for the years 2005 and 2019, respectively.	**Residual Method**; $\sum_{i=1}^{n} Q_i \times (P_i - C_i)$
	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	**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

		Rs/Ha/Year (VDF). They are comparable to studies from India and the global database (EVSD), considering GDP(PPP) per capita for India and exchange rate.	the per hectare values based on EVSD, considering 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 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)	InVEST carbon model, quantity of carbon sequestered annually and the social cost of carbon from MOSPI (MoSPI 2020)

	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. The economic value of groundwater (after deducting costs) is about 262.5 Rs/kilo cum of water.	InVEST provides the quantum of water recharge within the natural forested areas.
	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	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

		National Beekeeping & Honey Mission (NBHM, 2019).	
	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
	Waste treatment	The spatial extent of forest ecosystems and 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 G 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 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 compiled (Annexure 3.3) 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	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 method and supplemented with case-studies from India – benefit transfer method

		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	
	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 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).	Based on funding – field research component
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

4.2 Valuation of services from agriculture ecosystems

The revenue due to the services from the agriculture ecosystems is determined through 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, 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 literature reviews (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 used. The method for evaluating the services from the agriculture ecosystem is illustrated in Figure 4.2.1. Table 4.2.1 depicts the revenue of various services per hectare, iv) Total ecosystem supply value, and (v) NPV.

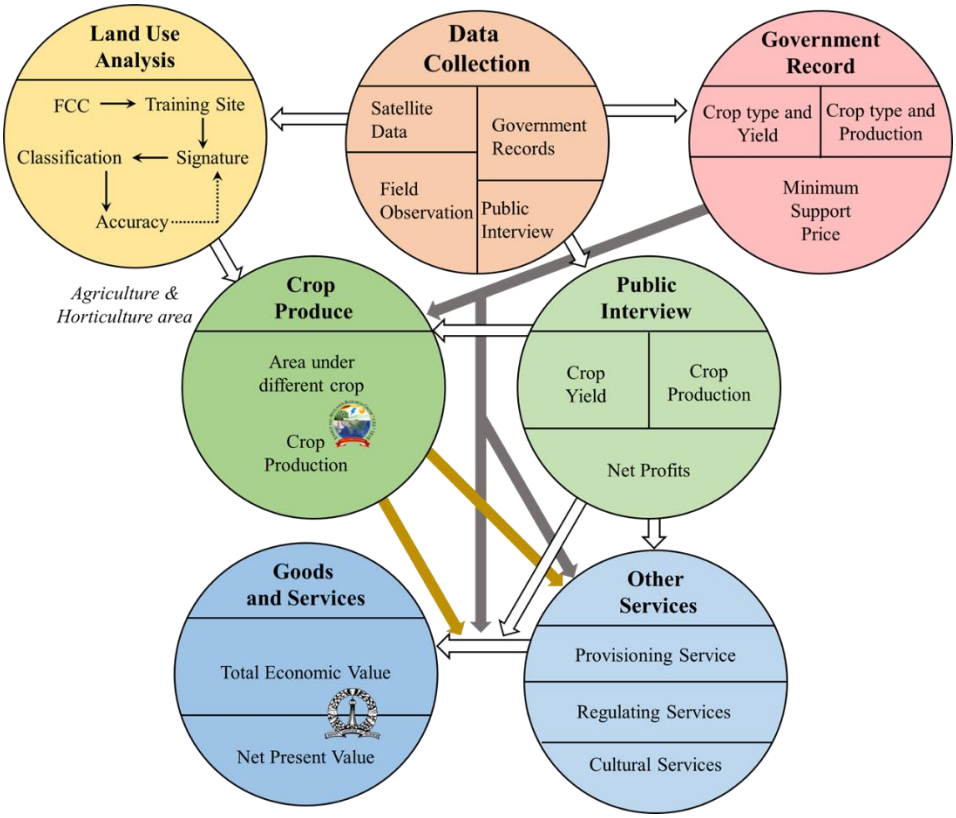


Figure 4.2.1. Method for accounting services in the agriculture (croplands and horticulture) ecosystem

Table 4.2.1. Revenue generated per unit area

Services	Variables	Data and source	Approach
Provisioning	Food	MSP – Cost of production government records and public interview	**Residual Method** $\sum_{i=1}^{n} Q_i \times (P_i - C_i)$
	Fodder	**3000** – 5000 Rs/Acre, 7500-12500 Rs/Ha	

		Public interview, the lowest value is used for accounting	Where Qi represents quantity, Pi is the price, Ci is the cost involved in the harvest
	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 regulation	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 regulation - carbon sequestration	**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 the Indian case studies (Murali 2010)	InVEST carbon model
	Soil carbon sequestration	**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 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)	CHN elemental analyses of representative soil samples, Benefit transfer method InVEST carbon model
	Water flow (groundwa	**Agriculture (croplands)** 792 Rs/Ha/Year	InVEST

	ter recharge)	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	
	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 and inorganic materials	5760 Rs/Ha/Year (Nayak et al. 2019)	Benefit transfer method (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

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 to 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, taking into account 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.

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

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).

Section 5.0 Results and Discussion

Valuation of ecosystem services entails the computation of spatial extent and conditions of the respective ecosystems, and quantification of services in physical and monetary units. The spatial extent (Ramachandra et al. 2021a) and the condition of forests (Ramachandra et al. 2021b) assessed district-wise earlier for Karnataka (Ramachandra et al. 2021a, b) were 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 present (i) the extent of ecosystems in Karnataka, (ii) valuation of ecosystem services, (iii) computation of TESV: Total ecosystem supply value and 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, areca nut, 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).

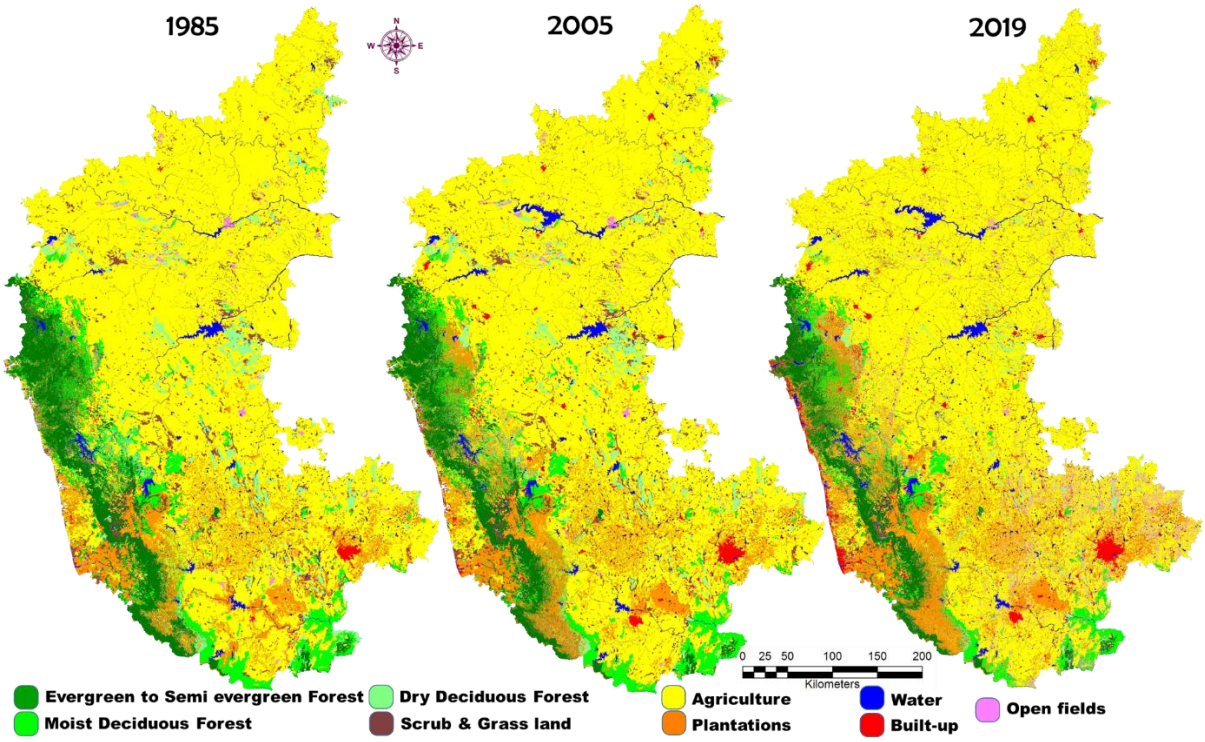


Figure 5.1. Land uses from 1985 to 2019 in Karnataka

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 areca nut 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 a loss of agricultural areas in the sub-urban regions with new layouts and satellite towns. The land-use transitions (Table 5.2) from 1985 to 2019 are computed to understand the probability of changes in each land use type from time t_1 to time t_2. Table 5.3 summarises the ecosystem extent account for Karnataka, which uses land use - land cover (LULC) classes as proxies for ecosystem type.

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 km^2 area under VDF (2019), which accounts for 6% of the entire landscape, and MDF covers 12,869 km^2, which accounts for 7% of the state land area (Figure 5.2).

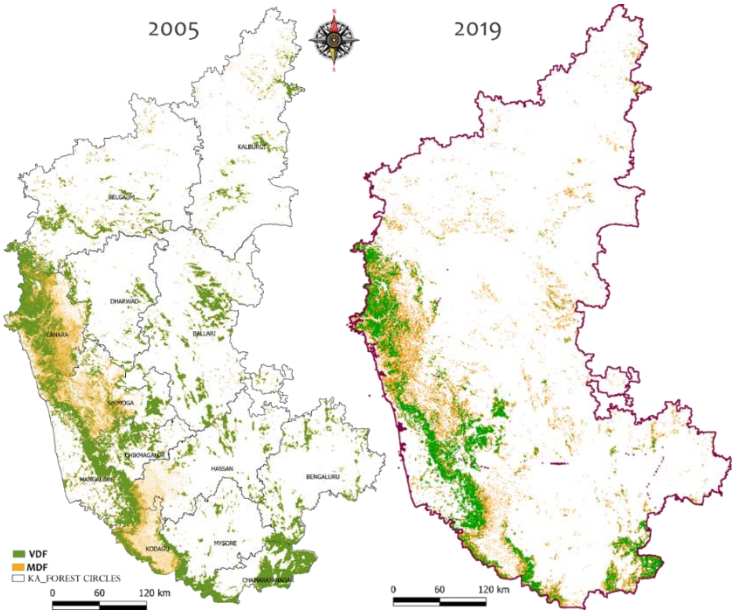


Figure 5.2. Very dense forest (VDF) and medium-density forests (MDF) in Karnataka

Table 5.4 provides a breakdown 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.

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

Ecosystem type / Year	Units	Built-up	Crop land	Horticulture	Fallow land	Evergreen forest	Moist deciduous forest	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	

Table 5.2. Ecosystem extent change matrix from 1985 to 2019 – Karnataka State (extent in sq.km and percentage)

2019 Ecosystem type / 1985	Units	Built-up	Agriculture - Crop lands	Horticulture	Fallow land	Evergreen forest	Moist deciduous forest	Dry deciduous forest	Scrub /Grass lands	Water	Total (opening stock) 1985
Built-up	sq.km.	859	20	15	2	1	3	1	2	2	904
	%	95.0	2.2	1.7	0.2	0.2	0.4	0.1	0.2	0.3	
Agriculture - Crop lands	sq.km.	3194	114202	4003	390	940	98	1109	2451	2081	128468
	%	2.5	88.9	3.1	0.3	0.7	0.1	0.9	1.9	1.6	
Horticulture	sq.km.	775	3344	11661	185	243	258	93	108	122	16790
	%	4.6	19.9	69.5	1.1	1.4	1.5	0.6	0.6	0.7	
Fallow land	sq.km.	50	843	32	710	1	2	12	13	15	1678
	%	3.0	50.2	1.9	42.3	0.1	0.1	0.7	0.8	0.9	
Evergreen Forest	sq.km.	175	416	2372	151	9097	1402	211	286	182	14293
	%	1.2	2.9	16.6	1.1	63.6	9.8	1.5	2.0	1.3	
Moist Deciduous Forest	sq.km.	190	1973	1648	485	388	5581	470	164	61	10960
	%	1.7	18.0	15.0	4.4	0.4	54.1	4.3	1.5	0.6	
Dry Deciduous Forest	sq.km.	85	3374	779	458	68	419	2306	87	47	7622
	%	1.1	44.3	10.2	6.0	0.9	5.5	30.3	1.1	0.6	
Scrub/Grass lands	sq.km.	327	3056	701	438	136	113	72	1787	103	6733
	%	4.9	45.4	10.4	6.5	2.0	1.7	1.1	26.5	1.5	
Water	sq.km.	93	734	114	35	14	16	7	9	3321	4344
	%	2.1	16.9	2.6	0.8	0.3	0.4	0.2	0.2	76.5	
Closing Stock, 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	

Table 5.3. Net additions and reductions in ecosystems in Karnataka State, India

Ecosystem type	Disaggregated ecosystem type	Karnataka				
		Opening stock 1985	Additions to stock	Reduction in stock	Closing stock 2019	Net change (in%) during 1985 to 2019
Built-up land	Built-up	904	4866	45	5725	533.1
	Urban					
	Rural					
	Mining					
	Sub-Total 1	**904**	**4866**	**45**	**5725**	**533.1**
Agricultural land	Horticulture	16790	9711	5129	21371	27.3
	Cropland	128468	13760	14317	127910	-0.4
	Fallow Land	1678	6284	968	6994	316.7
	Sub-Total 2	**146936**	**29754**	**20414**	**156275**	**6.4**
Forests	Evergreen/Semi-Evergreen	14293	921	5196	10018	-29.9
	Moist Deciduous	10960	2333	5379	7914	-27.8
	Dry Deciduous	7622	981	5316	3288	-56.9
	Scrub Forest	6733	922	4946	2710	-59.8
	Forest Plantation					
	Swamp/Mangroves					
	Sub-Total 4	**39607**	**5158**	**20836**	**23929**	**-39.6**
Grass / Grazing	Grass / Grazing					
	Sub-Total 5					
Snow and glacier	Snow and Glacier					
	Sub-Total 6					
Wetlands / water bodies	Inland Wetland					
	Coastal Wetland					
	River/stream/canals					
	Waterbodies	4344	2541	1023	5862	35.0
	Sub-Total 7	4344	2541	1023	5862	35.0
Grand total		191791	42319	42319	191791	

Table 5.4. Circle wise forest ecosystem reclassified as VDF and MDF

Sno	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).

Forests are multi-functional: they provide an often complex array of goods and services. Forests, both natural and planted, and including trees spread across the terrain, have a critical role in the ecology, aesthetics, and recreational benefits. Tables 5.2.1 and 5.2.2 present the biophysical ecosystem supply from forests between 2005 and 2019. The flows for each ecosystem service are recorded using a unit of measure that is appropriate for that ecosystem service (for example, cubic meters for timber, kg's/tons for NTFP or fuelwood, etc.).

Recording monetary values for ecosystem services underpins the compilation of two of the ecosystem accounts: the ecosystem services flow account in monetary terms and the monetary ecosystem asset account. The monetary ecosystem services flow account records the monetary value of flows of ecosystem services based on their exchange values. The data from this account can be used to understand the relative economic significance of different ecosystem services (within the valuation framing of the System of National Accounts), support aggregation of ecosystem services to

compare the role of different ecosystem assets, understand changes in monetary value over time, underpin comparison of the inputs of different ecosystem services to different users, and support understanding the role of ecosystem services in different locations (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. Tables 5.2.3 and 5.2.4 record ecosystem provisioning services in monetary terms for 2005 (at 2019 values) and 2019, respectively.

A comparison of values of services of 2019 with 2005 (at 2019 values) 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 5.2.5 and Table 5.2.6 list services by ecosystem type (forest, agriculture, and horticulture) for 2005 (at 2019-2020 values) and 2019, respectively. Table 5.2.7 gives a comparison of 2019 ecosystem services values with 2005. 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 5.2.1. Ecosystem supply in physical terms, by ecosystem type, 2005

Ecosystem type / Year / Units		Built-up	Crop land	Horticulture	Fallow land	Evergreen forest	Moist deciduous forest	Dry deciduous forest	Scrub \ grass land	Water	Total
2005	sq.km	2,666	127,196	20,209	1,185	12,445	9,900	7,410	5,604	5,177	191,791
Extent	%	1.4	66.3	10.5	0.6	6.5	5.2	3.9	2.9	2.7	100
Ecosystem Goods (Physical) – Karnataka											
Rosewood (Cum)						7,536	5,994				13,530
Teak wood (Cum)								3,242			3,242
Eucalyptus (Cum)							8,367	6,263	4,736		19,366
Soft wood (Cum)						4,915	3,910				8,825
Other kinds of timber (Cum)							17,629	13,195	9,979		40,802
Pulpwood (Cum)							1,397	1,046	791		3,234
Round Poles (numbers)							16,176	12,108	9,157		37,441
Sandal wood (Kg)							9,500	7,111	5,378		21,989
Bamboo Nos							7,39,718	5,53,668	4,18,725		17,12,112
Canes Nos						1,80,407	1,43,514				3,23,921
Firewood Ton			15,274	2,427	147	2,14,94,440	1,70,98,832	1,27,98,216	96,78,975		6,10,88,306
Honey ton						2,00,126	1,59,200	1,19,159	90,117		5,68,602
Soap nut ton							1,84,700	1,38,245	1,04,552		4,27,497
Cashew ton							11,194	8,379	6,336		25,909
Tamarind ton							12,978	9,714	7,347		30,039
Ramapatre (nutmeg – *Myristica malabarica*) ton						9,571					9,571
Dalchini ton						5,379	4,279				9,658

Murugalu (kokum or *Garcinia indica*) ton					2859	2275				5,134
Fish ton					57,305	45,586	34,121	25,805	23,838	1,86,655
Fodder k ton		12	19	1	13,749	10,937	8,186	6,191		39,063
Medicine ton					2,72,010	2,16,384	1,61,960	1,22,486		7,72,840
Water million m^3	1,433	68,369	10,863	637	6,689	5,321	3,983	3,012	2,782	1,03,090
Genetic ton					1,33,79,956	1,06,43,757	79,66,691	60,25,012		3,80,15,416
Cereals tons		1,09,39,568		1,01,917						1,10,41,485
Pulses tons		14,13,459		13,168						14,26,627
Oilseeds tons		18,74,861		17,467						18,92,328
Commercial plantation (sugarcane, coffee, tobacco) tons		140,59,607	22,33,801	1,30,984						1,64,24,392
Horticulture (arecanut, coconut)) tons			14,18,616							14,18,616
Fruits tons	30,456	14,53,078	2,30,866	13,537						17,27,937
Vegetables- tons	25,301	11,98,204	1,89,761	10,843						14,24,110

Table 5.2.2. Ecosystem supply in physical terms, by ecosystem type, 2019

Ecosystem type / Year / Units		Built-up	Crop land	Horticulture	Fallow land	Evergreen forest	Moist deciduous forest	Dry deciduous forest	Scrub _grass lands	Water	Total Area
2019	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	66.7	11.1	1.5	5.7	4.1	2.2	2.6	3.1	100
Ecosystem Goods (Physical) - Karnataka											
Rosewood (Cum)						4,591	3,653				8,244
Teak wood (Cum)								3,538			3,538
Eucalyptus (Cum)							10,893	8,153	6,166		25,212

Soft wood (Cum)					4,447	3,538				7,985
Other kinds of timber (Cum)						17,225	12,893	9,751		39,869
Pulpwood (Cum)						2,393	1,791	1,355		5,539
Round Poles (Nos)						17,752	13,287	10,049		41,088
Sandal wood (Kg)						3,786	2,833	2,143		8,762
Bamboo Nos						54,819	41,031	31,031		1,26,881
Canes Nos					19,987	15,900				35,887
Firewood ton		38,320	6,834	861	132,948	1,05,760	79,160	59,867		4,23,921
Honey ton					5,610	4,462	3,340	2,526		15,938
Soap nut ton						36,516	27,331	20,670		84,517
Cashew ton						401	300	227		929
Tamarind ton						3,318	2,484	1,878		7,680
Rampatri (nutmeg – *Myristica malabarica*) ton					4					4
Dalchini ton					77	62				139
Murugalu (kokum or *Garcinia indica*) ton					73	58				131
Fish ton					57,305	45,586	34,121	25,805	23,838	1,86,655
Fodder k ton		113,412	18,872	1,145	5,913	4,704	3,521	2,662		16,936
Medicine ton					1,88,268	1,49,767	112,098	84,777		5,34,911
Water million m^3	686	32,745	5,202	305	3,203	2,548	1,907	1,442	1,332	49,374
Genetic ton					75,94,703	60,41,588	45,22,037	34,19,905		2,15,78,233
Cereals tons		1,05,74,120		2,35,840						1,08,09,959
Pulses tons		16,39,096		36,558						16,75,654
Oilseeds tons		9,76,167		21,772						9,97,939
Commercial plantation (sugarcane, coffee, tobacco) tons		3,54,33,331	59,05,001	7,90,287						4,21,28,620
Horticulture (arecanut, coconut) tons			34,10,492							34,10,492
Fruits tons	2,23,851	49,83,364	8,30,483	1,11,146						61,48,844
Vegetables- tons	2,41,652	53,72,724	8,94,112	1,20,826						66,29,314

Table 5.2.3. Ecosystem supply in monetary terms (million ₹), by ecosystem type, 2005

Year / Ecosystem type	Units	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	21.13
Ecosystem Goods (monetary, million ₹) - Karnataka											
Rosewood						₹ 530.9	₹ 422.4				₹ 953.3
Teak wood								₹ 212.0			₹ 212.0
Eucalyptus							₹ 61.3	₹ 45.9	₹ 34.7		₹ 141.9
Soft wood						₹ 6.6	₹ 5.2	₹ 0.0	₹ 0.0		₹ 11.8
Other kinds of timber							₹ 152.7	₹ 114.3	₹ 86.4		₹ 353.4
Pulpwood							₹ 2.2	₹ 1.6	₹ 1.2		₹ 5.0
Round Poles							₹ 5.8	₹ 4.3	₹ 3.3		₹ 13.4
Sandal wood							₹ 142.6	₹ 106.7	₹ 80.7		₹ 330.0
Bamboo							₹ 28.2	₹ 21.1	₹ 15.9		₹ 65.2
Canes						₹ 0.7	₹ 0.5				₹ 1.2
Fuelwood						₹ 17,195.6	₹ 13,679.1	10,238.6	7,743.2		₹ 48,856.4
Honey						₹ 28,043.6	₹ 22,308.7	16,697.7	12,628.1		₹ 79,678.1
Soap nut							₹ 23,947.4	17,924.3	13,555.7		₹ 55,427.3
Cashew							₹ 1,119.4	₹ 837.9	₹ 633.6		₹ 2,590.9
Tamarind							₹ 847.3	₹ 634.2	₹ 479.6		₹ 1,961.1
Ramapatre (nutmeg - *Myristica malabarica*)						₹ 765.7					₹ 765.7
Dalchini						₹ 33.3	₹ 26.5				₹ 59.8

Murugalu (kokum or *Garcinia indica*)					₹ 1,143.7	₹ 909.9				₹ 2,053.6
Fish					₹ 2,408.6	₹ 1,916.1	1,434.2	1,084.6	1,002.0	₹ 7,845.4
Fodder					₹ 23,550.2	₹ 18,734.2	14,022.3	10,604.7	₹ 0.0	₹ 66,911.4
Medicine					₹ 272.0	₹ 216.4	₹ 162.0	₹ 122.5	₹ 0.0	₹ 772.8
Water	₹ 8,598.0	₹ 4,10,214.1	₹ 65,175.1	₹ 3,821.7	₹ 40,135.8	₹ 31,928.0	23,897.7	18,073.2	₹ 16,696.1	₹ 6,09,941.8
Genetic		₹ 0.0	₹ 0.0	₹ 0.0	₹ 1,33,799.6	₹ 1,06,437.6	₹ 79,666.9	₹ 60,250.1		₹ 3,80,154.2
Cereals		₹ 69,204.2		₹ 644.7						₹ 69,848.9
Pulses		₹ 20,397.4		₹ 190.0						₹ 20,587.4
Oilseeds		₹ 43,023.4		₹ 400.8						₹ 43,424.2
Commercial plantation (sugarcane, coffee, tobacco)		₹ 35,475.4	5,636.4	₹ 330.5						₹ 41,442.2
Horticulture (arecanut, coconut)			73,636.0							₹ 73,636.0
Fruits	₹ 372.7	₹ 17,783.2	2,825.4	₹ 165.7						₹ 21,147.0
Vegetables	₹ 191.1	₹ 9,050.7	1,433.4	₹ 81.9						₹ 10,757.1

Table 5.2.4. Ecosystem supply in monetary terms (million ₹), by ecosystem type, 2019

Ecosystem type / Year / Units	Built-up	Crop land	Horticulture	Fallow land	Evergreen forest	Moist deciduous forest	Dry deciduous forest	Scrub _grass lands	Water	Total
2019 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	66.7	11.1	1.5	5.7	4.1	2.2	2.6	3.1	17.68
Ecosystem Goods (monetary, million ₹) - Karnataka										
Rosewood					₹ 307.6	₹ 244.7	₹ 0.0			₹ 552.3
Teak wood							₹ 230.0			₹ 230.0

Eucalyptus						₹ 71.9	₹ 53.8	₹ 40.7		₹ 166.4
Soft wood						₹ 5.5				₹ 12.5
Other kinds of Timber						₹ 144.7	₹ 108.3	₹ 81.9		₹ 334.9
Pulpwood						₹ 3.7	₹ 2.8	₹ 2.1		₹ 8.6
Round Poles						₹ 6.2	₹ 4.6	₹ 3.5		₹ 14.3
Sandal wood						₹ 56.8	₹ 42.5	₹ 32.1		₹ 131.4
Bamboo						₹ 2.1	₹ 1.6	₹ 1.2		₹ 4.8
Canes					₹ 0.1	₹ 0.1				₹ 0.1
Firewood					₹ 20,172.4	₹ 16,047.1	₹ 12,011.0	₹ 9,083.6		₹ 57,314.2
Honey					₹ 785.3	₹ 624.7	₹ 467.6	₹ 353.6		₹ 2,231.3
Soap nut						₹ 4,747.0	₹ 3,553.1	₹ 2,687.1		₹ 10,987.2
Cashew						₹ 40.1	₹ 30.0	₹ 22.7		₹ 92.9
Tamarind						₹ 215.7	₹ 161.4	₹ 122.1		₹ 499.2
Ramapatri					₹ 0.3					₹ 0.3
Dalchini					₹ 24.0	₹ 19.1				₹ 43.1
Murugalu (kokum or *Garcinia indica*)					₹ 29.2	₹ 23.2				₹ 52.4
Fish					₹ 3,724.8	₹ 2,963.1	₹ 2,217.8	₹ 1,677.3	₹ 1,549.5	₹ 12,132.6
Fodder					₹ 13,748.7	₹ 10,937.1	₹ 8,186.3	₹ 6,191.1		₹ 39,063.2
Medicine					₹ 188.3	₹ 149.8	₹ 112.1	₹ 84.8		₹ 534.9
Water	₹ 4,118.0	₹ 1,96,471.6	₹ 31,215.6	₹ 1,830.4	₹ 19,223.0	₹ 15,291.9	₹ 11,445.8	₹ 8,656.1	₹ 7,996.6	₹ 2,92,130.9
Genetic					₹ 75,947.0	₹ 60,415.9	₹ 45,220.4	₹ 34,199.0		₹ 2,15,782.3
Cereals		₹ 81,497.5		₹ 1,817.7						₹ 83,315.2
Pulses		₹ 28,348.2		₹ 632.3						₹ 28,980.4
Oilseeds		₹ 19,894.0		₹ 443.7						₹ 20,337.7
Commercial (sugarcane, coffee, tobacco)		₹ 97,843.3	₹ 16,305.7	₹ 2,182.2						₹ 1,16,331.3
Horticulture (arecanut, coconut)			₹ 80,605.9							₹ 80,605.9
Fruits	₹ 2,480.9	₹ 55,229.5	₹ 9,204.1	₹ 1,231.8						₹ 68,146.2
Vegetables	₹ 1,481.1	₹ 32,929.1	₹ 5,480.0	₹ 740.5						₹ 40,630.6

Table 5.2.5. Ecosystem wise – Provisioning, regulatory and cultural services – 2005 (Million ₹)
(at 2019-2020 values, 2005 values were adjusted to 2019 considering inflation)

Ecosystem type / Year / Units	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 5.2.6. Ecosystem wise – Provisioning, regulatory and cultural services (Million ₹) – 2019

Year / Ecosystem type / Units		Built-up	Crop land	Horticulture	Fallow land	Evergreen forest	Moist deciduous forest	Dry deciduous forest	Scrub _grass lands	Water	Total
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 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

The provisioning services - timber (rosewood (*Dalbergia latifolia*), teak wood (*Tectona grandis, Terminalia arjuna Terminalia elliptica*, *Anogeissus latifolia*, etc.), eucalyptus (*Eucalyptus globulus*), soft wood (*Artocarpus hirsutus, Ailanthus excelsa*, etc.), round poles, pulp wood, sandal wood, other timber), bamboo (Bambusa arundinacea, *Dendrocalamus strictus*, etc.), cane (*Calamus neelagiricus, C. vattayila, C. pseudofeanus, etc.*), NTFP (honey, soap nut (*Sapindus saponaria*), cashew nut (*Anacardium occidentale*), tamarind (Tamarindus indica), dalchini (cinnamon - *Cinnamomum malabatrum*, *Cinnamomum verum*); rampatri (nutmeg - *Myristica malabarica*); murgalu (kokum or *Garcinia indica*)); fuelwood; fodder, etc. extracted (in physical units) with seigniorage values from each circle are provided in Tables 5.3.1 to 5.3.3, and Figures 5.3.1 to 5.3.3 presents circle wise provisioning services. The seigniorage value for 2005 and 2019 are the same for all provisioning services, as per the forest department reports.

***Timber**:* Timber includes rosewood, teak wood, eucalyptus, softwood, round pole, etc. The provisioning services (monetary) of all timber wood products extracted from each circle are assessed considering the respective seigniorage value of individual forest goods are listed in Table 5.3.4. Based on the extraction area, per hectare values of each timber type are computed, which are listed in Table 5.3.5. Figures 5.3.3 and 5.3.4 depict the spatial variability of the ecosystem value of timber goods in Karnataka. The total provisioning value of timber extracted from Karnataka state is 2,023, and 1,445 billion rupees, respectively, for 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, and Mysore circles. Sandalwood is extracted in large quantities from Dharwad, Hassan circles. These values are comparable to the earlier studies in India (Verma et al., 2013). 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 observed is 9,246 Rs/Ha/yr in Hassan, and the minimum value is 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 for 158,134, and 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 from the Mysore circle is 9,241 Rs/Ha/yr, and the minimum value is 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 2005. In 2019 maximum value from the Bangalore circle is 4,295 Rs/Ha/yr, and the minimum value is 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 from the Mysore circle is 9,224 Rs/Ha/yr and the minimum value is 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 from Hassan circle is 9,240 Rs/Ha/yr and the minimum value is 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 the forest inventory. The ecosystem supply value from bamboo and canes was estimated (Table 5.3.6, Figure 5.3.5). Circles such as Canara and Mangalore are getting higher revenue from bamboo, and Bengaluru, Canara Dharwad, and Mangalore are getting 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 2005. In 2019 maximum value from the Hassan circle is 8,911 Rs/Ha/yr, and the minimum value is 1,303 Rs/Ha/yr from the Canara circle.

Fodder Production: Table 5.3.7 lists circle-wise fodder in physical and monetary values per hectare per year. Figure 5.3.6 depicts the circle-wise ecosystem value for fodder, and 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: The quantity of harvested NTFP in physical quantities is assessed and listed category-wise in Table 5.3.8 for 2005 and 2019. The spatial variability is depicted in Figure 5.3.7. These are comparable to a study from India (Verma et al., 2013). Table 5.3.9 lists NTFP values for various forest types per hectare per year. Figure 5.3.8 depicts circle-wise the ecosystem values from NTFP in a million rupees. 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, the 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, and Bengaluru provide moderate amounts, and the least amount is provided by Gulbarga circle.

Table 5.3.1 Timber extracted from each forest circle of Karnataka during 2005 (based on the averages of 2001 to 2005 data) and 2019 (based on the averages of 2015 to 2018), with values in physical units -cum

Sno	Circle name	TIMBER									
		Rosewood (Cum)		Teak wood (Cum)		Eucalyptus (Cum)		Softwood (Cum)		Other kinds of timber (Cum)	
		2005	2019	2005	2019	2005	2019	2005	2019	2005	2019
1	Bengaluru	0	0	0	0	331	561	0	0	854	421
2	Belgaum	46	14	13	15	5	6	0	0	2392	1309
3	Ballari	0	0	0	0	0	0	0	0	387	115
4	Chamarajanagar	0	0	0	0	0	0	0	0	13	77
5	Chikmagalur	324	231	121	212	0	1	133	233	3033	5280
6	Dharwad	4	1	61	85	45	62	0	0	116	93
7	Kalaburagi	0	0	0	0	261	198	0	0	934	708
8	Hassan	37	16	3	3	1894	1556	0	0	180	148
9	Canara	2219	1505	2616	2805	2717	2914	706	758	16682	16715
10	Kodagu	3029	1914	182	163	378	339	174	156	1496	1279
11	Mangalore	50	43	57	77	5861	7911	361	488	2745	3706
12	Mysore	23	14	17	31	5389	9546	0	0	788	1351
13	Shimoga	7798	4506	172	147	2485	2118	7451	6350	11182	8667
Seigniorage Value (₹)		67000	67000	6500	65000	6600	6600	1560	1560	8400	8400

Table 5.3.2. Provisioning services (pulpwood, round poles, sandalwood, bamboo, canes) extracted from each forest circle of Karnataka during 2005 and 2019, with values in physical units

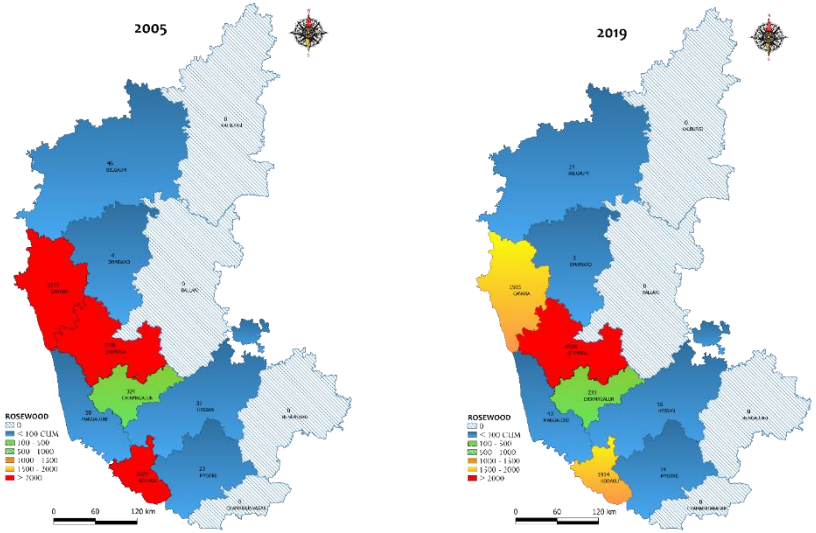
Sno	Circle name	Pulpwood (Cum)		Round Poles (Nos)		Sandalwood (Kg)		Bamboo (Nos)		Canes (Nos)	
		2005	2019	2005	2019	2005	2019	2005	2019	2005	2019
1	Bengaluru	1928	3266	786	1333	38	66	0	0	9150	15500
2	Belgaum	0	0	2337	2605	90	101	318480	0	0	0
3	Ballari	0	0	0	0	0	0	0	0	0	0
4	Chamarajanagar	0	0	0	0	0	0	0	0	0	0
5	Chikmagalur	1306	2273	3675	6396	103	180	26885	14731	0	0
6	Dharwad	0	0	1663	2289	9829	4255	167558	267	1466	2018
7	Kalaburagi	0	0	0	0	0	0	0	0	0	0

8	Hassan	0	0	62	51	4127	3391	0	0	2398	1970
9	Canara	0	0	4824	5173	574	616	489139	85412	272293	10393
10	Kodagu	0	0	2	2	0	0	4820	0	0	0
11	Mangalore	0	0	2261	3052	26	36	17829	21298	33611	6000
12	Mysore	0	0	1720	3048	5263	117	52764	469	3	6
13	Shimoga	0	0	20111	17139	1939	0	634637	4704	5000	0
Seigniorage value (₹)		**1560**	**1560**	**348**	**348**	**15000**	**15000**	**38**	**38**	**4**	**4**

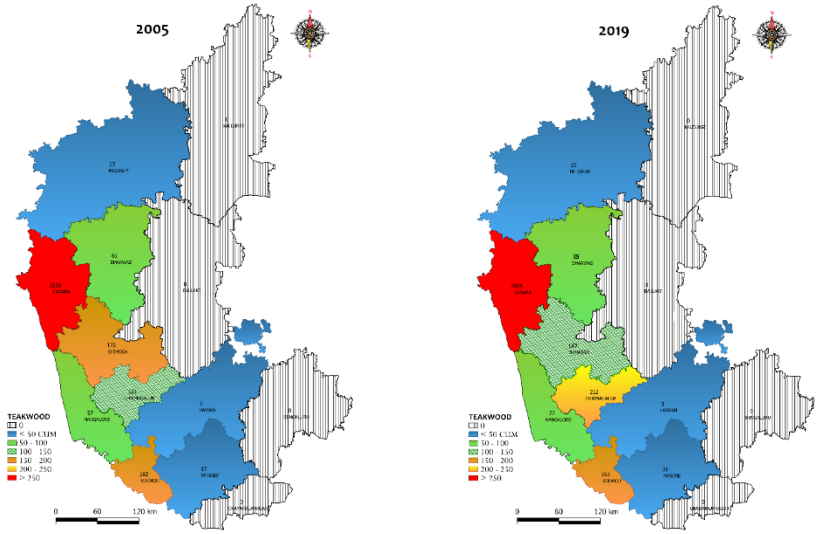
Table 5.3.3. Provisioning services (NTFP - honey, soap nut (*Sapindus saponaria*), cashew nut (*Anacardium occidentale*), tamarind (Tamarindus indica), dalchini (cinnamon - *Cinnamomum malabatrum*, *Cinnamomum verum*); rampatri (nutmeg - *Myristica malabarica*); murgalu (kokum or *Garcinia indica*)) extracted from each forest circle of Karnataka during 2005 and 2019 (in physical tons)

Sno	**Circle name**	**NTFP (tons)**													
		Honey		**Soapnut**		**Cashew**		**Tamarind**		**Ramapatre**		**Dalchinni**		**Murugalu**	
		2005	**2019**	**2005**	**2019**	**2005**	**2019**	**2005**	**2019**	**2005**	**2019**	**2005**	**2019**	**2005**	**2019**
1	Bengaluru	0	0	0	0	1804	67	3967	490	0	0	0	0	0	0
2	Belgaum	0	0	0	0	21282	800	314	35	0	0	0	0	0	0
3	Ballari	0	0	0	0	0	0	139	16	0	0	0	0	0	0
4	Chamarajanagar	33153	9034	868	1000	0	0	0	0	0	0	0	0	0	0
5	Chikmagalur	1109	14	853	101	0	0	38	2	0	0	186	133	574	6
6	Dharwad	0	0	3640	0	0	0	986	75	0	0	9281	0	0	0
7	Kalaburagi	0	0	0	0	0	0	281	13	0	0	0	0	0	0
8	Hassan	0	0	0	0	2508	28	0	0	402	2	0	0	0	0
9	Canara	146	22	15	0	42	11	0	0	14	2	0	0	939	125
10	Kodagu	20775	293	188375	10388	0	0	0	0	8835	0	0	0	3148	0
11	Mangalore	0	0	93937	0	273	23	0	0	320	0	7	6	0	0
12	Mysore	464515	3000	0	0	0	0	4748	150	0	0	184	0	0	0
13	Shimoga	48904	3575	139809	73028	0	0	19566	6899	0	0	0	0	473	0
Seigniorage value (₹)		140000	140000	130000	130000	100000	100000	65000	65000	80000	80000	310000	310000	400000	400000

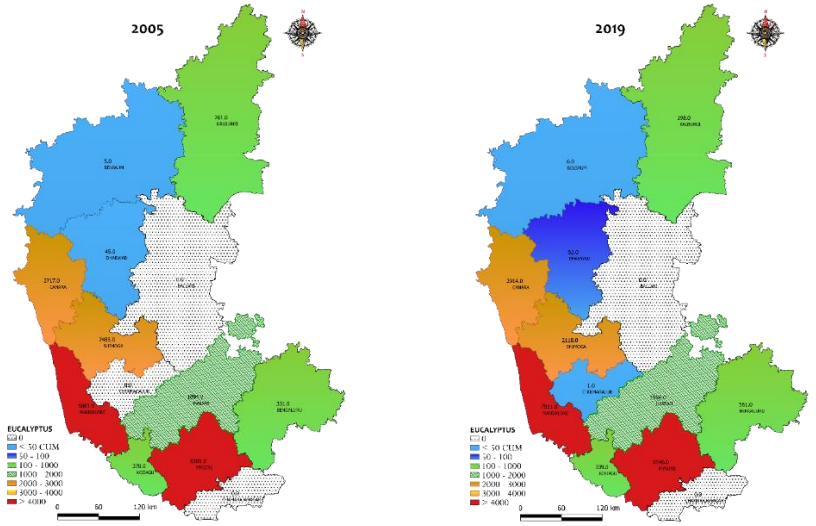
Figure 5.3.1 Timber, bamboo and canes extracted (in the physical units) across forest circles in Karnataka for the years 2005 and 2019



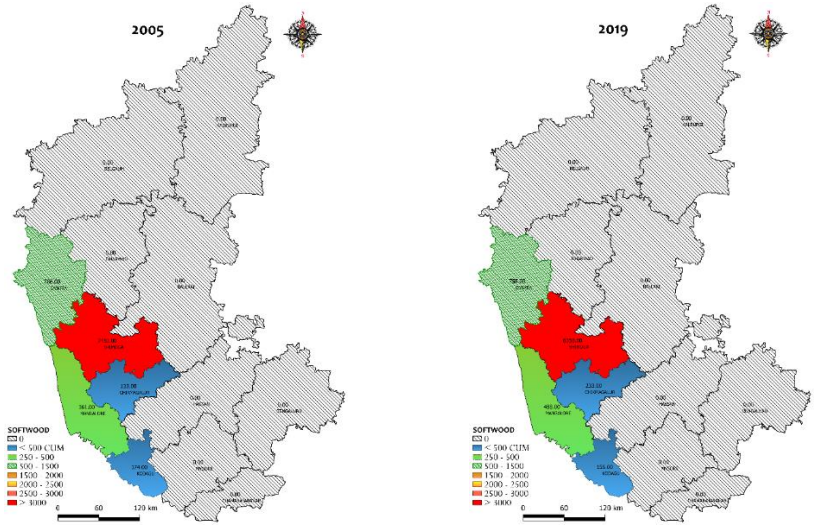
Rosewood



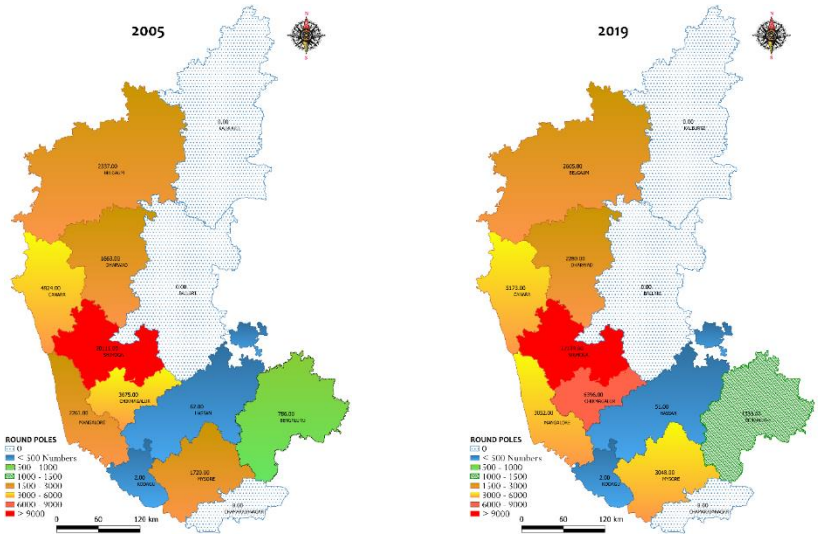
Teak wood



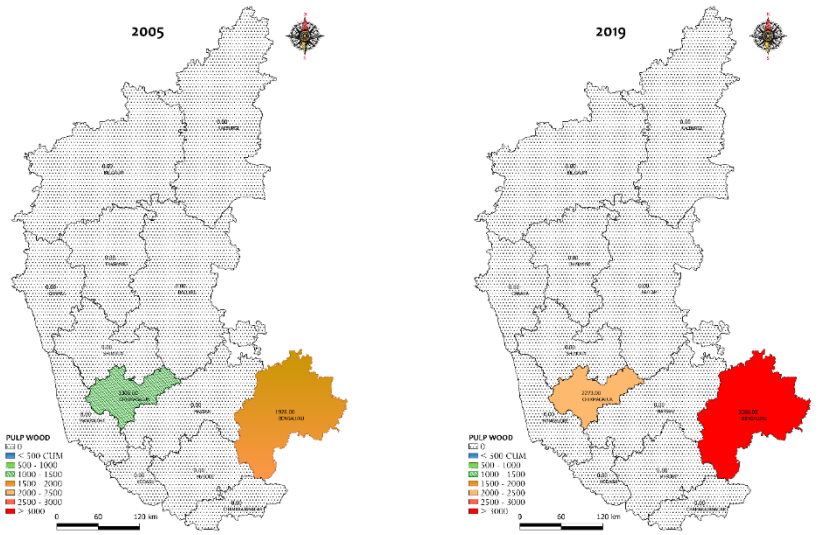
Eucalyptus



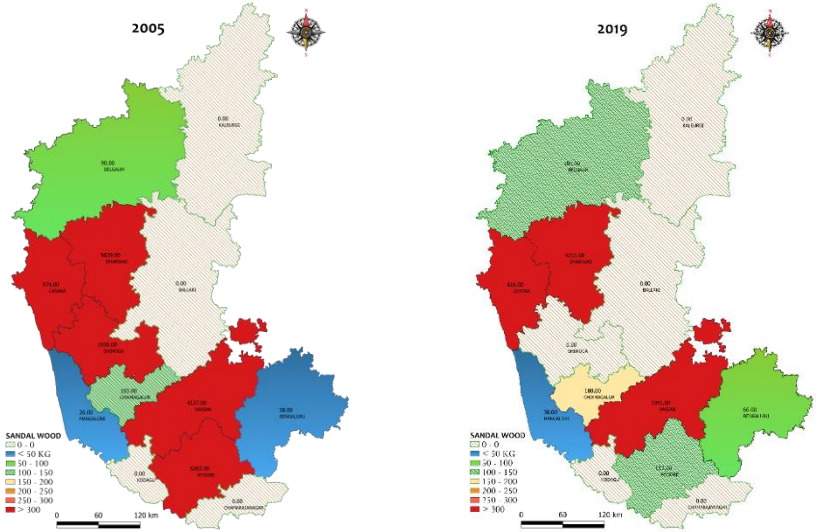
Soft wood



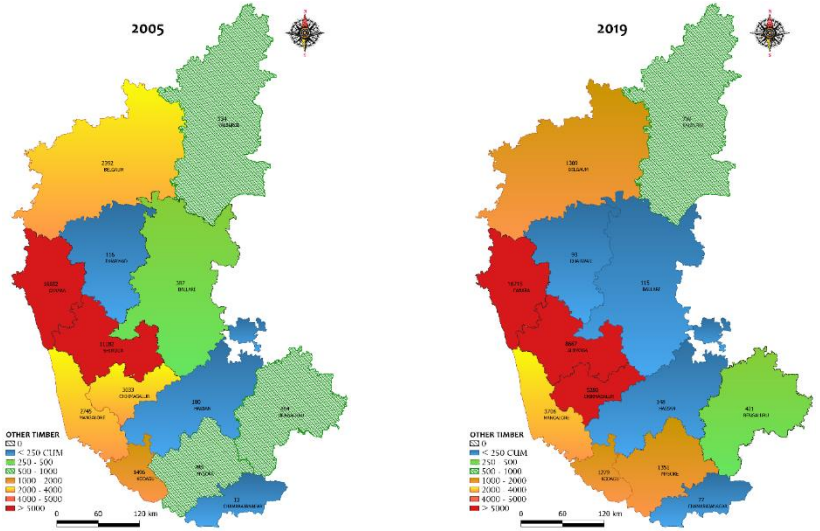
Round poles



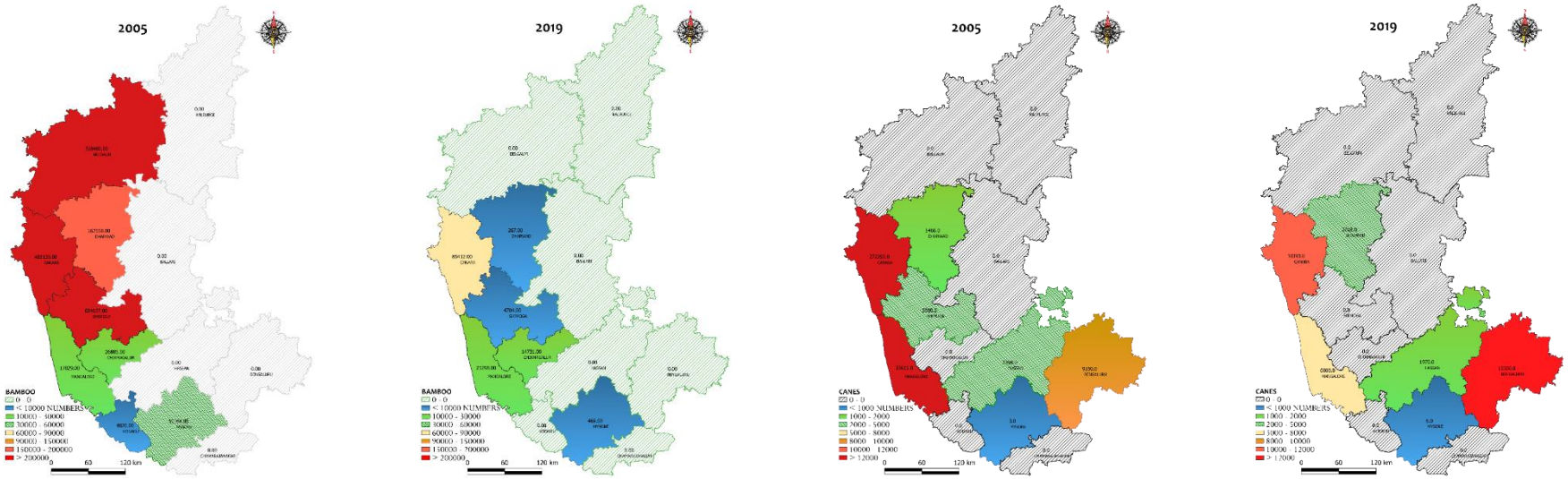
Pulp wood



Sandalwood

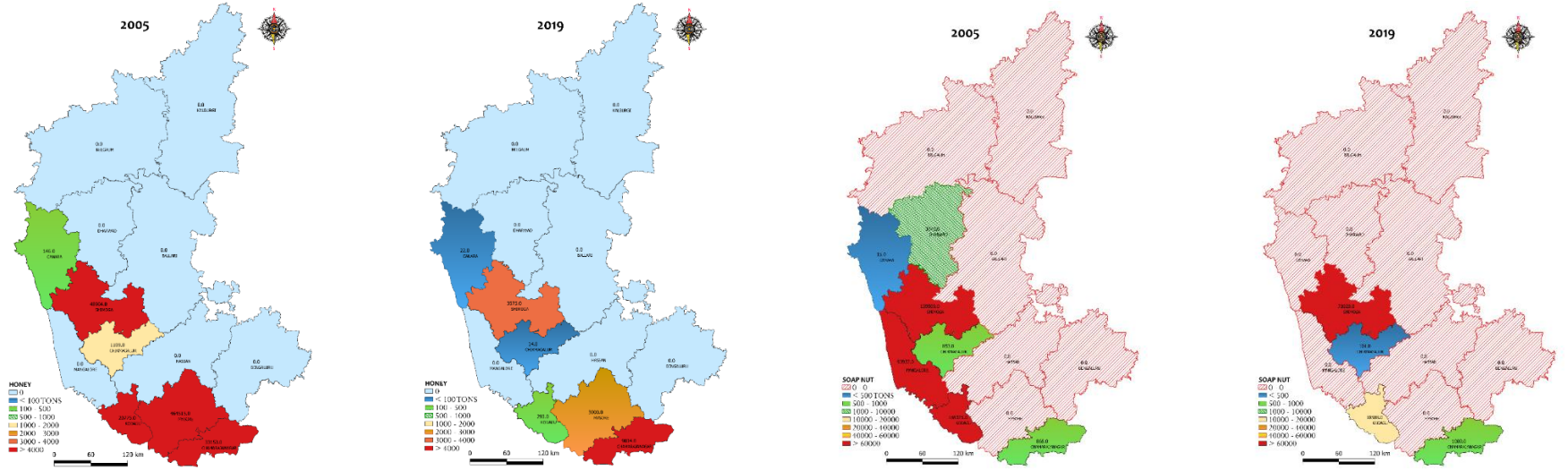


Other timber

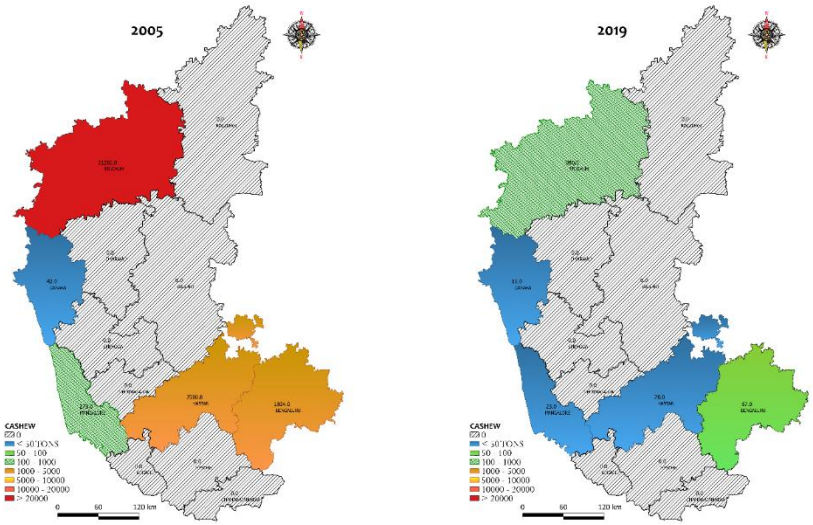


Bamboo Canes

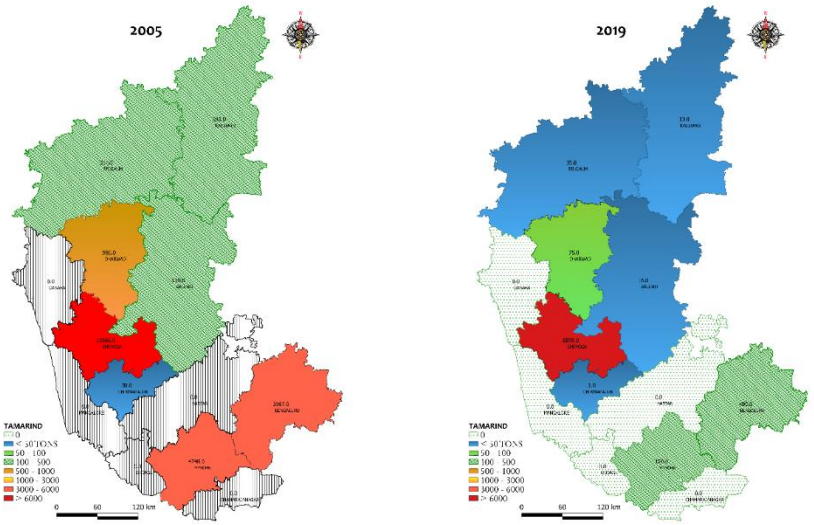
Figure 5.3.2. Quantity of NTFP collected (in physical units) across the circles in Karnataka during 2005 and 2019



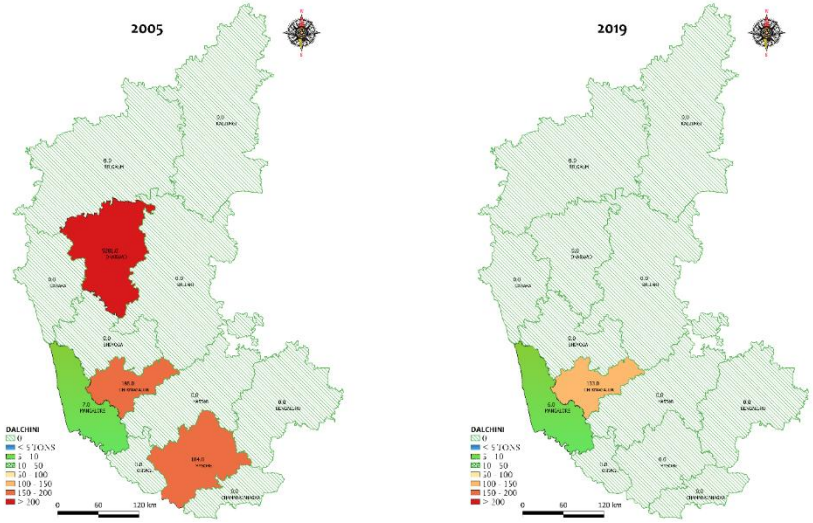
Honey Soap nut



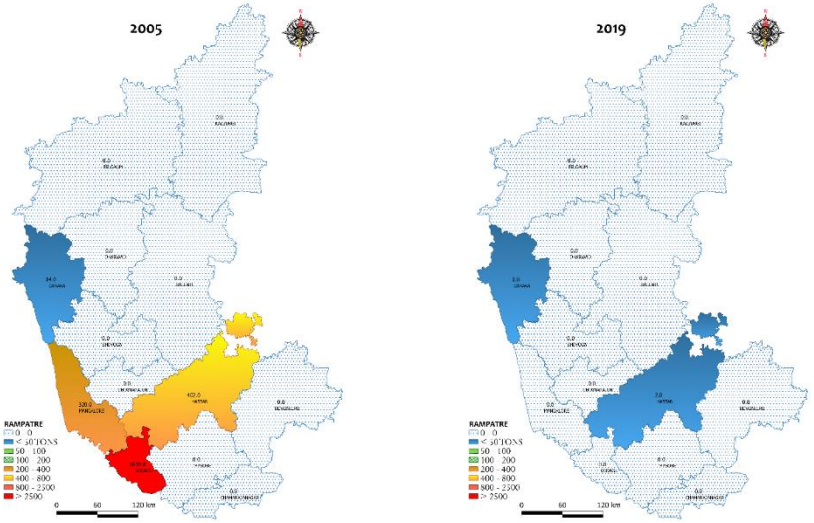
Cashew nut



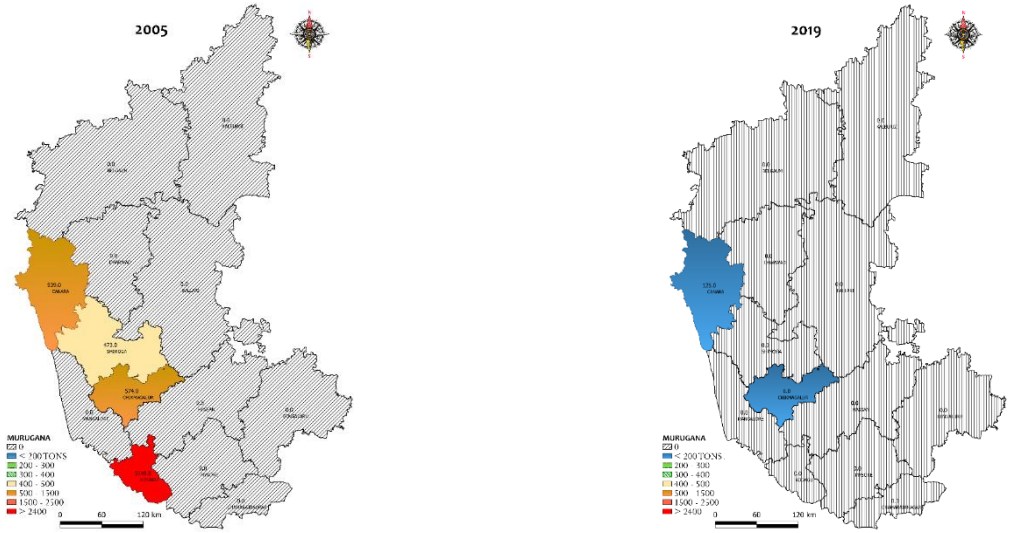
Tamarind



Dalchini (Cinnamon)



Rampatri (Nutmeg)



Murgalu (Kokum)

Table 5.3.4. District-wise ecosystem supply value (₹-INR) of timber, based on seigniorage values and quantity of timber harvested

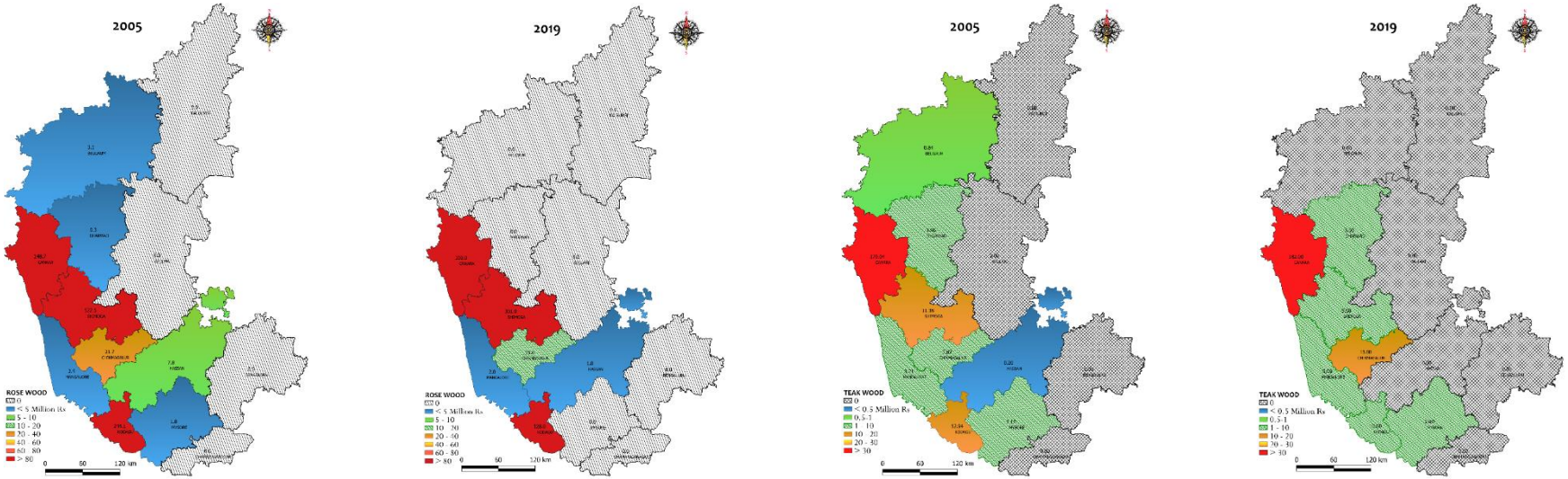
S. no	Circle name	TIMBER (Million Rupees)																	
		Rose wood		Teak wood		Eucalyptus		Soft wood		Other kinds of timber		Pulpwood		Round poles		Sandal wood		Total timber	
		2005	2019	2005	2019	2005	2019	2005	2019	2005	2019	2005	2019	2005	2019	2005	2019	2005	2019
1	Bengaluru	0	0	0	0	2	3	0	0	7	3	3	5	0	0	1	0	13	37
2	Belgaum	3	0	1	0	0	0	0	0	20	10	0	0	1	0	1	1	26	63
3	Ballari	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3	7
4	Chamarajanagar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Chikmagalur	22	15	8	13	0	0	0	0	25	44	2	3	1	2	2	2	60	199
6	Dharwad	0	0	4	5	0	0	0	0	1	0	0	0	1	0	147	63	154	375

7	Kalaburagi	0	0	0	0	2	1	0	0	8	5	0	0	0	0	0	0	10	25
8	Hassan	8	1	0	0	13	10	0	0	2	1	0	0	0	0	62	50	84	230
9	Canara	149	100	170	182	18	19	1	1	140	140	0	0	2	1	9	9	488	1428
10	Kodagu	244	128	13	10	3	2	0	0	14	10	0	0	0	0	0	0	274	698
11	Mangalore	3	2	4	5	52	52	1	0	31	31	0	0	1	1	1	0	93	277
12	Mysore	2	0	1	2	36	63	0	0	7	11	0	0	1	1	79	1	125	327
13	Shimoga	522	301	11	9	17	13	12	9	95	72	0	0	7	5	29	0	694	1797

Table 5.3.5. Value of various timber (₹/Ha/Yr.) in Karnataka (Forest circle wise / forest type-wise)

Sno	Circle name	Timber type (₹/Ha/Yr.)															
		Rose wood		Teak wood		Eucalyptus		Soft wood		Other kinds of timber		Pulpwood		Round poles		Sandal	
		2005	2019	2005	2019	2005	2019	2005	2019	2005	2019	2005	2019	2005	2019	2005	2019
1	Bengaluru					4284	4280			4278	4278	4272	4295	4274	4286	4318	4285
2	Belgaum	154100	151290	76818	77381	3300	3960			3826	3827			3836	3825	3835	3826
3	Ballari									4277	4293						
4	Chamarajanagar									9100	4293						
5	Chikmagalur	150750	150262	77871	77416		3300	3842	3826	3827	3826	3830	3829	3841	3824	3834	3830
6	Dharwad	60909	60909	41302	41231	4368	4263			4293	4292			4319	4306	4274	4274
7	Kalaburagi					4643	4634			4629	4631						
8	Hassan	125355	126117	65000	65000	9246	9235			9276	9208			10788	8874	9237	9240
9	Canara	240571	240656	156863	156906	1302	1303	1303	1307	1302	1302			1303	1304	1302	1302
10	Kodagu	240303	240597	157744	158134	1302	1302	1307	1308	1302	1302			1392	1547		
11	Mangalore	152273	154892	78830	78203	3826	3827	3864	3864	3826	3826			3834	3834	3857	3857
12	Mysore	124759	134000	65000	65000	9238	9235			9245	9241			9353	9224	9237	9237
13	Shimoga	149148	149235	77381	78320	3827	3827	3828	3828	3826	3826			3828	3828	3826	

Figure 5.3.3. Ecosystem supply value (INR) of various timber across the circles for 2005 and 2019

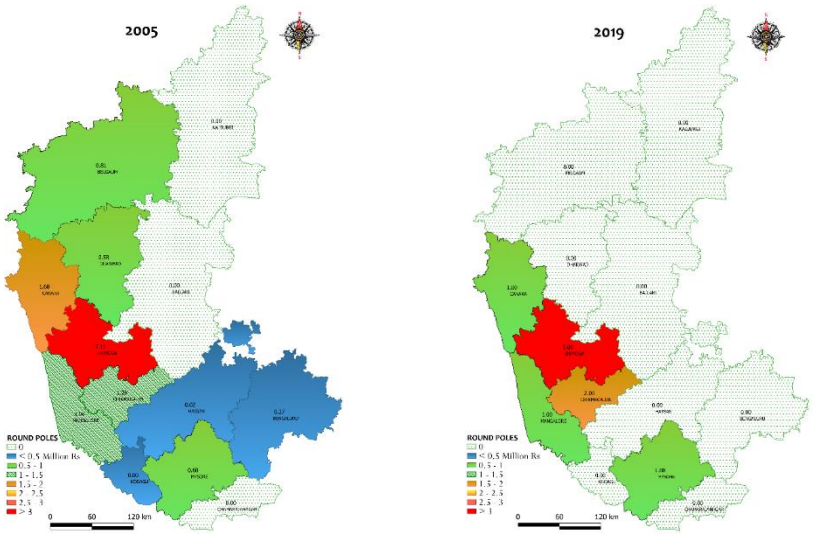


Rosewood

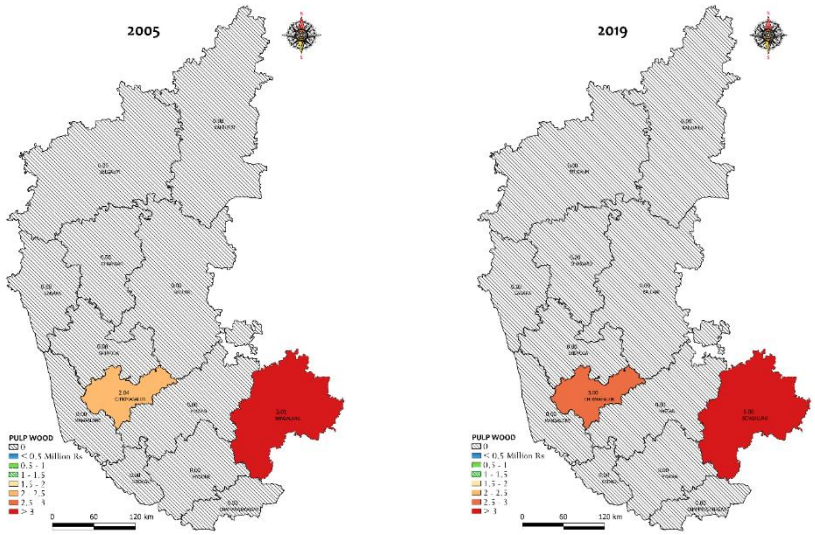
Teak wood

Eucalyptus

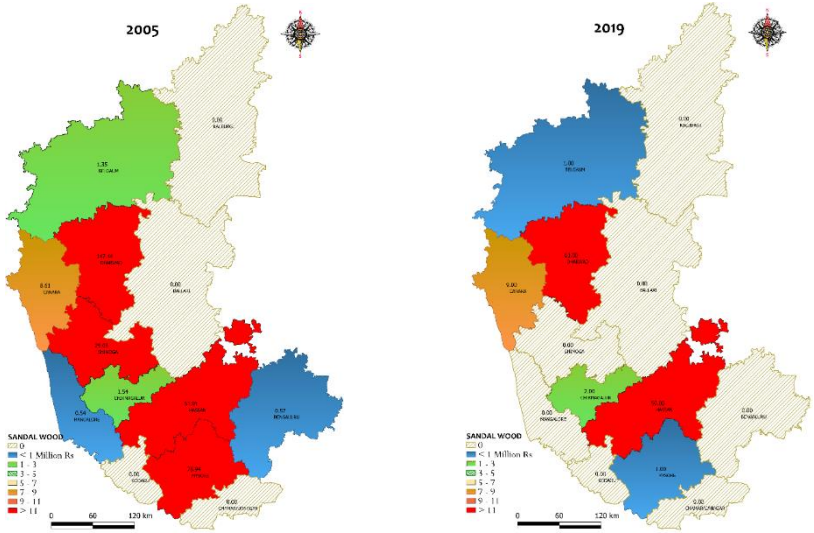
Soft wood



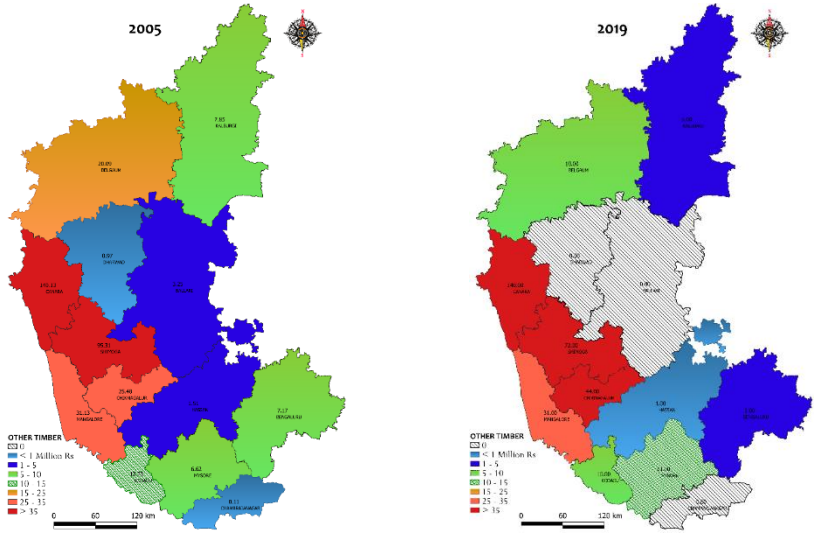
Round poles



Pulp wood



Sandalwood



Other timber

Figure 5.3.4. Aggregated values of timber from forest ecosystems in Karnataka (in a million INR)

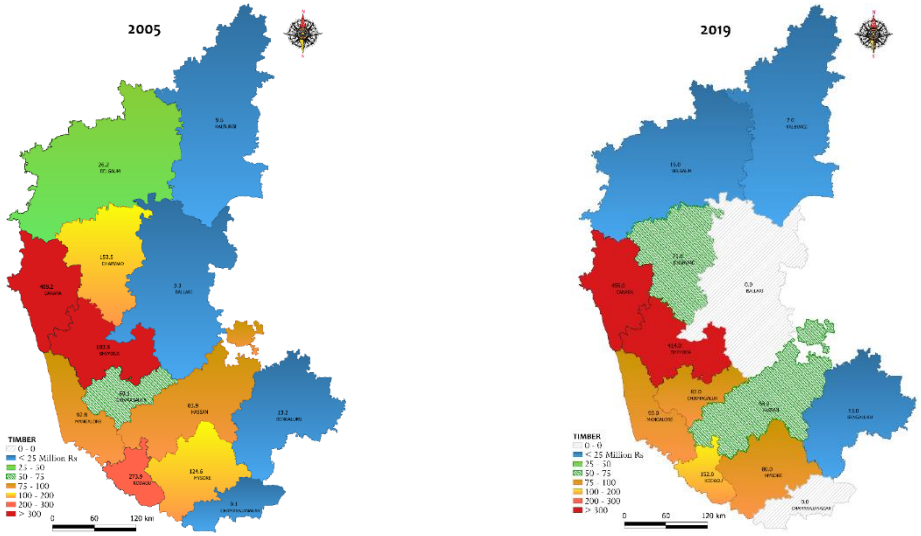
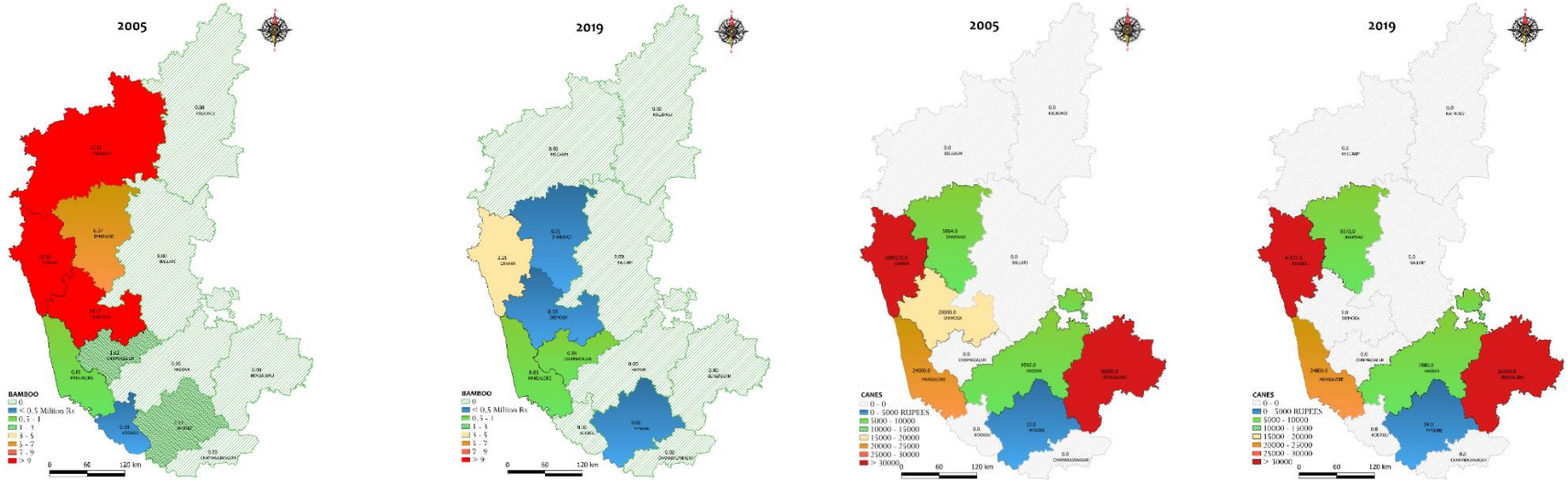


Figure 5.3.5. Ecosystem supply value of bamboo and canes from forests of Karnataka



Bamboo

Canes

Table 5.3.6. Value of extracted bamboo and canes across Karnataka

Sno	Circle name	Bamboo (Million Rupees)		Canes (Million Rupees)		Bamboo (₹/Ha/Yr.)		Cane (₹/Ha/Yr.)	
		2005	2019	2005	2019	2005	2019	2005	2019
1	Bengaluru	0	0	0.037	0.1			24400	23846
2	Belgaum	12	0	0	0	3826			
3	Ballari	0	0	0	0				
4	Chamarajanagar	0	0	0	0				
5	Chikmagalur	1	0.6	0	0	3841	3861		
6	Dharwad	6	0	0.006	0	4279	4612	29320	23741
7	Kalaburagi	0	0	0	0	0			
8	Hassan	0	0	0.010	0	0		5642	5629
9	Canara	19	3.2	1.089	0	1302	1303	1304	1341
10	Kodagu	0	0	0	0	1308		0	
11	Mangalore	1	0.8	0.024	0	3836	3836	194	192
12	Mysore	2	0	0	0	9283	8911	5356	5356
13	Shimoga	24	0.2	0.020	0	3827	3886	191	
Seigniorage rate (₹)		38	38	4	4				

Table 5.3.7. Quantity of fodder produced and its ecosystem supply value across Karnataka

Sno	Circle name	Fodder (Ton)		Fodder (MRs)		Fodder INR/ha/yr	
		2005	2019	2005	2019	2005	2019
1	Bengaluru	1658001	548868	3855	1276	8104	13023
2	Belgaum	2580175	1645663	5999	3826	7233	13586
3	Ballari	1988121	449821	4622	1046	7923	12779
4	Chamarajanagar	2722751	2160460	6330	5023	8988	20050
5	Chikmagalur	2210524	1261473	5139	2933	8344	16143

6	Dharwad	922640	317365	2145	738	7985	14089
7	Kalaburagi (Gulbarga)	998633	255515	2322	594	7202	13173
8	Hassan	1807242	1119519	4202	2603	7368	14064
9	Canara	4918160	3220533	11435	7488	6781	15382
10	Kodagu	1511207	1277404	3514	2970	6538	15895
11	Mangalore	2772886	1506332	6447	3502	8320	17671
12	Mysore	1322496	1131299	3075	2630	8395	17808
13	Shimoga	3366242	1907104	7827	4434	7388	17528

Figure 5.3.6. Ecosystem supply value of fodder

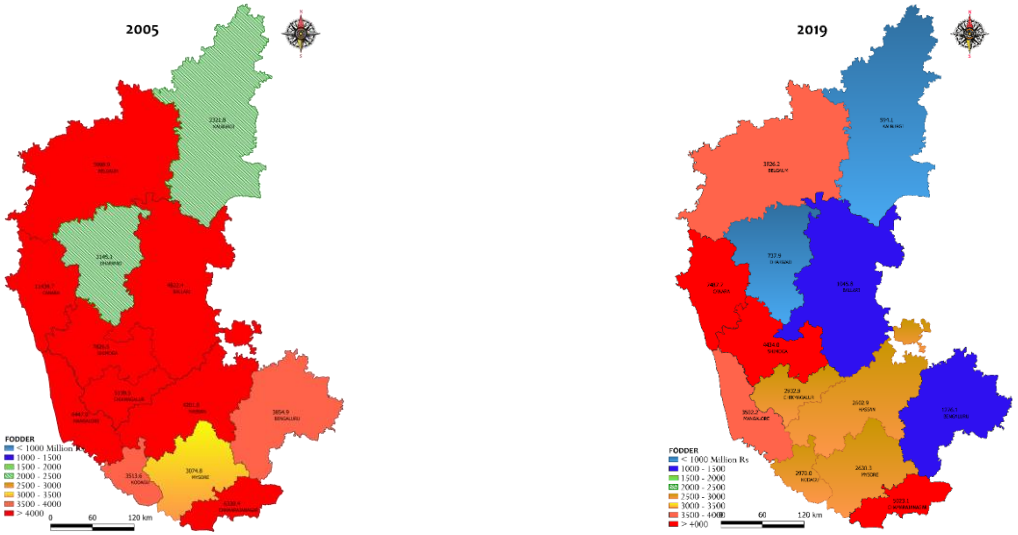
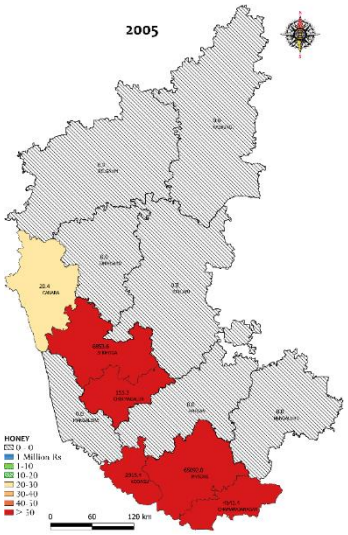
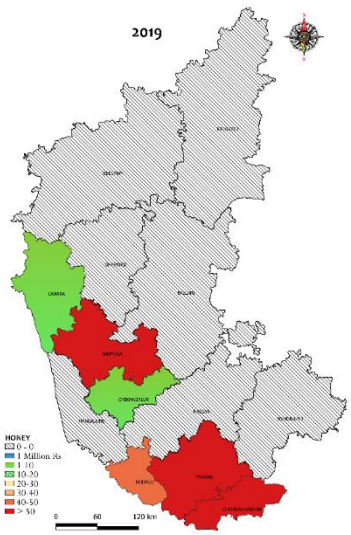
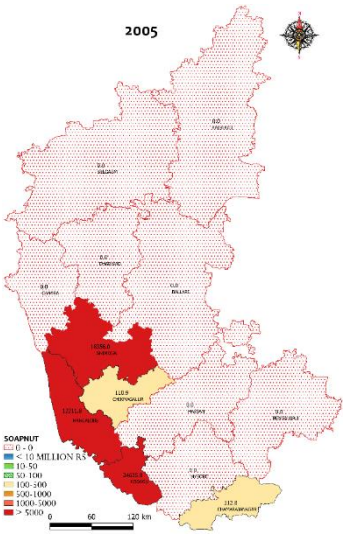


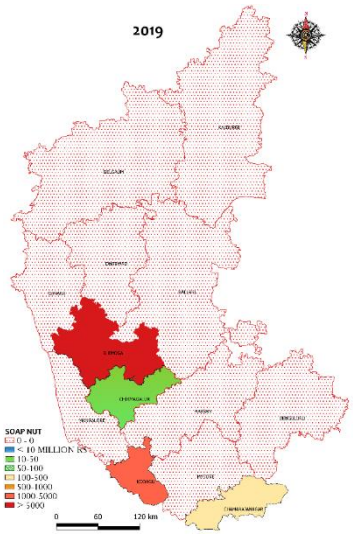
Figure 5.3.7. Ecosystem supply value of from various goods under NTFP category



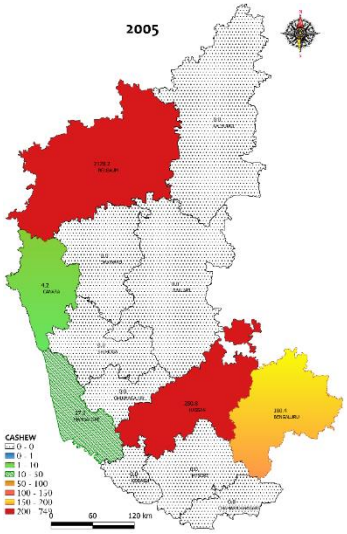


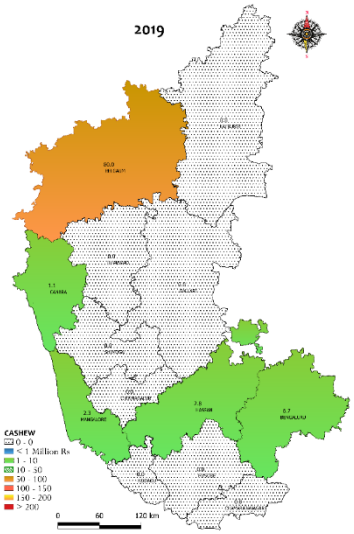
Honey



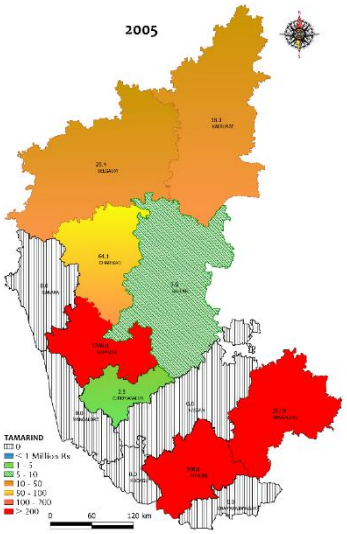


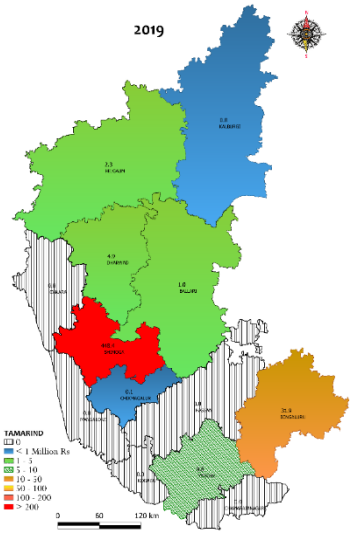
Soap nut



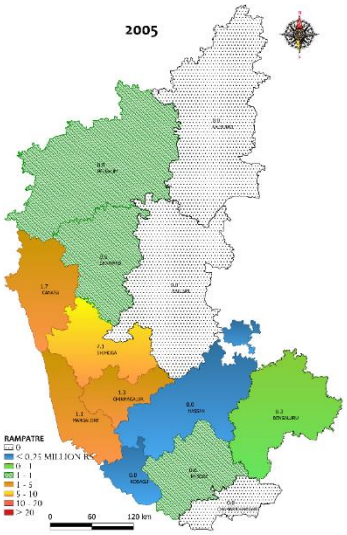


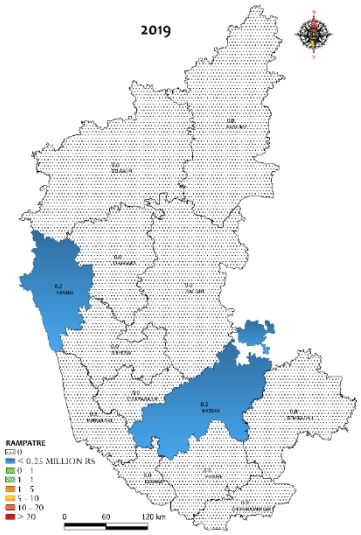
Cashew nut



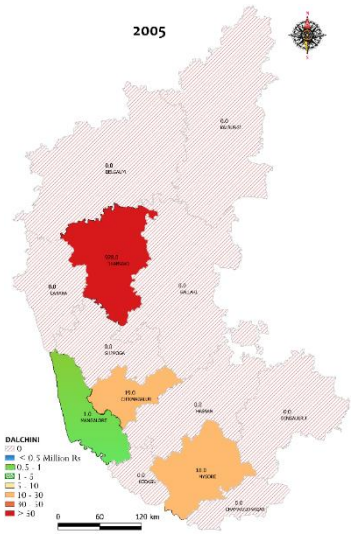


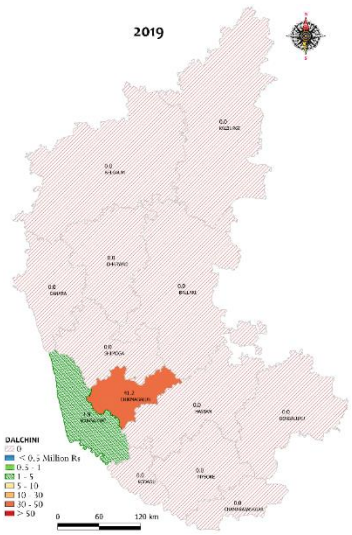
Tamarind



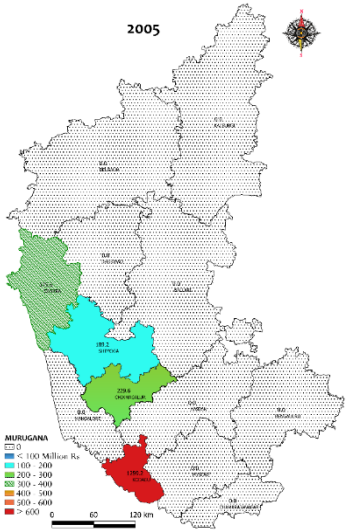


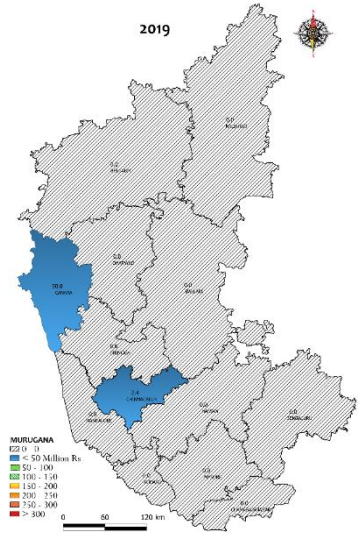
Rampatri (Nutmeg)





Dalchini (Cinnamon)





Murugalu (Kokkam)

Figure 5.3.8. Ecosystem supply of NTFP (million INR)

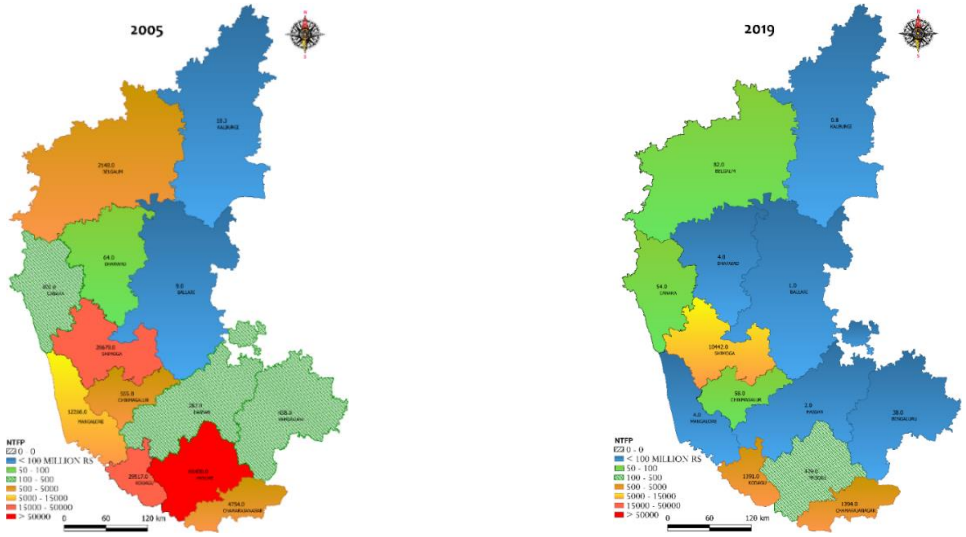


Table 5.3.8. Ecosystem value based on NTFP during 2005 and 2019

Sno	Circle name	NTFP (Million Rupees)															
		Honey		Soapnut		Cashew		Tamarind		Ramapatre		Dalchini		Murugalu		Total	
		2005	2019	2005	2019	2005	2019	2005	2019	2005	2019	2005	2019	2005	2019	2005	2019
1	Bengaluru	0	0.00	0	0.00	64	6.70	179	31.85	0	0.00	0	0.00	0	0.00	242	39
2	Belgaum	0	0.00	0	0.00	749	80.00	14	2.28	0	0.00	0	0.00	0	0.00	763	82
3	Ballari	0	0.00	0	0.00	0	0.00	6	1.04	0	0.00	0	0.00	0	0.00	6	1
4	Chamarajanagar	8089	1264.76	56	130.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	8146	1395
5	Chikmagalur	271	1.96	55	13.13	0	0.00	2	0.13	0	0.00	19	41.23	57	2.40	404	59
6	Dharwad	0	0.00	0	0.00	0	0.00	44	4.88	0	0.00	928	0.00	0	0.00	972	5
7	Kalaburagi	0	0.00	0	0.00	0	0.00	13	0.85	0	0.00	0	0.00	0	0.00	13	1
8	Hassan	0	0.00	0	0.00	88	2.80	0	0.00	4	0.16	0	0.00	0	0.00	92	3
9	Canara	36	3.08	0	0.00	1	1.10	0	0.00	0	0.16	0	0.00	94	50.00	131	54

10	Kodagu	5081	41.02	12318	1350.44	0	0.00	0	0.00	88	0.00	0	0.00	315	0.00	17802	1391
11	Mangalore	0	0.00	6106	0.00	10	2.30	0	0.00	3	0.00	1	1.86	0	0.00	6119	4
12	Mysore	113446	420.00	0	0.00	0	0.00	214	9.75	0	0.00	18	0.00	0	0.00	113678	430
13	Shimoga	11945	500.50	9178	9493.64	0	0.00	886	448.44	0	0.00	0	0.00	47	0.00	22056	10443

Table 5.3.9. Value of various NTFP per hectare per year (₹/Ha/Yr.)

Sno	**Circle name**	**NTFP** (₹/Ha/Yr.)													
		Honey		**Soap nut**		**Cashew**		**Tamarind**		**Ramapatri**		**Dalchini**		**Murugalu (Kokkum)**	
		2005	**2019**	**2005**	**2019**	**2005**	**2019**	**2005**	**2019**	**2005**	**2019**	**2005**	**2019**	**2005**	**2019**
1	Bengaluru					17029	17048	17027	17032						
2	Belgaum					11714	11715	11726	11727						
3	Ballari							17044	17049						
4	Chamarajanagar	13411	13413	16757	16757										
5	Chikmagalur	13060	13067	11722	11723			11793	11819			13333	13478	11714	11765
6	Dharwad							17033	17045						
7	Kalaburagi							11423	11575						
8	Hassan					16758	16766			16891	16842				
9	Canara	13063	13106			11827	11765			11667	12030			11714	11715
10	Kodagu	13059	13060	11714	11714					11714				11716	
11	Mangalore			11714		11733	12432			11714		13333	13478		
12	Mysore	13411	13412					16758	16810						
13	Shimoga	13059	13060	11714	11715			11713	11714					11722	

Fuelwood

The ecosystem supply values of fuelwood vary with forest type and canopy cover, as described in Table 5.3.10. The ecosystem supply of fuelwood is depicted in Figure 5.3.9. 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.

Figure 5.3.9. Quantity of fuelwood extracted and its Ecosystem Supply Value

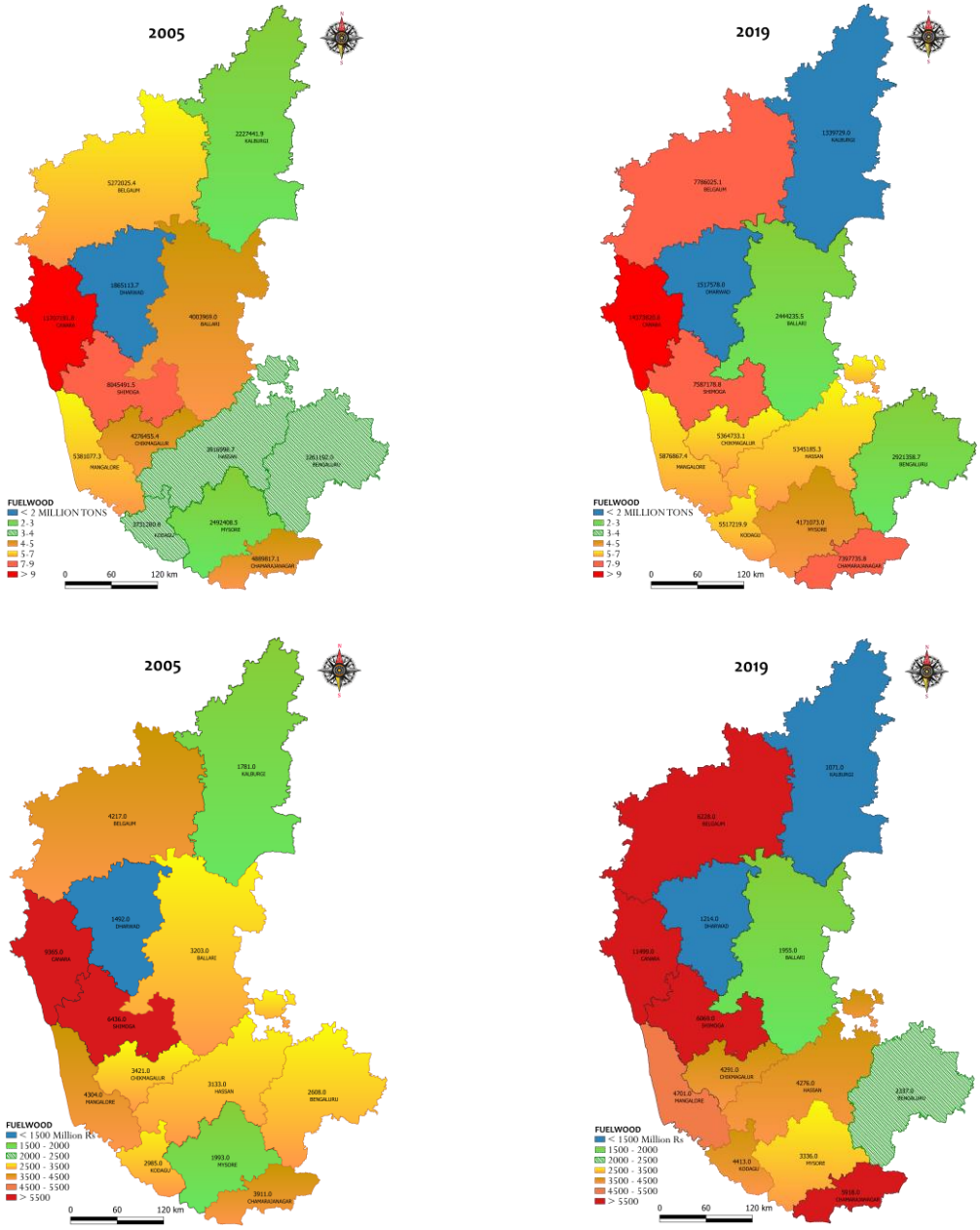


Table 5.3.10. Quantity of fuelwood extracted and its ecosystem supply value across Karnataka

Sno	Circle name	Fuelwood (Tons)		Fuelwood (Million Rupees)	
		2005	2019	2005	2019
1	Bengaluru	3261192	2921359	2609	2337
2	Belgaum	5272025	7786025	4218	6229
3	Ballari	4003969	2444235	3203	1955
4	Chamarajanagar	4889817	7397736	3912	5918
5	Chikmagalur	4276455	5364733	3421	4292
6	Dharwad	1865114	1517578	1492	1214
7	Kalaburagi (Gulbarga)	2227442	1339729	1782	1072
8	Hassan	3916999	5345185	3134	4276
9	Canara	11707192	14373821	9366	11499
10	Kodagu	3731281	5517220	2985	4414
11	Mangalore	5381077	5876867	4305	4701
12	Mysore	2492408	4171073	1994	3337
13	Shimoga	8045491	7587179	6436	6070
Fuelwood INR/ha/yr				5097	23623

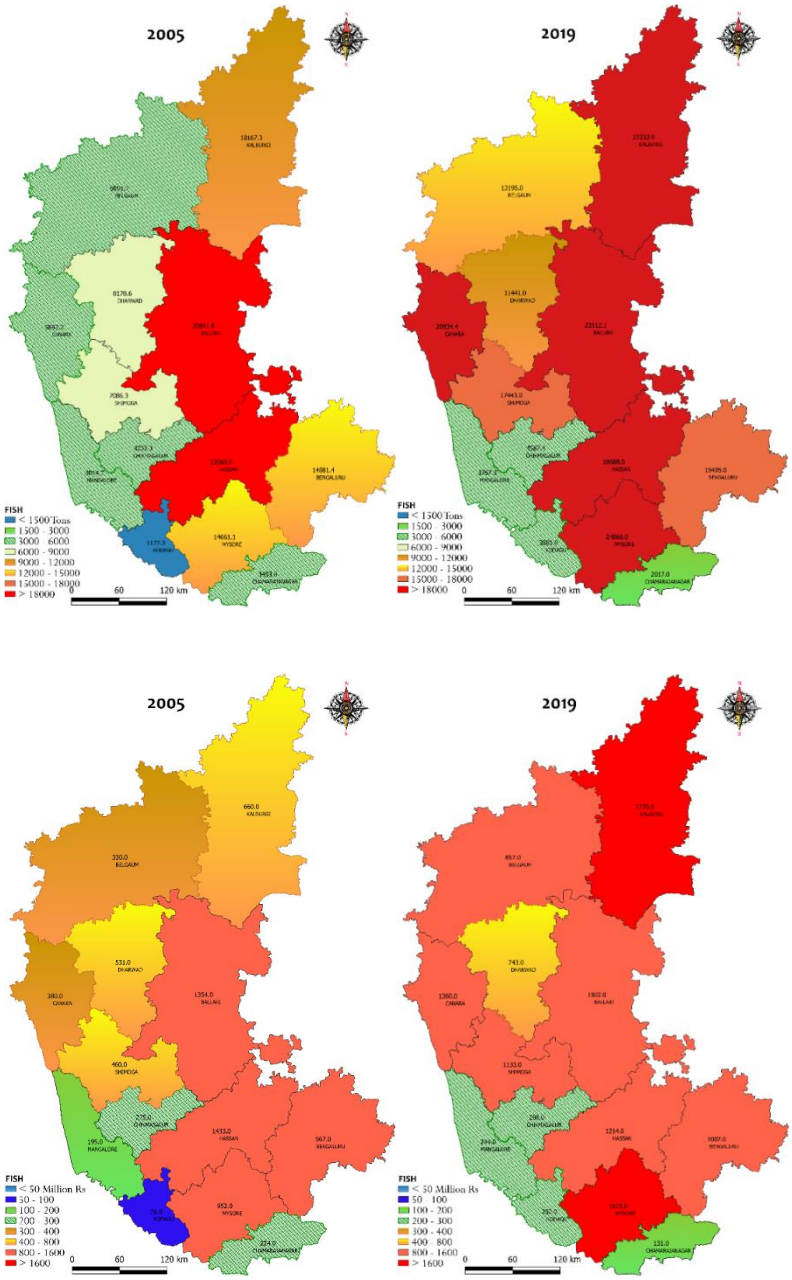
Fish and other aquatic products provisioning services

The quantity of the fish harvested in tons, and revenue generated from fishes is given in Table 5.3.11. 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. Spatial variability in the availability of fish and other aquatic products with the ecosystem supply value is evident in Figure 5.3.10

Table 5.3.11. Fish quantity and ecosystem supply value (physical – tons, monetary – million Rs.)

Sno	Circle name	Fish quantity (Tons)		Ecosystem supply value (Million Rs)	
		2005	2019	2005	2019
1	Bengaluru	14881	15495	967	1007
2	Belgaum	5092	13195	330	857
3	Ballari	20842	23112	1354	1502
4	Chamarajanagar	3454	2017	224	131
5	Chikmagalur	4232	4587	275	298
6	Dharwad	8179	11441	531	743
7	Kalaburagi	10167	27234	660	1770
8	Hassan	22061	18688	1433	1214
9	Canara	5852	20934	380	1360
10	Kodagu	1177	3881	76	252
11	Mangalore	3015	3767	195	244
12	Mysore	14661	24860	952	1615
13	Shimoga	7086	17443	460	1133
Total		120699	186655	7837	12126

Figure 5.3.10. Fish harvested and its ecosystem supply value



Water supply

The quantity of water and its service value is assessed and depicted in Figure 5.3.11, and forest circle-wise details are listed in Table 5.3.12. 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.

Figure 5.3.11. Ecosystem value of water supply (million INR) in 2005 and 2019

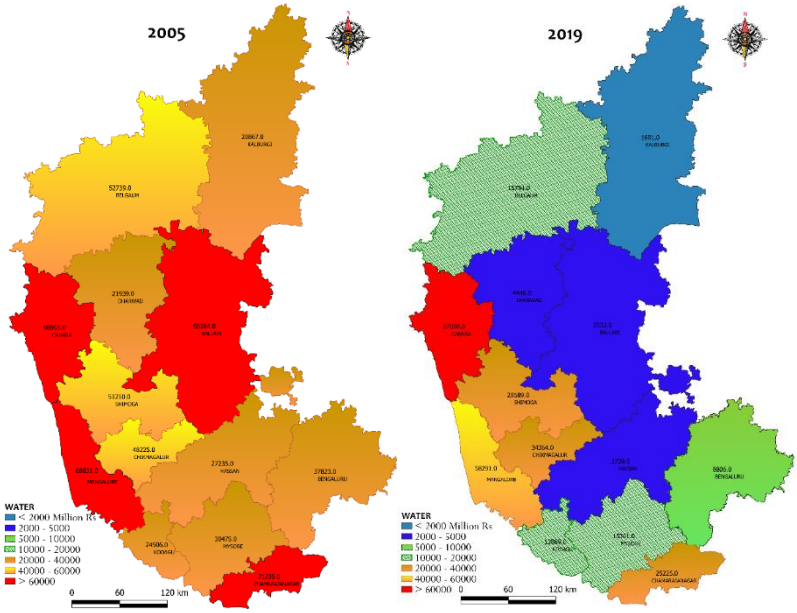


Table 5.3.12. Ecosystem value of water supply across forest circles

Sno	Circle name	Water supply (Million cum)		Ecosystem supply value of water (Million Rs)		% Change (2005 to 2019)
		2005	2019	2005	2019	
1	Bengaluru	1729	1713	37823	8806	-76.7
2	Belgaum	1688	1712	52739	15784	-70.1
3	Ballari	836	860	65284	3532	-94.6
4	Chamarajanagar	299	337	71235	25225	-64.6
5	Chikmagalur	1507	1519	48225	34364	-28.7
6	Dharwad	1392	1409	21939	4446	-79.7
7	Kalaburagi	1996	2011	20867	1681	-91.9
8	Hassan	811	811	27235	3739	-86.3
9	Canara	2072	2077	98965	67098	-32.2
10	Kodagu	1982	1981	24506	12869	-47.5
11	Mangalore	7038	7035	68031	58291	-14.3
12	Mysore	713	719	30475	15361	-49.6
13	Shimoga	2157	2188	51210	29589	-42.2
Total		24219	24371	618534	280785	-54.6

Medicine

Ecosystem value from medicinal plants is assessed and listed circle-wise in Table 5.3.1, accounting for 766 million rupees and 514 million rupees for 2005 and 2019, respectively. The spatial variability of the medicinal value of forests is depicted in Figure 5.3.12.

Figure 5.3.12. Ecosystem supply value of medicine across Karnataka

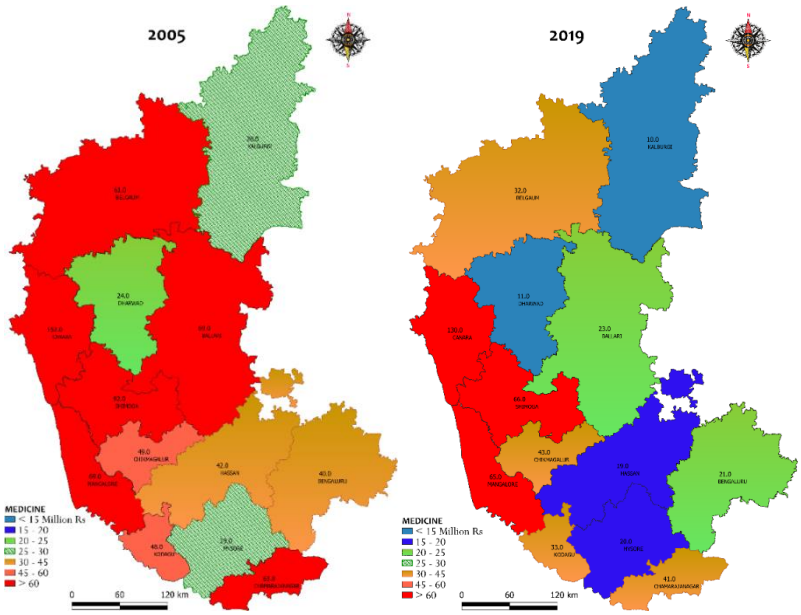


Table 5.3.13. Ecosystem value of medicine in 2005 and 2019

Sno	Circle name	Ecosystem supply value of medicine (Million Rs)	
		2005	2019
1	Bengaluru	40	21
2	Belgaum	61	32
3	Ballari	69	23
4	Chamarajanagar	63	41
5	Chikmagalur	49	43
6	Dharwad	24	11
7	Kalaburagi	28	10
8	Hassan	42	19
9	Canara	152	130
10	Kodagu	48	33
11	Mangalore	69	65
12	Mysore	29	20
13	Shimoga	92	66
Total		766	514

Genetic material service:

The ecosystem value of genetic material services varies with forest type and is accounted for through the 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). Table 5.3.14 lists genetic materials (monetary) estimates by forest circle, and the spatial variability across Karnataka is depicted in Figure 5.3.13. The loss in economic values between 2005 and 2019 points to the change in forest cover in forest circles such as Bengaluru, Belgaum, Ballari and Shimoga, Hassan, and Mysore.

Figure 5.3.13. Genetic material service value across the circles

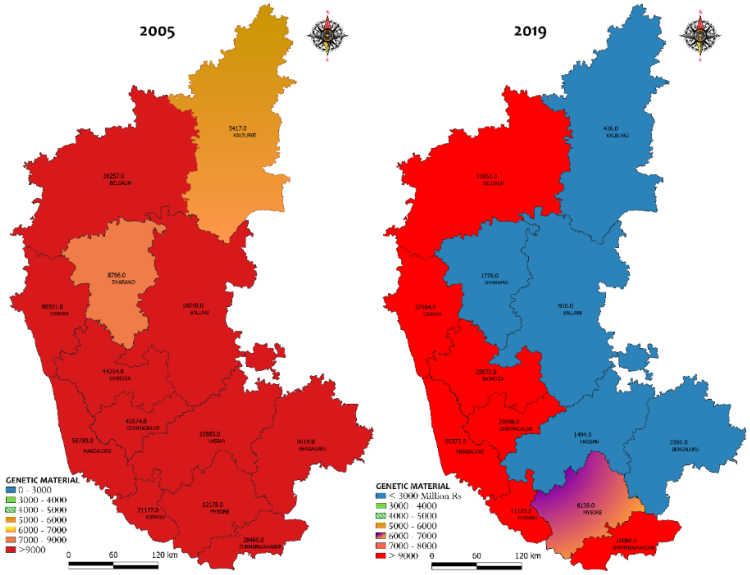


Table 5.3.14. Ecosystem supply value of genetic material service

S.no	Circle name	Ecosystem supply value of genetic material service (Million Rs)	
		2005	2019
1	Bengaluru	9819	2286
2	Belgaum	36257	10851
3	Ballari	16948	916
4	Chamarajanagar	28465	10080
5	Chikmagalur	41674	29696
6	Dharwad	8766	1776
7	Kalaburagi	5417	436
8	Hassan	10883	1494
9	Canara	85521	57984
10	Kodagu	21177	11120
11	Mangalore	58790	50373
12	Mysore	12178	6138
13	Shimoga	44254	25570
Total		380149	208725

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). The carbon sequestration from forests as per InVEST shows that the forest circles located in the Western Ghats have higher sequestration than other parts of the State due to lower disturbances (Figure 5.3.14). 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. Circles such as Mysore, Ballari, and Kalaburagi have lower carbon sequestration due to deforestation from rapid land-use changes (Table 5.3.15, Figure 5.3.15). The ecosystem supply value of carbon sequestration is 794949 and 571138 million rupees for 2005 and 2019, respectively (Figure 5.3.15 and Table 5.3.16). Canara, Mangalore, and Chikmagalur forest circles are contributing larger quantities.

Figure 5.3.14. Carbon sequestration asper InVEST model

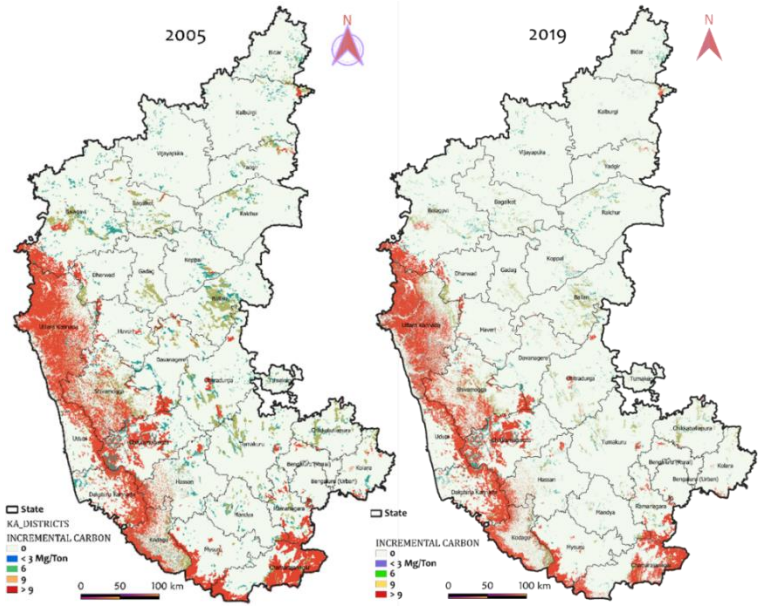


Table 5.3.15. Annual carbon sequestration (**CO_2**) from forests in Karnataka

Sno	Circle name	Carbon sequestration (CO_2 Gg/Yr)		CO_2 sequestration (Million Rs)	
		2005	2019	2005	2019
1	Bengaluru	5787	3374	37065	21615
2	Belgaum	8320	5026	53275	32187
3	Ballari	6487	2395	41541	15345
4	Chamarajanagar	12066	7934	77250	50800
5	Chikmagalur	9581	8681	61343	55578
6	Dharwad	3285	1699	21039	10887
7	Kalaburagi	2981	1075	19100	6905

8	Hassan	5571	2861	35677	18322
9	Canara	28568	23708	182897	151785
10	Kodagu	8242	5835	52770	37358
11	Mangalore	12752	12174	81650	77946
12	Mysore	5063	3782	32420	24218
13	Shimoga	15450	10650	98922	68192
Total		124153	89194	794949	571138

Figure 5.3.15. Carbon (CO_2) sequestration across the circles

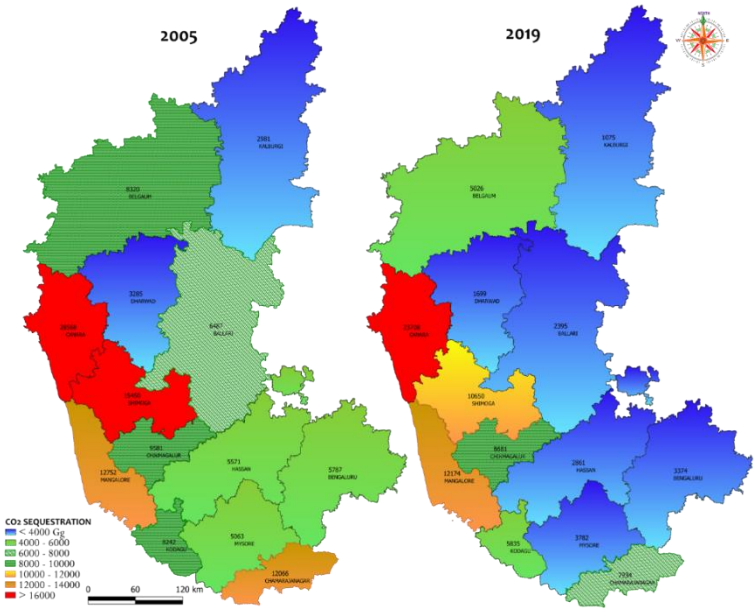
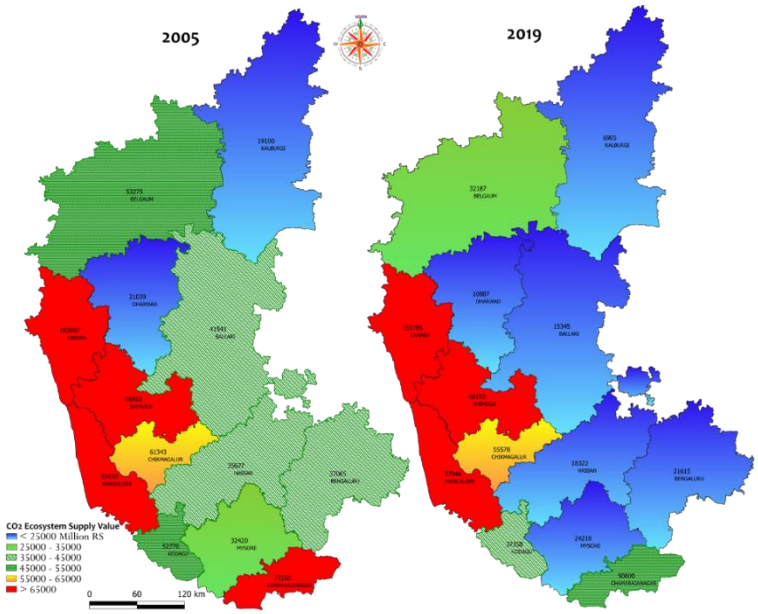


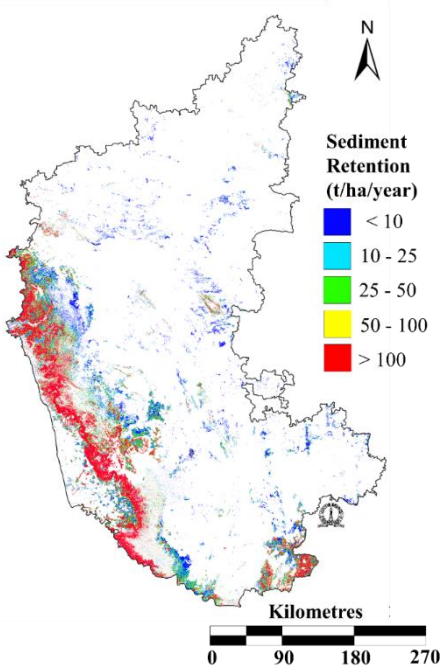
Figure 5.3.16. Ecosystem supply value of CO_2 sequestration across districts in Karnataka



Soil Conservation and Soil Fertility

InVest, and the Revised Universal Soil Loss Equation (RUSLE) use the knowledge of soil characteristics, land use characteristics, vegetation characteristics, farming practices, topographic effects, etc., to derive the sediment yield and retention characteristics. Figure 5.3.17 depicts the local soil retention map within the natural forested areas of Karnataka. 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.

Figure 5.3.17: Sediment retention as per InVEST



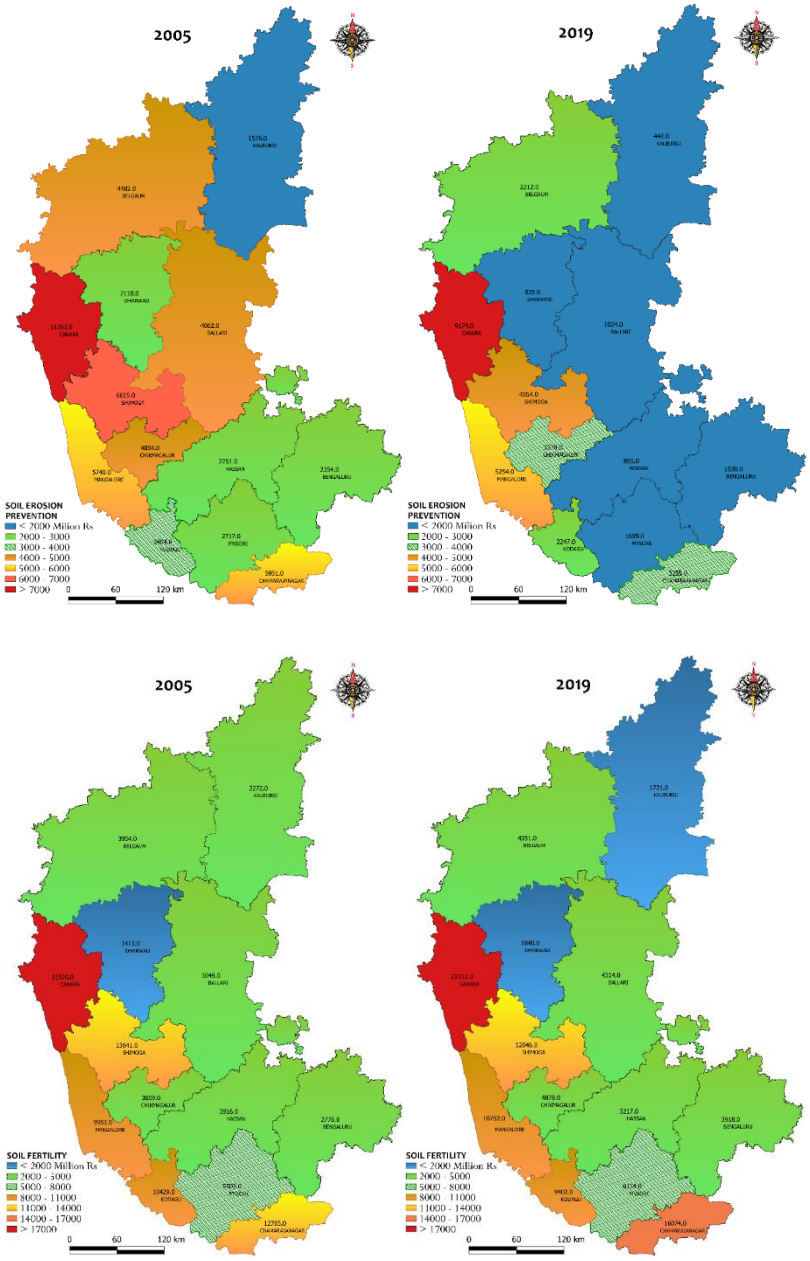
The ecosystem service of soil conservation and maintaining soil fertility is computed for forest ecosystems and is listed circle-wise in Table 5.3.17. Spatial variability of soil conservation services of forests, circle-wise, is depicted in figure 5.3.18. The ability of forest ecosystems to prevent erosion 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.

Table 5.3.17. Ecosystem supply value of soil conservation & soil fertility services

Sno	Circle name	Soil conservation (million Rs)		Soil fertility (million Rs)	
		2005	2019	2005	2019
1	Bengaluru	2354	1038	2776	3918
2	Belgaum	4482	2212	3954	4351
3	Ballari	4062	1024	3049	4314
4	Chamarajanagar	5951	3255	12785	16074

5	Chikmagalur	4054	3370	3659	4878
6	Dharwad	2118	839	1413	1840
7	Kalaburagi	1576	440	2272	1721
8	Hassan	2251	855	3916	3217
9	Canara	11262	9174	21520	22512
10	Kodagu	3404	2247	10429	9402
11	Mangalore	5740	5254	9953	10792
12	Mysore	2717	1699	5503	6154
13	Shimoga	6615	4554	13641	12046
Total		56856	35969	94870	101227

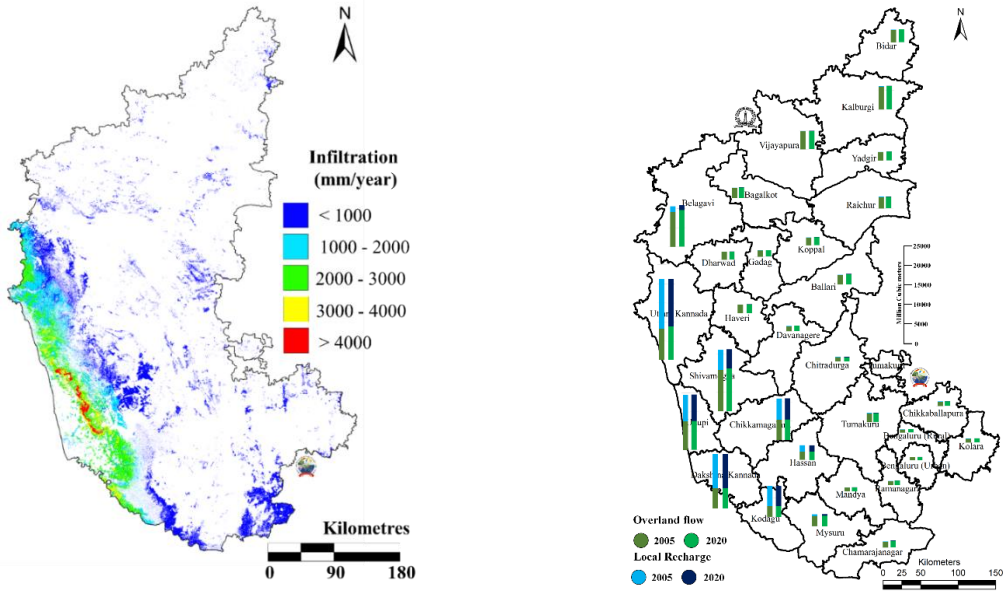
Figure 5.3.32. Ecosystem supply value at circle wise from soil conservation and fertility services



***Water regulation and groundwater recharge*:**

Figure 5.3.19 depicts the local recharge map (seasonal water yield as per INVEST 3.9.0) for the natural forested areas of Karnataka. 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.

Figure 5.3.19: Local recharge in the natural forested areas of Karnataka



The ecosystem supply values across the circles are depicted in Figure 5.3.20 and Table 5.3.18, and the value amounts to 7,109 million INR/Yr (2019).

Figure 5.3.20. Ecosystem services of ground-water recharge

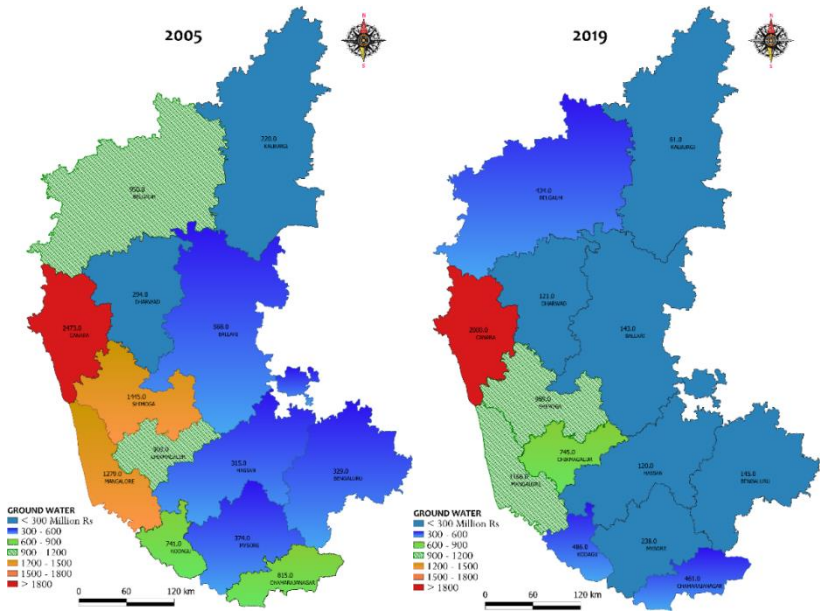


Table 5.3.18. Ecosystem services of groundwater recharge across forest circles

S. No	Circle name	Groundwater recharge (million Rs), 2019
1	Bengaluru	145
2	Belgaum	434
3	Ballari	143
4	Chamarajanagar	461
5	Chikmagalur	745
6	Dharwad	121
7	Kalaburagi	61
8	Hassan	120
9	Canara	2000
10	Kodagu	486
11	Mangalore	1166
12	Mysore	238
13	Shimoga	989
Total		7109

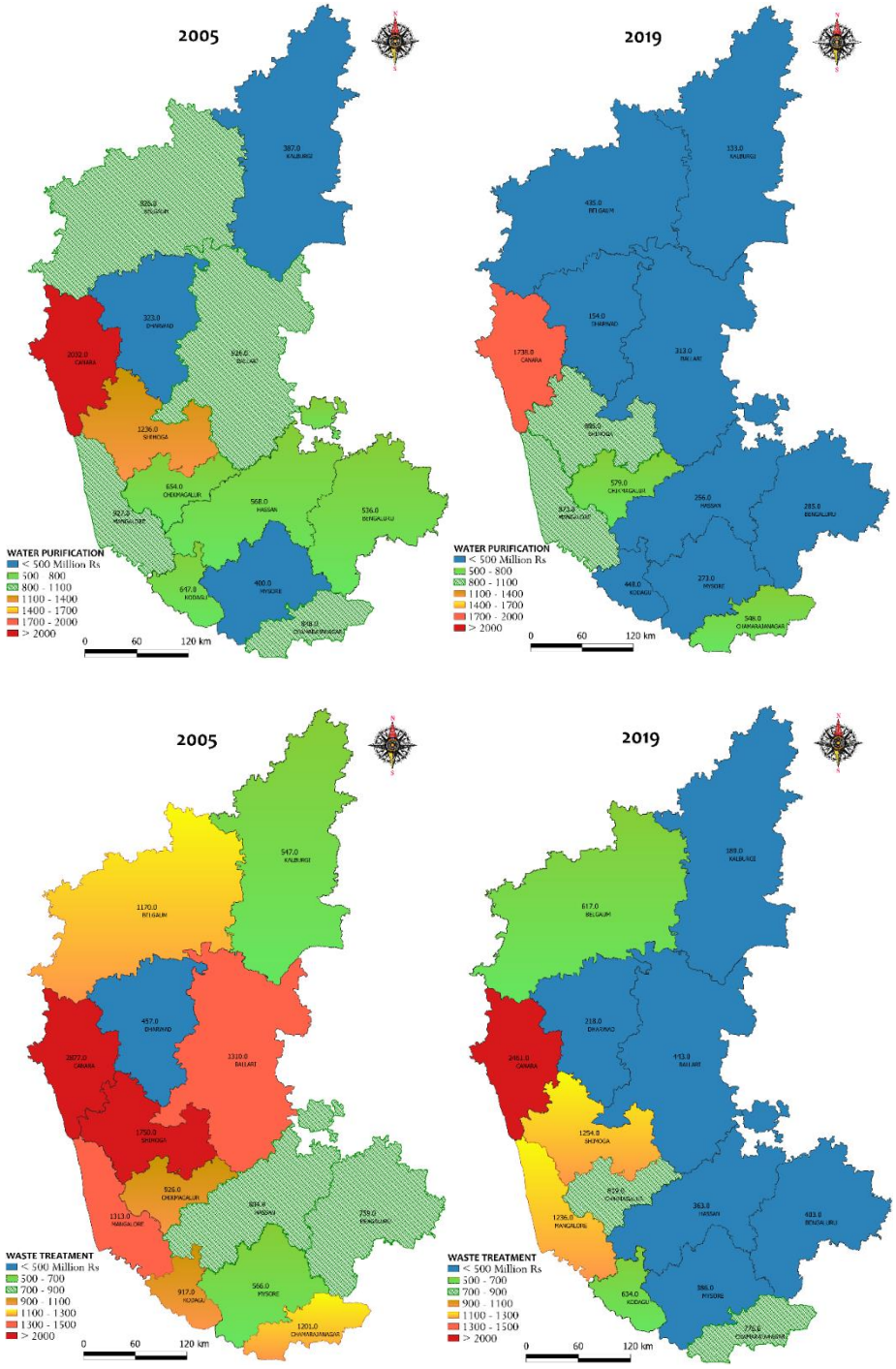
Water Purification: The ecosystem service of water purification ranges from 10,310 INR/Ha/Yr (2005) to 6,921 INR/Ha/Yr (Table 5.3.19 and Figure 5.3.21)

Waste treatment: waste treatment (remediation) amounts to 14,597 million INR/Yr (2005) to 9,799 million INR/Yr (2019). The waste treatment services of forest ecosystem are given in Table 5.3.19 and Figure 5.3.21

Table 5.3.19. Forest ecosystem supply value of water purification and treatment services

Sno	Circle name	Water purification (million Rs)		Waste treatment (million Rs)	
		2005	2019	2005	2019
1	Bengaluru	536	1038	759	403
2	Belgaum	826	2212	1170	617
3	Ballari	926	1024	1310	443
4	Chamarajanagar	848	3255	1201	776
5	Chikmagalur	654	3370	926	819
6	Dharwad	323	839	457	218
7	Kalaburagi	387	440	547	189
8	Hassan	568	855	804	363
9	Canara	2032	9174	2877	2461
10	Kodagu	647	2247	917	634
11	Mangalore	927	5254	1313	1236
12	Mysore	400	1699	566	386
13	Shimoga	1236	4554	1750	1254
Total		10310	6921	14597	9799

Figure 5.3.21. Ecosystem services of water purification and waste treatment

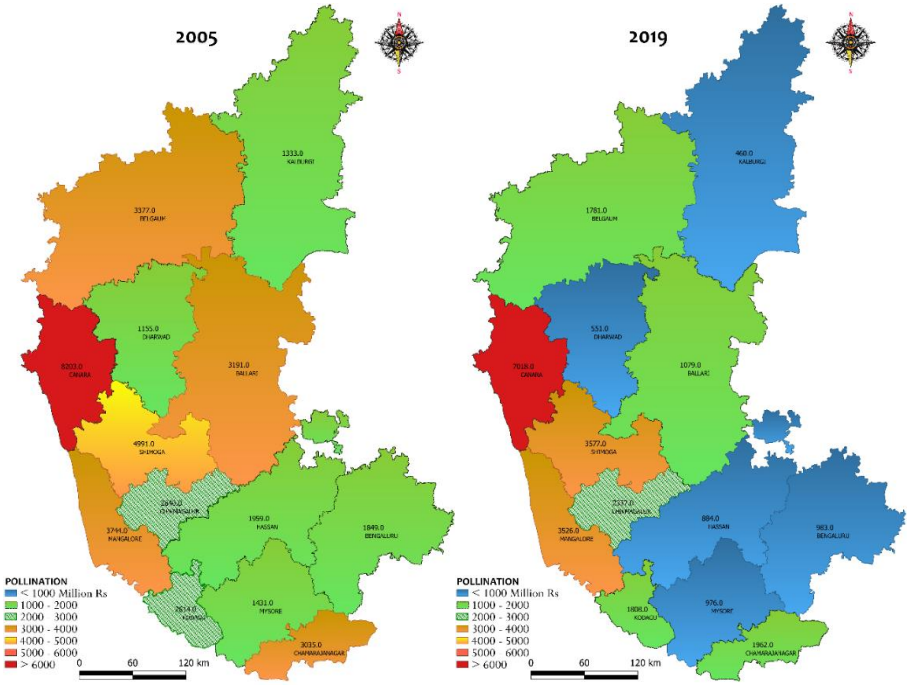


Pollination service: The ecosystem supply value of pollination services depicts higher values in Canara, Shimoga, Mangalore circles, and the State aggregate value is 26,942 million rupees per year (Table 5.3.20, Figure 5.3.22).

Table 5.3.20. Circle wise ecosystem supply value from pollination service

Sno	Circle name	Pollination services -2019 (Million Rs/Yr)
1	Bengaluru	983
2	Belgaum	1781
3	Ballari	1079
4	Chamarajanagar	1962
5	Chikmagalur	2337
6	Dharwad	551
7	Kalaburagi	460
8	Hassan	884
9	Canara	7018
10	Kodagu	1808
11	Mangalore	3526
12	Mysore	976
13	Shimoga	3577
Total		26942

Figure 5.3.22. Ecosystem supply value of pollination service

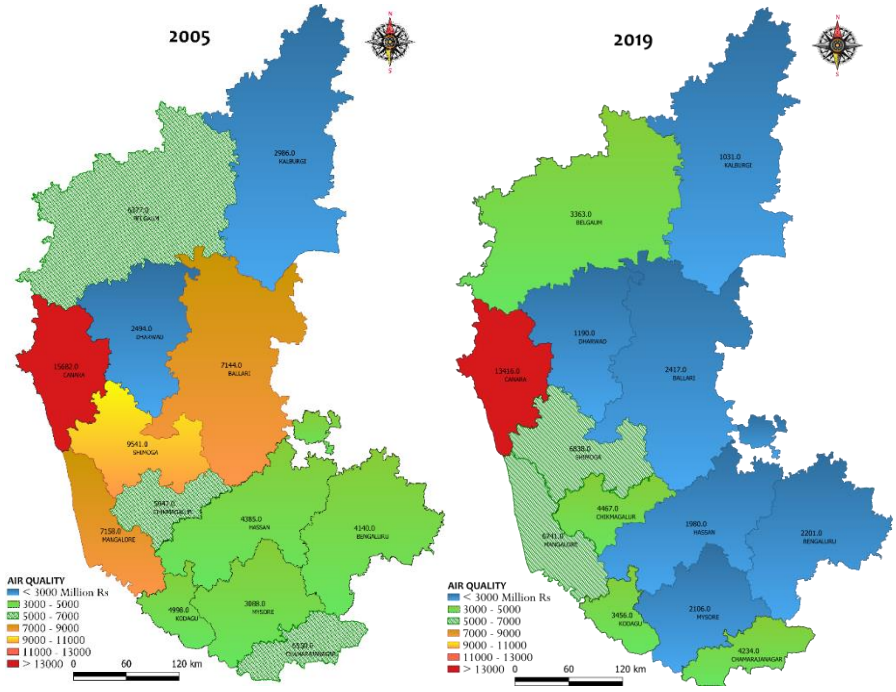


Air filtration services: The total ecosystem supply value of air quality regulation services is estimated as 79,590 (2005) and 53,440 (2019) million rupees, with Canara, Shimoga, Mangalore, and Kodagu circles contributing a higher share (Table 5.3.21). The spatial variability of air quality regulation services is depicted in Figure 5.3.23. The degradation in the forest cover from 2005 to 2019 has resulted in the decline of air filtration services.

Table 5.3.21. Ecosystem supply value from air filtration service

S.no	Circle name	Air filtration services (Million Rs)	
		2005	2019
1	Bengaluru	4140	2201
2	Belgaum	6377	3363
3	Ballari	7144	2417
4	Chamarajanagar	6550	4234
5	Chikmagalur	5047	4467
6	Dharwad	2494	1190
7	Kalaburagi	2986	1031
8	Hassan	4385	1980
9	Canara	15682	13416
10	Kodagu	4998	3456
11	Mangalore	7158	6741
12	Mysore	3088	2106
13	Shimoga	9541	6838
Total		79590	53440

Figure 5.3.23. Air quality regulation services from forest ecosystems in Karnataka

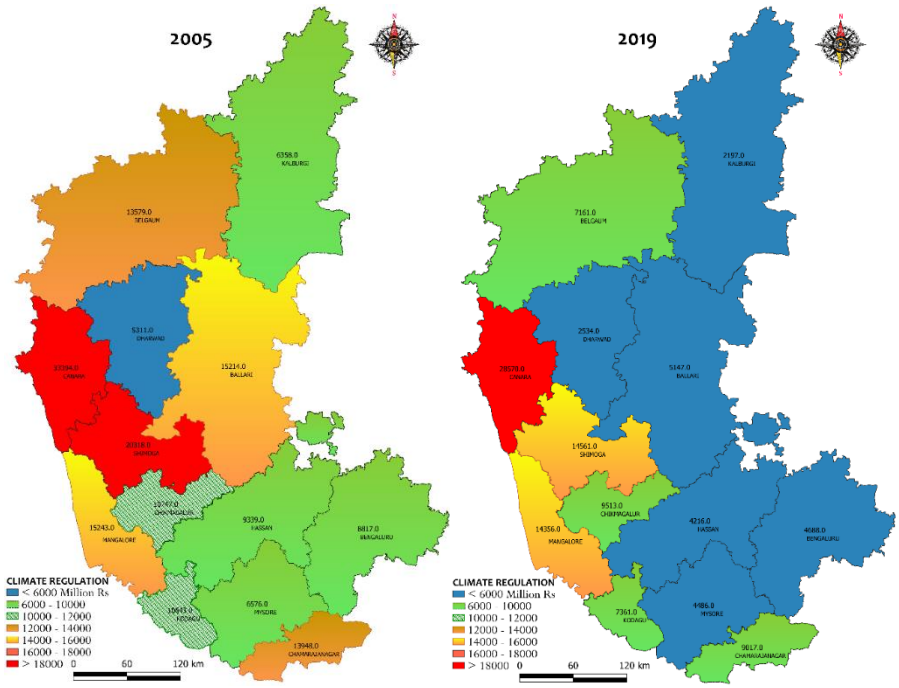


Local (micro and meso) climate regulation services: The ecosystem value of moderating climate listed in Table 5.3.22 accounts for 169,487 (2005) and 113,807 (2019) million rupees. Canara, Shimoga, Mangalore, and Kodagu circles contribute a higher share due to good forest cover, which is responsible for moderating the climate (Figure 5.3.24). All forest circles show a decline in local climate regulation ecosystem value due to the loss of forest cover.

Table 5.3.22. Ecosystem services of local climate regulation

Sno	Circle name	Local climate regulation (million Rs)	
		2005	2019
1	Bengaluru	8817	4688
2	Belgaum	13579	7161
3	Ballari	15214	5147
4	Chamarajanagar	13948	9017
5	Chikmagalur	10747	9513
6	Dharwad	5311	2534
7	Kalaburagi	6358	2197
8	Hassan	9339	4216
9	Canara	33394	28570
10	Kodagu	10643	7361
11	Mangalore	15243	14356
12	Mysore	6576	4486
13	Shimoga	20318	14561
Total		169487	113807

Figure 5.3.24. Local climate regulation service from forests of Karnataka



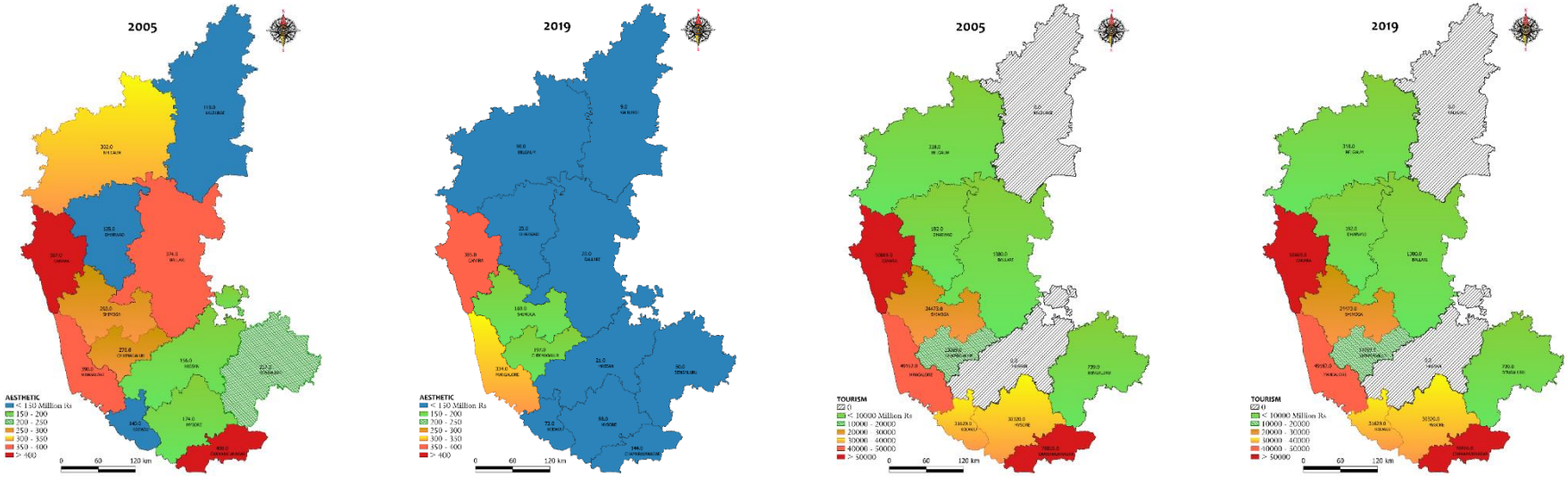
Cultural services from forest ecosystems:

The ecosystem values of various cultural services are listed in Table 5.3.23, and the spatial variability based on ecosystem extent variations is depicted in Figure 5.3.25.

Table 5.3.23. Ecosystem supply value of cultural services

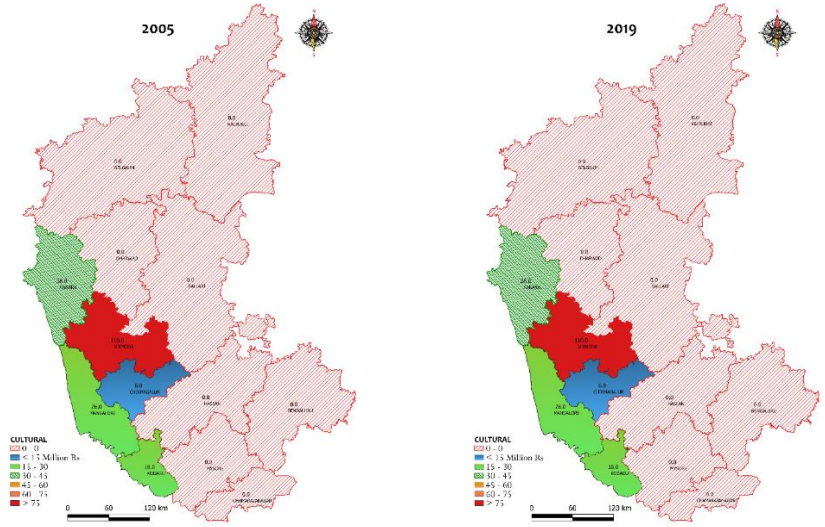
Sno	Circle name	Cultural services (million ₹)									
		Aesthetic		Tourism and recreational		Spiritual and historic		Artistic and culture		Education, scientific and research	
		2005	2019	2005	2019	2005	2019	2005	2019	2005	2019
1	Bengaluru	217	50	765	739			87	46	873	464
2	Belgaum	302	90	329	318			134	71	1345	709
3	Ballari	374	20	1380	1380			151	51	1507	510
4	Chamarajanagar	408	144	78816	78816			138	89	1381	893
5	Chikmagalur	276	197	13089	13089			106	94	1064	942
6	Dharwad	125	25	189	182			53	25	526	251
7	Kalaburagi	119	9					63	22	630	218
8	Hassan	156	21					92	42	925	418
9	Canara	567	385	50669	50669	38	25	331	283	3307	2829
10	Kodagu	140	73	31629	31629	18	18	105	73	1054	729
11	Mangalore	390	334	49162	49162	26	22	151	142	1510	1422
12	Mysore	174	88	30320	30320			65	44	651	444
13	Shimoga	293	169	24473	24473	110	110	201	144	2012	1442
Total		3541	1605	280821	280777	198	179	1679	1127	16786	11271

Figure 5.3.25. Cultural services of Karnataka and their ecosystem supply values

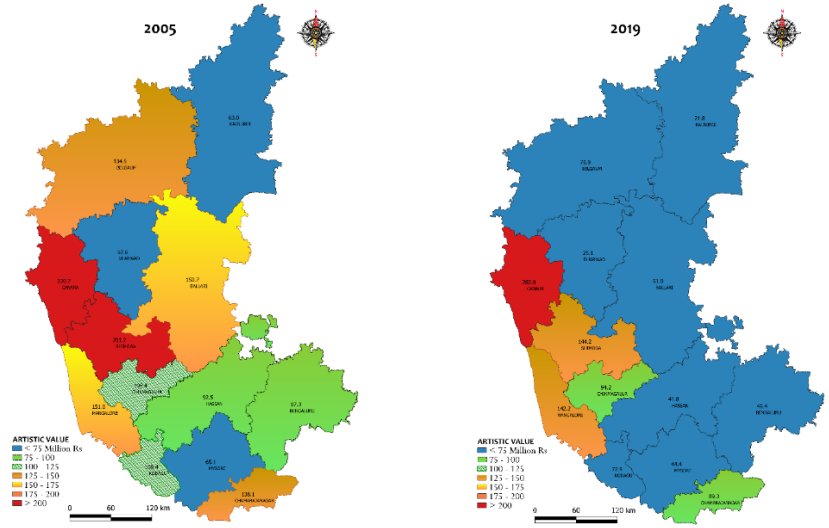


Aesthetic

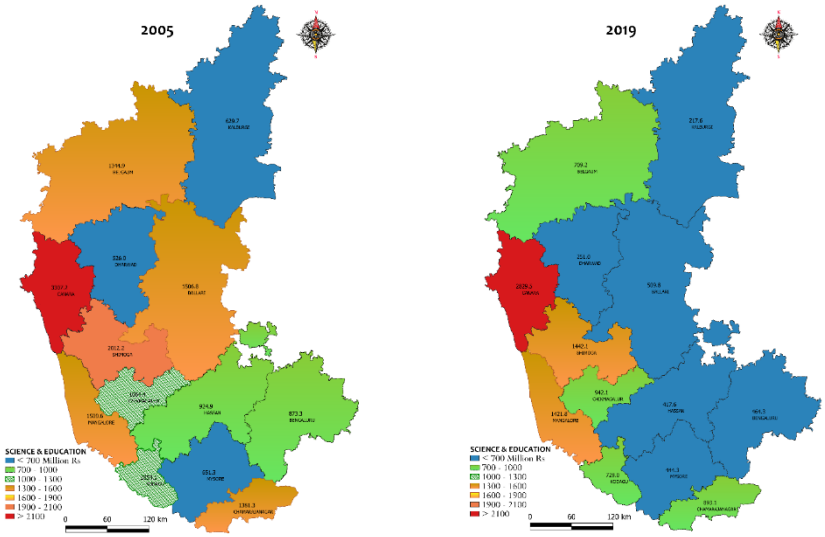
Tourism & recreational



Spiritual and historic



Artistic & cultural



Education, science, and research

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 provisioning service of forests (Figure 5.3.26). 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 (Table 5.3.24). The provisioning services of forest ecosystems in Karnataka amount to 517 (2005) and 531 (2019) billion rupees per year.

Figure 5.3.26. Provisioning services from forests of Karnataka

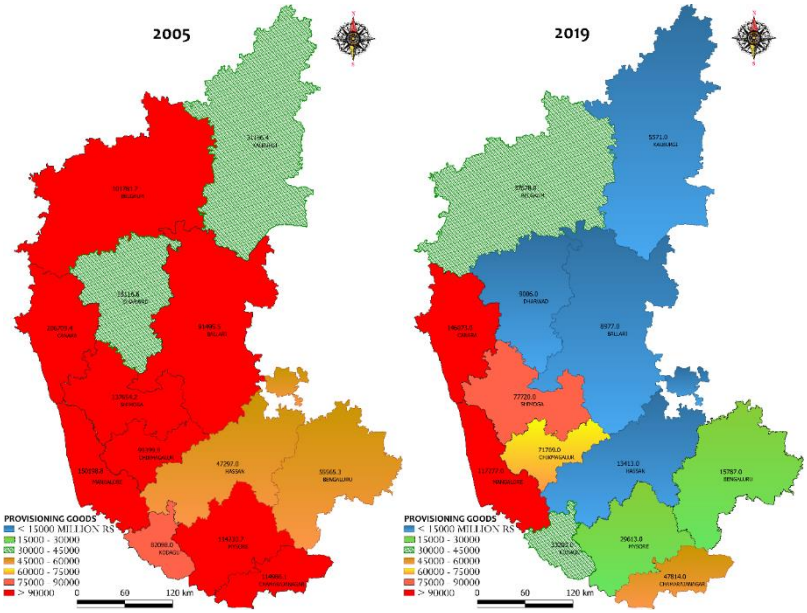


Table 5.3.24. Total provisioning services from forest ecosystems in Karnataka

Sno	Circle name	Provisioning services (million Rs)	
		2005	2019
1	Bengaluru	21224	13387
2	Belgaum	30294	28955
3	Ballari	34804	7308
4	Chamarajanagar	46220	38523
5	Chikmagalur	26944	65249
6	Dharwad	13203	7512
7	Kalaburagi	12261	4500
8	Hassan	16474	7297
9	Canara	56439	129283
10	Kodagu	32361	26364
11	Mangalore	42976	110150
12	Mysore	130886	24535
13	Shimoga	53047	68305
Total		517134	531375

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 (Table 5.3.25). Spatial variations in regulating services across forest landscapes in Karnataka are depicted in Figure 5.3.27. 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.

Figure 5.3.27. Regulating services provided by forests of Karnataka

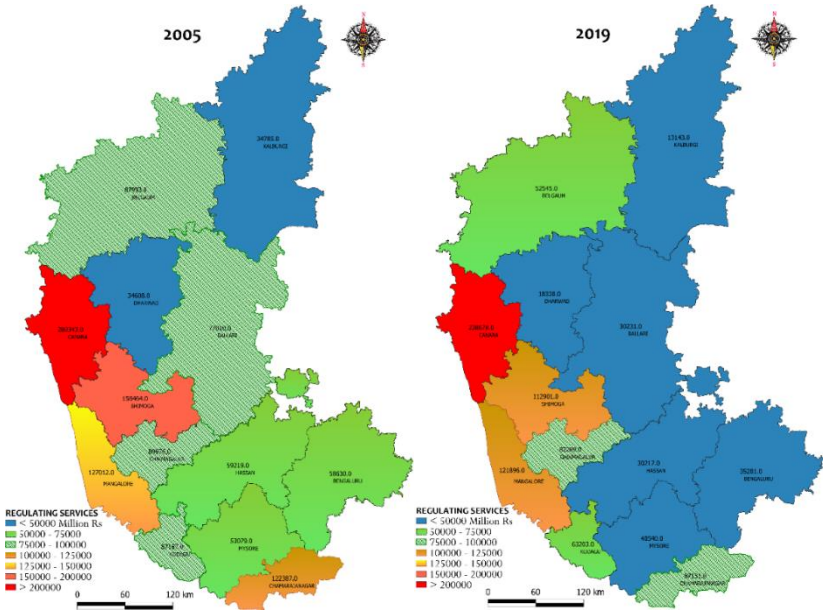


Table 5.3.25. Regulating services of forest ecosystem (circle wise) in Karnataka

Sno	Circle name	Regulating services (million Rs)	
		2005	2019
1	Bengaluru	58630	35281
2	Belgaum	87993	52545
3	Ballari	77010	30231
4	Chamarajanagar	122387	87131
5	Chikmagalur	89976	82289
6	Dharwad	34608	18338
7	Kalaburagi	34785	13143
8	Hassan	59219	30217
9	Canara	280343	238678
10	Kodagu	87167	63203
11	Mangalore	127012	121896
12	Mysore	53079	40540
13	Shimoga	158464	112901
Total		1270673	926393

Cultural services of forest ecosystems in Karnataka: The total cultural services amount to 303 (2005) and 295 (2019) billion rupees per year (Figure 5.3.28, Table 5.3.26). 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.

Figure 5.3.28. Cultural services provided by forests of Karnataka

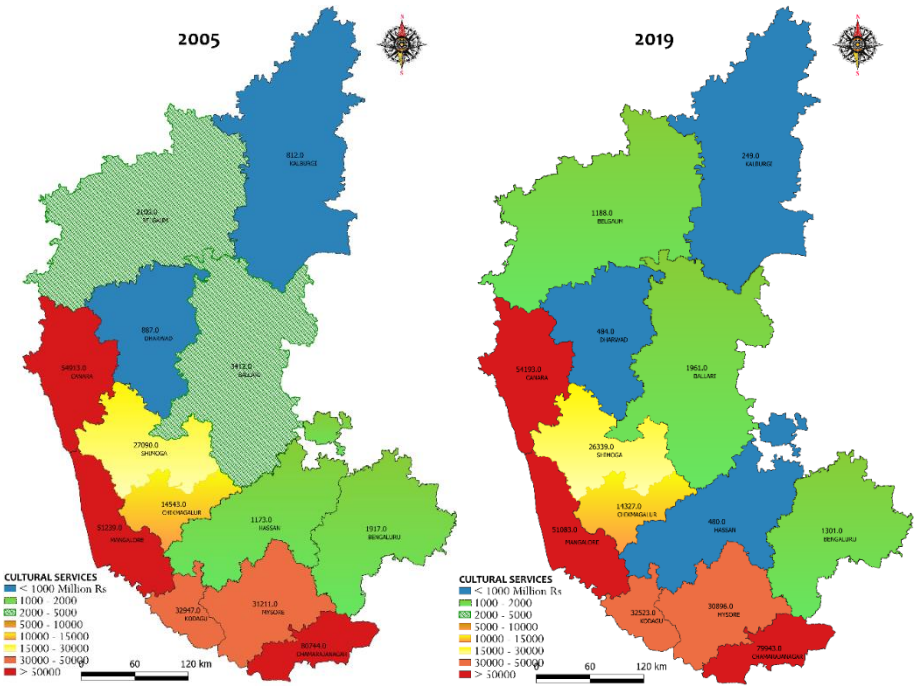


Table 5.3.26. Ecosystem supply value of cultural services

Sno	Circle name	Cultural services (million ₹)	
		2005	2019
1	Bengaluru	1942	35281
2	Belgaum	2111	52545
3	Ballari	3412	30231
4	Chamarajanagar	80744	87131
5	Chikmagalur	14543	82289
6	Dharwad	893	18338
7	Kalaburagi	812	13143
8	Hassan	1173	30217
9	Canara	54913	238678
10	Kodagu	32947	63203
11	Mangalore	51239	121896
12	Mysore	31211	40540
13	Shimoga	27090	112901
Total		303030	294967

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

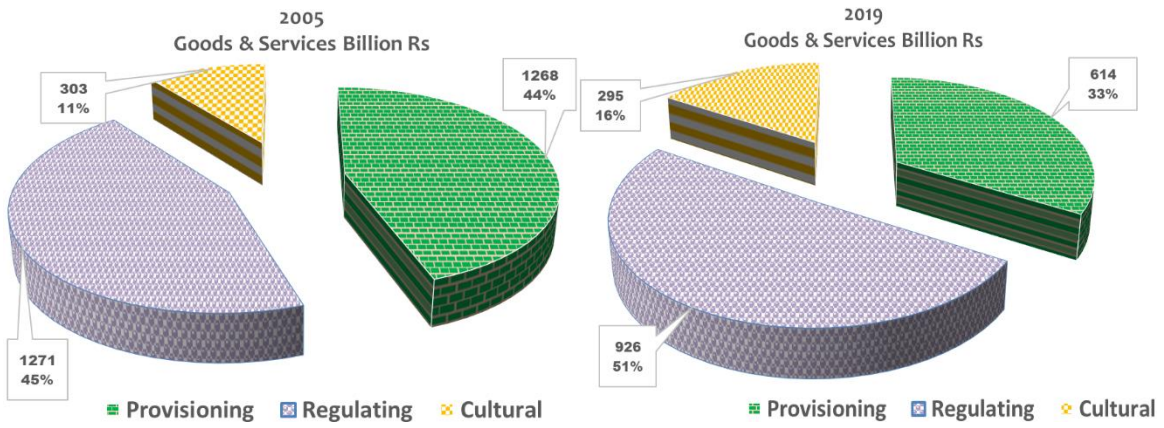
The total ecosystem supply value (TESV) of the forest ecosystem is computed by aggregating all the ecosystem services as given in equation 5.1 below:

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 5.3.29). Similarly, provisioning services constitute 34%, regulating services 51%, and cultural services 16% of total TESV for the year 2019 (Figure 5.3.29).

Figure 5.3.29. 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. Figure 5.3.30 shows that circles such as Canara, Shimoga, Mangalore, Chamarajanagar, Chikmagalur, and Kodagu contribute more to TESV

(Table 5.3.27). 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.

Figure 5.3.30. TESV of forest ecosystem, Karnataka (forest circle wise)

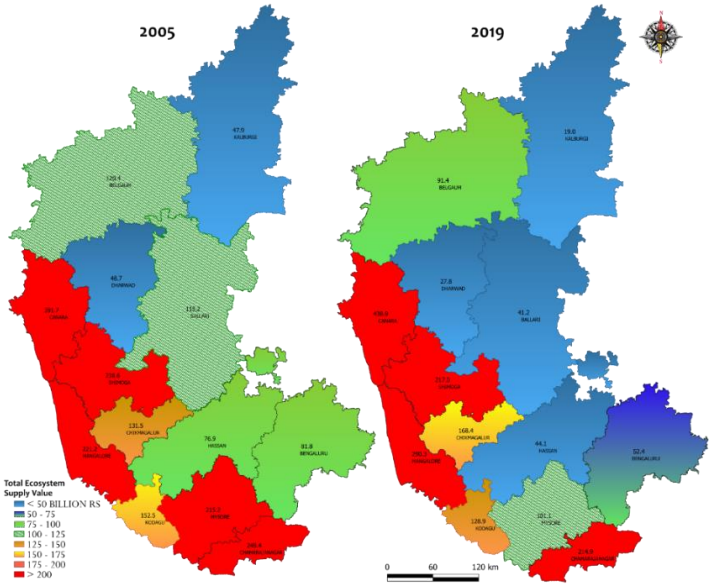


Table 5.3.27. Total ecosystem supply value (TESV) of forest ecosystem (circle wise) in Karnataka

Sno	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**

Annexure 5.3 provides a district-level assessment of forest ecosystem services (provisioning, regulating, cultural, and TESV).

5.4 Valuation of agriculture (croplands and horticulture) ecosystem services

Karnataka is a state with 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.). Table 5.4.1.1 lists the crops grown in the State according to the Directorate of Economics and Statistics, Government of Karnataka (DES 2017; DSO 2019).

Table 5.4.1.1. Crop classification as per the Department of Agriculture

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 (Hyacinth bean), Cowpea, Bengal gram, etc.
3	Oilseeds	Groundnut, sunflower, safflower, Castor, sesamum, soybean, Niger seed, linseed, etc.
4	Fruits	Banana, mango, lemon, pineapple, guava, grapes, sapota, pomegranate, 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
7	Horticulture	Rubber, coffee, cotton, coconut, arecanut, etc.

Crop yield per hectare: Crop yield per hectare varies across the State based on the agro-climatic zones and water resources available. The yield of some crops is given in Table 5.4.1.2 (based on government records and public interviews in the select ten districts).

Table 5.4.1.2. The yield of crops in Karnataka

Crop	Data source	Paddy	Jowar	Bajra	Maize	Ragi	Wheat	Tur Dal	Horse gram
Yield kg/ha	D	1150	674	423	1334	423	501	320	200
	PI	6306	2993	1513	4045	3157	2598	1340	2678
Crop	**Data source**	**Black gram**	**Green gram**	**Avare**	**Cowpea**	**Bengal gram**	**Ground nut**	**Sunflower**	**Safflower**
Yield kg/ha	D	114	108	259	244	450	454	303	329
	PI	695	671	2999	1833	1056	1591	2778	1757
	Data source	**Castor**	**Sesamum**	**Niger Seed**	**Soybean**	**Linseed**	**Cotton**	**Sugarcane**	**Tobacco**
Yield kg/ha	D	256	177	123	179	136	154	69000	738
	PI	1757	1528	1053	1562	626	2400	120000	1165

Note: D: data from the Department of Agriculture, PI: public interviews

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 was collated from the government records at the district level (DSO 2019).

Tables 5.4.2 to 5.4.6 list the spatial extent district-wise under different crops. The area under cultivation of crops (cereals, pulses, fruits, vegetables, oilseeds, 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. (Figure 5.4.1). 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 of 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 (Figure 5.4.1). Kalaburagi (Gulbarga) leads in the 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 (Figure 5.4.1). 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 Kolar and Chikkaballapura districts, followed by Vijayapura (Bijapur), with areas ranging from 200 sq. km to 250 sq. km. Vegetable cultivation dominates the districts of Hassan and Dharwad, with a spatial extent of over 400 sq. km.

Horticulture crops (areca nut, 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.

Table 5.4.7 lists the spatial extent of croplands and horticulture in 2005 and 2019 at the district level. 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 the 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.

Table 5.4.2. The spatial extent of croplands under cereals (2005 – area in hectares)

District	Cereals, 2005 – area in hectares								
	Paddy	Jowar	Bajra	Maize	Ragi	Wheat	Barley	Others	Total
Bagalkot	64	155574	50947	50963	0	21202	0	54	278804
Bengaluru Rural	3726	0	0	3123	54283	0	0	0	61132
Belgaum	71341	225605	40727	121537	1960	56811	0	5799	523780
Bellary	66807	88970	18570	53782	5794	848	0	9702	244473
Bengaluru Urban	3503	0	0	724	38454	0	0	26	42707
Bidar	7999	94797	8912	320	0	7373	0	369	119770
Vijayapura (Bijapur)	30	244437	97629	19436	0	49116	0	394	411042
Chamarajanagar	16030	27177	619	20119	22210	0	0	64	86219
Chickmagalur	45659	12663	0	2007	57892	6	0	1376	119603
Chikkaballapura	3777	0	40	12842	56383	0	0	252	73294
Chitradurga	4695	33804	7183	44645	43424	658	0	10299	144708
Dakshina Kannada	58838	0	0	0	0	0	0	0	58838
Davanagere	106549	38767	604	164632	23101	316	0	784	334753
Dharwad	23825	57816	0	20723	129	39502	0	3716	145711
Gadag	1343	93659	2015	22621	101	36348	0	917	157004
Gulbaraga	52520	198207	46697	1550	0	11207	0	435	310617
Hassan	53184	5260	0	30071	108854	0	0	319	197688
Haveri	37313	66271	178	133587	1323	783	0	10663	250118
Kodagu	37228	0	0	2875	462	0	0	0	40565
Kolar	3546	0	37	12055	52929	0	0	236	68803
Koppal	62457	63929	73307	16583	0	9762	0	7425	233463
Mandya	91993	1278	0	4116	66654	3	0	0	164044
Mysore	118084	19819	0	18218	79824	0	0	0	235945
Ramanagara	5647	0	0	4734	82277	0	0	0	92658
Raichur	107990	136756	74849	433	0	2746	0	497	323271
Shimoga	123470	607	0	44954	2776	0	0	0	171807
Tumkur	25874	2754	260	10770	173134	0	0	4459	217251
Udupi	62290	0	0	0	0	0	0	0	62290
Uttara Kannada	79144	77	0	442	21	0	0	0	79684
Yadgir	24886	93919	22127	735	0	5310	0	206	147182

Table 5.4.3. The spatial extent of croplands under pulses and commercial crops

District	Pulses, 2005 – area in hectares				Commercial, 2005 – area in hectares			
	Bengal gram	Turdal	Others	Total	Sugarcane	Cotton	Tobacco	Total
Bagalkot	20960	3105	42989	67054	47556	7315	0	54871
Bengaluru Rural	56	2119	10067	12242	870	0	0	870
Belgaum	41421	5517	68035	114973	115849	37659	20707	174215
Bellary	10510	8889	14027	33426	5352	42373	560	48285
Bengaluru Urban	25	1008	6064	7097	25	0	0	25
Bidar	40496	70100	108430	219026	28019	1914	0	29933
Vijayapura (Bijapur)	49658	36948	73566	160172	19166	3043	0	22209
Chamarajanagar	2130	1898	39563	43591	8958	14169	100	23227
Chickmagalur	3038	891	19710	23639	2876	2037	135	5048
Chikkaballapura	74	4078	13969	18122	268	0	0	268
Chitradurga	6295	7746	22573	36614	111	15420	287	15818
Dakshina Kannada	0	0	3120	3120	95	0	0	95
Davanagere	1715	5692	14051	21458	7000	6732	1623	15355
Dharwad	39111	2893	50714	92718	2018	86481	0	88499
Gadag	38988	2784	108500	150272	123	59863	52	60038
Gulbaraga	84154	234573	106398	425124	4657	18917	0	23574
Hassan	2864	2111	41648	46623	6913	1809	7876	16598
Haveri	1877	4375	32606	38858	1865	63400	7	65272
Kodagu	25	0	845	870	0	0	300	300
Kolar	70	3829	13113	17011	252	0	0	252
Koppal	14117	11807	38339	64263	60	29156	0	29216
Mandya	49	1245	37605	38899	28233	5	0	28238
Mysore	983	5309	112724	119016	9535	71938	59482	140955
Ramanagara	86	3212	15258	18556	1318	0	0	1318
Raichur	18483	17583	13817	49883	13	35250	83	35346
Shimoga	39	212	2073	2324	9976	3833	96	13905
Tumkur	518	10787	47383	58688	509	784	75	1368
Udupi	0	0	7684	7684	16	0	0	16
Uttara Kannada	7	105	2182	2294	786	5715	0	6501
Yadgir	39875	111150	50415	201441	2207	8964	0	11171

Twelve districts among 30 in Karnataka witnessed an increase in spatial extent under pulses. Kodagu, Bengaluru Urban, and Haveri districts have seen over 70% of the area under pulses due to a shift in cropping pattern. Bidar was the only district with a 90% increase in area under oilseeds, while the rest showed a decline in the area. Bengaluru rural and Dakshina Kannada showed over 90% decline in area under oilseeds. About 26 districts showed an increase in the spatial extent under fruit cultivation, and four districts showed a reduction in area. In particular, Bengaluru urban has lost 48% area under fruits. In terms of districts, which increased fruit cultivation, the districts of Dakshina Kannada, Udupi, Kodagu, and Belgaum show over 250% increase in area under fruits, while the districts of Chitradurga, Chamarajanagar, Kolar, Haveri, Uttara Kannada, Koppala, Davanagere, Kalaburagi, Bagalkot, Mysore showed a significant 100% to 200% increase in area under fruits (Figure 5.4.2).

Similarly, 17 districts showed an increase in area under vegetable cultivation (Figure 5.4.2). Koppal was highest, indicating an over 300% increase in area under vegetable cultivation. Similarly, Bagalkot, Chamarajanagar, Kodagu, Raichur, Chitradurga, Mandya, Tumkur, Bellary, Kolar showed a 100% to 200% increase in area under vegetation. On the other hand, Ramanagara, Uttara Kannada and Dharwad districts lost over 50% area under vegetable cultivation.

In terms of commercial crops (sugarcane, cotton, rubber, and tobacco), the districts of Yadgir, Udupi, and Kalaburagi (Gulbarga) saw an increase in extent by 200%. Vijayapura (Bijapur) saw a 176% increase, while about 12 districts witnessed over a 25% increase in area under commercial crops (Figure 5.4.2), and 17 districts showed a decline in area under commercial crops. Kodagu, Bengaluru Urban, Bengaluru Rural, Kolar, and Dakshina Kannada districts witnessed a decline of 90% area under commercial cropping.

Five districts show an increasing trend in agriculture ranging between 5% to 18%, which include Udupi (18%), Chikkaballapura (13%), Kalaburagi (12%), Kolar (8%), Dakshina Kannada (6%) and Bagalkot (5%), while the rest showed declining trends. Bengaluru urban showed a 58% decline in croplands, followed by Mysore with 37%, Bengaluru Rural with 31%, and Tumkur with 30%. Similarly, the area under horticulture has increased in 17 districts (Figure 5.4.3), with a 100% increase in Bidar, Gadag, and Haveri districts. On the other hand, Chamarajanagar, Yadgir, Kalaburagi (Gulbarga), and Bengaluru rural districts witnessed a decline of 70% of the area under horticulture.

Figure 5.4.1. The spatial extent of croplands under cereals, pulses, oilseeds – 2005

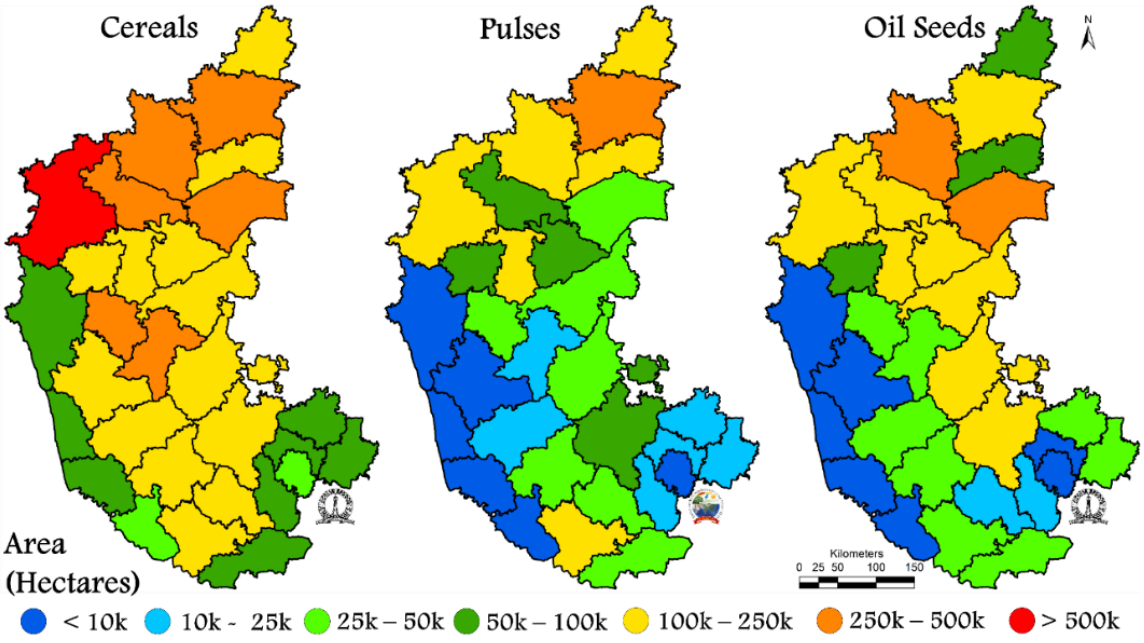


Figure 5.4.2. The spatial extent of commercial crops, fruits, vegetables – 2005

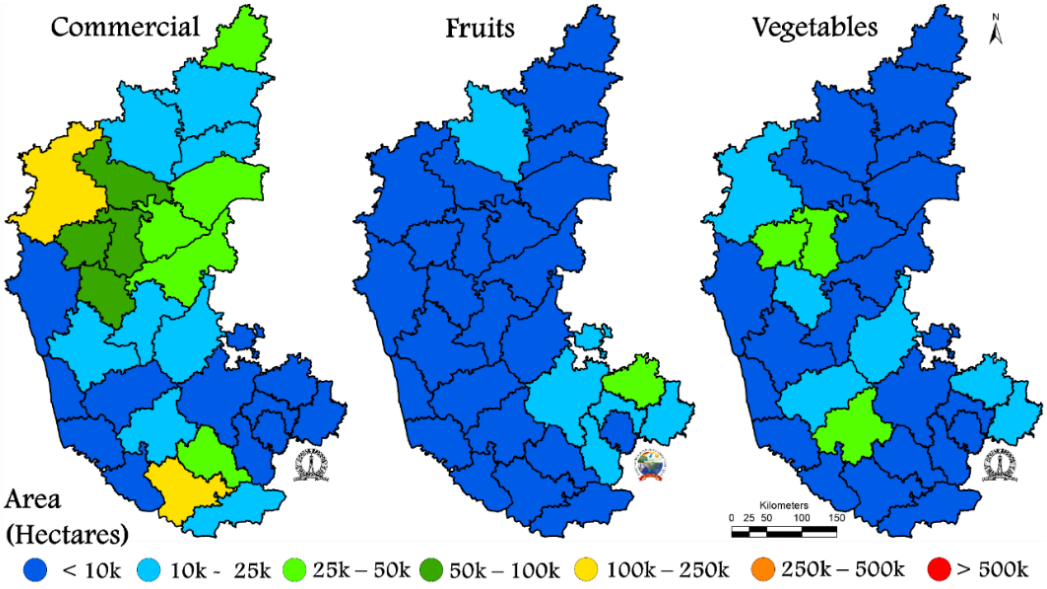


Figure 5.4.3. The spatial extent of horticulture – 2005

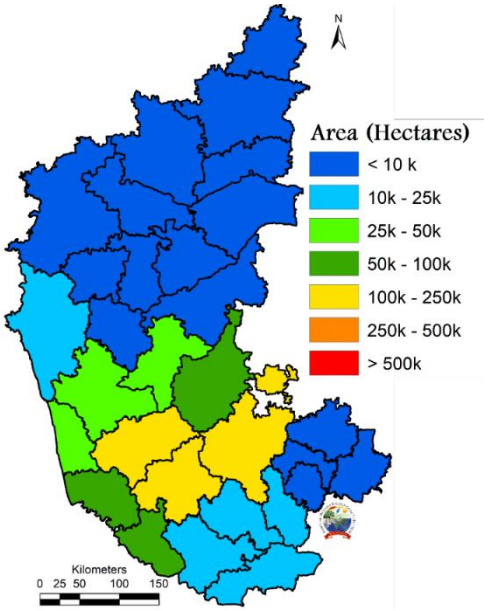


Table 5.4.4. Spatial extent of croplands under oilseeds (2005 – area in hectares)

District	Oil Seeds										
	Groundnut	Castor seed	Sesamum	Rape seed /Mustard	Linseed	Soybean	Niger seed	Sunflower	Safflower	Other oil seeds	Total
Bagalkot	22287	2	948	70	3348	9183	226	117258	2857	0	156179
Bengaluru Rural	6802	623	586	558	0	0	652	266	0	0	9488
Belgaum	79533	205	588	254	1750	97168	755	56448	11490	3	248194
Bellary	72964	209	6495	17	10	0	831	88158	5975	284	174943
Bengaluru Urban	203	457	124	645	0	0	655	11	0	0	2095
Bidar	1526	0	8161	10	536	28175	6120	12282	12160	0	68970
Vijayapura (Bijapur)	81452	0	912	0	4338	40	836	307674	5644	0	400896
Chamarajanagar	20904	629	1602	0	0	0	728	5875	0	0	29738
Chickmagalur	4573	537	5953	226	0	0	1115	14909	10	164	27487
Chikkaballapura	25919	153	0	462	0	0	418	2803	0	0	29756
Chitradurga	159559	1315	4699	192	0	0	338	42952	4090	0	213145
Dakshina Kannada	0	0	491	0	0	0	0	0	0	123	614
Davanagere	20746	222	3104	218	0	0	539	14652	151	73	39705
Dharwad	37907	0	441	3	197	22827	408	10052	15581	0	87416
Gadag	57846	102	2960	16	1329	76	632	84106	5142	83	152292
Gulbaraga	40063	47	11552	64	385	139	1321	117971	10425	0	181968
Hassan	2750	2435	4955	408	0	4	4991	10398	0	30	25971
Haveri	25596	133	928	40	40	1253	828	12950	1459	2	43229
Kodagu	43	0	0	0	0	0	0	0	0	460	503
Kolar	24332	144	0	433	0	0	393	2632	0	0	27933
Koppal	41830	1392	14641	175	2070	0	1452	93507	7295	0	162362
Mandya	4171	1538	13554	0	0	63	2145	48	0	155	21674
Mysore	7623	2373	10493	0	0	18	3673	1214	0	157	25551
Ramanagara	10310	945	889	847	0	0	988	402	0	0	14380
Raichur	35369	1598	5166	229	160	0	20	201961	7150	19	251672
Shimoga	3573	11	89	28	29	5	112	1427	4	145	5423
Tumkur	139384	4105	886	930	26	3	1604	13257	14	0	160209
Udupi	2006	0	89	0	0	0	0	0	0	323	2418
Uttara Kannada	3342	0	5	0	14	0	0	31	0	14	3406
Yadgir	18984	23	5474	30	182	66	626	55899	4940	0	86223

Table 5.4.6. Spatial extent of croplands under fruits (2005 – area in hectares)

District	Fruits							
	Mango	Banana	Citrus fruits	Grapes	Pome fruits	Papaya	Other fruits	Total
Bagalkot	158	379	354	520	456	34	1192	3093
Bengaluru Rural	8546	1544	8	533	714	14	98	11457
Belgaum	1119	1148	125	742	471	42	584	4231
Bellary	815	2302	92	17	784	81	2189	6280
Bengaluru Urban	1759	509	0	836	1820	56	28	5008
Bidar	634	225	98	63	158	47	33	1258
Vijayapura (Bijapur)	218	881	8300	4492	245	17	5870	20023
Chamarajanagar	498	1941	103	0	244	0	151	2937
Chickmagalur	2191	1650	415	20	138	0	49	4463
Chikkaballapura	21581	755	42	669	1889	70	271	25277
Chitradurga	1186	1365	222	13	564	261	1071	4682
Dakshina Kannada	1685	3115	55	0	262	82	1381	6580
Davanagere	1777	876	48	1	275	111	229	3317
Dharwad	3615	163	33	0	1587	15	42	5455
Gadag	305	258	54	14	213	2	133	979
Gulbaraga	823	849	843	61	381	33	247	3237
Hassan	2006	3332	480	6	745	53	357	6979
Haveri	889	1150	20	0	337	8	203	2607
Kodagu	44	545	1110	0	76	0	43	1818
Kolar	20258	709	39	628	1774	66	255	23729
Koppal	668	438	70	63	106	120	1219	2684
Mandya	2651	1481	37	0	588	5	83	4845
Mysore	3001	1820	7	0	777	4	73	5682
Ramanagara	12953	2340	11	809	1082	22	149	17366
Raichur	480	22	452	0	133	16	101	1204
Shimoga	2104	4313	36	0	276	23	1810	8562
Tumkur	9658	4530	63	6	500	42	1039	15838
Udupi	1690	1198	79	0	712	57	955	4691
Uttara Kannada	1242	1670	4	0	70	10	1129	4125
Yadgir	390	403	399	29	181	15	117	1534

Table 5.4.7. Spatial extent of croplands under vegetables,

Total croplands and horticulture (2005 – area in hectares)

District	Vegetable						Total croplands	Horticulture					
	Potato	Tapioca	Sweet potato	Onion	Others	Total		Rubber	Coffee	Cashew	Coconut	Arecanut	Total
Bagalkot	0	0	57	6986	1667	8710	569166	0	1	0	452	2	455
Bengaluru Rural	660	85	8	19	2155	2928	106871	5	80	19	7866	785	8755
Belgaum	5336	0	2164	6967	6660	21127	1087671	0	0	544	599	8	1151
Bellary	0	0	0	3761	2468	6229	514931	0	1	3	1259	32	1295
Bengaluru Urban	204	0	13	90	2838	3145	62818	0	10	0	2498	233	2741
Bidar	47	0	0	441	1887	2375	441386	0	0	30	24	0	54
Vijayapura	0	0	5	5436	1538	6979	1021499	0	0	0	178	0	178
Chamarajanagar	13	0	0	2547	1148	3708	202771	0	686	195	12161	309	13351
Chickmagalur	4051	36	177	5608	2449	12321	310860	709	69526	326	31122	16616	118299
Chikkaballapura	2078	0	0	777	12946	15801	164810	0	0	1181	1084	28	2293
Chitradurga	0	0	0	13134	1317	14451	487294	0	15	9	43354	14498	57876
Dakshina Kannada	0	698	537	0	2370	3605	155525	10113	82	29585	15684	27209	82673
Davanagere	3	0	0	5459	1888	7350	455984	0	20	33	11978	22015	34046
Dharwad	284	0	0	38112	2345	40741	461096	0	0	114	431	11	556
Gadag	0	0	0	30434	1256	31690	552900	0	0	0	622	3	625
Gulbaraga	3	0	21	1302	2343	3669	948687	0	0	0	498	0	498
Hassan	36151	0	68	107	5154	41480	438160	5	38219	16	61098	3483	102821
Haveri	1	0	0	10372	4405	14778	416743	0	0	17	1147	717	1881
Kodagu	0	9	12	0	91	112	134214	1926	83205	2198	1331	1386	90046
Kolar	1950	0	0	730	12153	14833	154714	0	0	1109	1017	26	2152
Koppal	3	0	0	960	2062	3025	495357	0	0	0	344	0	344
Mandya	115	4	14	414	3938	4485	281576	0	85	262	18165	879	19391
Mysore	15	0	0	5	3672	3692	551119	0	26	172	19404	676	20278
Ramanagara	1000	130	12	29	3267	4437	161987	8	121	29	11923	1190	13271
Raichur	0	0	0	1429	1031	2460	664277	0	0	0	441	0	441
Shimoga	0	10	0	20	352	382	240984	881	464	1473	6613	29150	38581
Tumkur	22	28	18	201	1596	1865	582441	0	6	82	110937	16197	127222
Udupi	0	66	439	4	1580	2089	120173	2295	0	19207	14464	5019	40985
Uttara Kannada	0	0	28	77	241	346	117023	6	11	2087	6276	12287	20667
Yadgir	1	0	10	617	1110	1738	449525	0	0	0	236	0	236

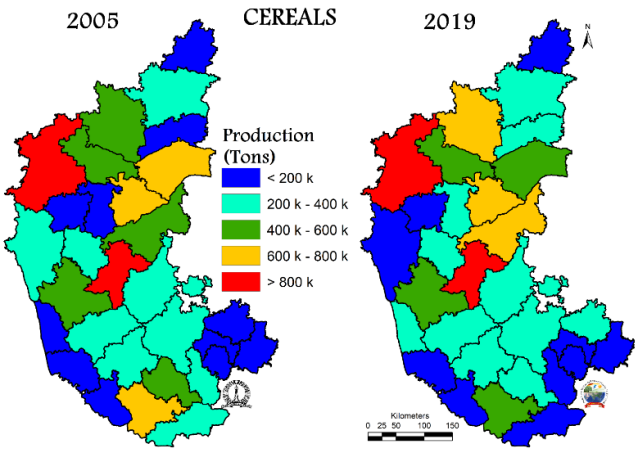
Crop production: Major crop production (opening and closing stock) is depicted in figures 5.4.4 to 5.4.10 and tables 5.4.8 to 5.4.14. The State has produced 11.0 million tonnes of cereals (Figure 5.4.4, Table 5.4.8), 1.4 million tonnes of pulses (Figure 5.4.5, Table 5.4.9), 1.9 million tonnes of oilseeds (Figure 5.4.6, Table 5.4.10), 16.4 million tonnes of commercial crops (Figure 5.4.7, Table 5.4.11), 1.7 million tonnes of fruits (Figure 5.4.8, Table 5.4.12) and 1.4 million tonnes of vegetables, summing up to 33.3 million tonnes of agricultural produce in 2005 (Figure 5.4.9, Table 5.4.13). In addition to this, 1.4 million tonnes of horticulture produce (Figure 5.4.10, Table 5.4.14). District wise assessment of crops indicates that Davanagere has the highest quantity of cereals, i.e., about 1.4 million tonnes (Table 5.4.8), followed by Belgaum with 0.98 million tonnes. Similarly, pulses are predominantly produced in Kalaburagi (Gulbarga), i.e., about 0.32 million tonnes (30% of state produce), followed by Vijayapura (Bijapur), Yadir, and Bidar, contributing over 0.1 million tonnes each (Table 5.4.9). Oilseeds are produced in the districts of Belgaum (0.24 million tonnes) and Vijayapura (Bijapur) (0.20 million tonnes). Belgaum contributes to 50% of the total production of all the commercial crops, i.e., 8.2 million tonnes, followed by Bidar, Mandya and Raichur, contributing over 1 million tonnes each. Fruits are produced the most in the district of Vijayapura (0.2 million tonnes), followed by Chikkaballapura (0.16 million tonnes), Kolar (0.15 million tonnes), and vegetables are produced the most in the districts of Gadag and Hassan, contributing over 0.19 million tonnes each. Aggregation of all produces of the agriculture ecosystem indicates Belgaum produces over 9.7 million tons, followed by Davanagere with 2.2 million tonnes, Bidar and Vijayapura (Bijapur) with 1.9 million tonnes each, Mysore and Mandya with 1.8 million tonnes each, and Bellary, Shimoga, and Kalaburagi contributing 1.0 to 1.2 million tonnes each (Table 5.4.13). Among all the districts, Tumkur produces 20% of the State's horticulture produce (Table 5.4.14), i.e., 0.29 million tonnes, followed by Hassan with 0.19 million tonnes, and Chickmagalur and Kodagu with 0.16 million tonnes each (*Note: each coconut was assumed to be 500 grams based on public interviews, this was necessary to convert to standard measuring unit*).

In the last 15 years, Karnataka has witnessed a 102% increase in agricultural production (Table 5.4.13) and a 140% increase in horticultural production (Table 5.4.14). Oilseed production has declined by 57%, and this was followed by cereals, i.e., about a 2% decline in production. Other crops showed an increase in production between 17% to 366%. Pulses showed an increase of 17%, followed by commercial crops with 157%, Fruits at 256%, and vegetables at 366%. The district-wise analysis is presented next.

Figure 5.4.4. Cereals production during 2005 and 2019

Table 5.4.8. Cereals production (tons)

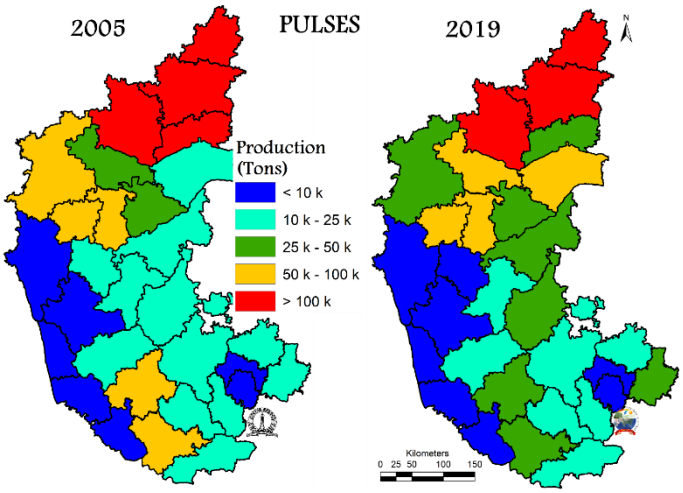
District	2005	2019
Bagalkot	422610	435628
Bengaluru Rural	154972	123505
Belgaum	980024	927751
Bellary	554970	735662



- Cereals: 12 districts show an increase in production level, including Chikkaballapura 62%, Chitradurga 39% and Gadag 38%. Mandya shows the highest decline, i.e., 43% followed by Bengaluru Urban with 42% (Table 5.4.8, Figure 5.4.4).

Bengaluru Urban	136525	78940
Bidar	184925	125111
Vijayapura (Bijapur)	498654	606556
Chamarajanagar	242243	177633
Chickmagalur	239929	277932
Chikkaballapura	185863	301048
Chitradurga	203566	282185
Dakshina Kannada	169924	151184
Davanagere	1399405	1183977
Dharwad	161946	190254
Gadag	165540	229184
Gulbaraga	389155	279202
Hassan	313705	349432
Haveri	320579	351813
Kodagu	121956	104055
Kolar	174477	128377
Koppal	604294	765876
Mandya	429152	243529
Mysore	639914	572461
Ramanagara	234894	151361
Raichur	620608	510574
Shimoga	555574	587997
Tumkur	371424	294060
Udupi	179894	215651
Uttara Kannada	200367	183582
Yadgir	184397	245440

Figure 5.4.5. Pulses production during 2005 and 2019

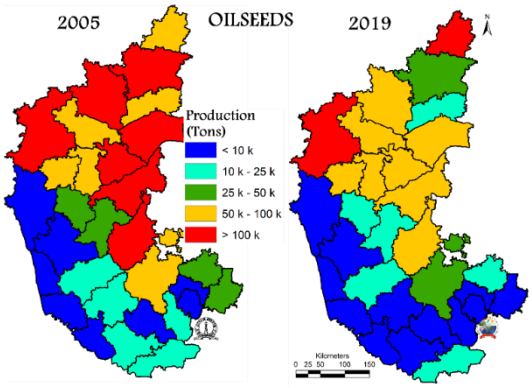


- Pulses: 12 district shows an increase in production level. Raichur, Vijayapura (Bijapur), and Bagalkot show more than a 135% increase; on the other hand, Yadgiri and Kodagu show over 70% decline (Table 5.4.9, Figure 5.4.5).

Table 5.4.9. Pulses (tons)

District	2005	2019
Bagalkot	42173	99092
Bengaluru Rural	7058	4132
Belgaum	55926	43716
Bellary	21944	26987
Bengaluru Urban	4786	3194
Bidar	185931	177150
Vijayapura (Bijapur)	102130	276434
Chamarajanagar	23050	21984
Chickmagalur	12679	13900
Chikkaballapura	24504	16451
Chitradurga	22419	35825
Dakshina Kannada	1501	1495
Davanagere	17417	11408
Dharwad	55792	84295
Gadag	73664	94321
Gulbaraga	325563	404209
Hassan	99586	41148
Haveri	14258	4383
Kodagu	358	30
Kolar	23003	32390
Koppal	25672	48092
Mandya	15746	12918
Mysore	55870	46339
Ramanagara	10697	13462
Raichur	24008	99749
Shimoga	1301	866
Tumkur	20247	14595
Udupi	3696	2477
Uttara Kannada	1384	963
Yadgir	154265	43648

Figure 5.4.6. Oilseed production during 2005 and 2019

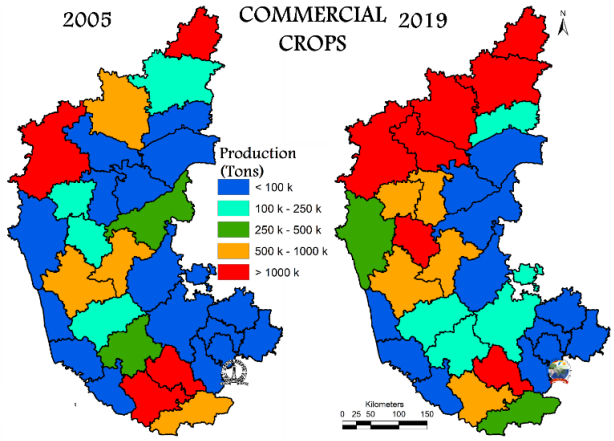


- Oilseeds: Bidar shows a 122% increase in production, followed by Udupi with a 92% increase; the rest of the districts showed a decline in production levels. Bengaluru Urban and Bengaluru Rural showed the highest reduction, i.e., over 92% decline (Figure 5.4.6, Table 5.4.10).

Table 5.4.10. Oilseed (tons)

District	2005	2019
Bagalkot	93831	56111
Bengaluru Rural	8188	424
Belgaum	243375	102841
Bellary	167272	88869
Bengaluru Urban	1557	119
Bidar	58914	131020
Vijayapura (Bijapur)	205267	50872
Chamarajanagar	21128	15521
Chickmagalur	17400	14177
Chikkaballapura	29385	17806
Chitradurga	161314	85044
Dakshina Kannada	398	253
Davanagere	36964	14861
Dharwad	74235	69025
Gadag	86367	54002
Gulbaraga	123521	38534
Hassan	20384	3899
Haveri	28575	20381
Kodagu	510	71
Kolar	27585	6667
Koppal	128720	80145
Mandya	7111	2727
Mysore	15521	8430
Ramanagara	12410	4181
Raichur	174598	67944
Shimoga	4725	2400
Tumkur	76757	33806
Udupi	2420	4644
Uttara Kannada	5368	3786
Yadgir	58529	19380

Figure 5.4.7. Commercial crops production during 2005 and 2019



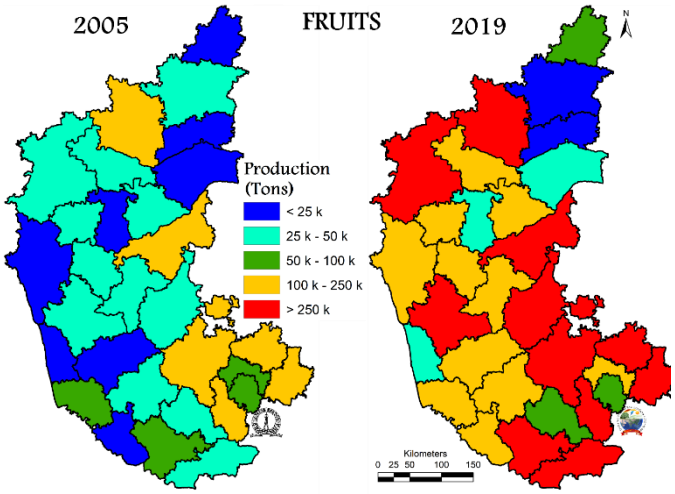
- Commercial: 18 districts showed an increase in commercial crop production.

Table 5.4.11. Commercial crops (tons)

District	2005	2019
Bagalkot	4148	9005885
Bengaluru Rural	0	3868
Belgaum	8247013	15422404
Bellary	354170	86811
Bengaluru Urban	0	0
Bidar	1532236	2187005
Vijayapura (Bijapur)	864909	3437251
Chamarajanagar	595720	370425
Chickmagalur	133483	202810
Chikkaballapura	18320	575
Chitradurga	4684	34235
Dakshina Kannada	0	1490
Davanagere	665263	676818
Dharwad	129803	853624
Gadag	33805	857004
Gulbaraga	192068	1878711
Hassan	266060	189286
Haveri	122662	1152447
Kodagu	221	24
Kolar	17197	468

Bangalore, Gadag, Udupi show over ten folds increase, while Chikkaballapura, Kolar and Kodagu show over a 90% decrease in production (Figure 5.4.7, Table 5.4.11).

Figure 5.4.8: Fruit production during 2005 and 2019



- Fruit and Vegetables: 27 districts showed an increase in fruit production, and three showed a decline in production. Chamarajanagar, Uttarakannada, Chickmagalur, Chitradurga showed over 7.5 times increase, while districts, namely Bengaluru urban, Kalaburagi (Gulbarga) and Yadgir, showed an 11 to 94% decline (Figure 5.4.8, Table 5.4.12). Twenty-six districts showed an increase in vegetable production, while four districts showed a decline in production. About 22 districts showed over a 100% increase in vegetable production of which Koppal, Tumkur, Mysore, Mandya, Bidar, Bengaluru Urban, and Kolar ranged the highest (between 15 to 33-folds).

- Croplands (aggregating all crops): Overall, 27 districts show an increase in crop production, of which 11 districts show an increase of over 100%, while three show a decline in crop production. The districts of Bagalkot, Haveri, and Kolar show over 250% increase in agricultural production, and

Koppal	7960	80708
Mandya	1384665	3468790
Mysore	1046969	869171
Ramanagara	0	66254
Raichur	12769	0
Shimoga	581993	585453
Tumkur	23958	126075
Udupi	972	14750
Uttara Kannada	92335	421679
Yadgir	91009	134599

Table 5.4.12. Fruit (tons)

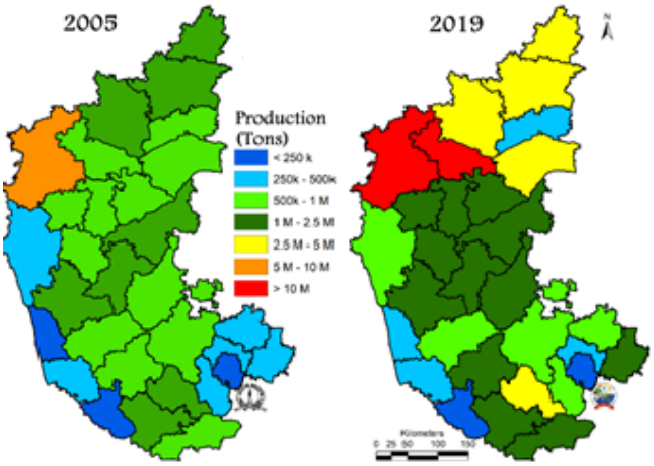
District	2005	2019
Bagalkot	30413	149094
Bengaluru Rural	88900	160955
Belgaum	49000	292565
Bellary	112504	333491
Bengaluru Urban	61848	54868
Bidar	12472	61246
Vijayapura (Bijapur)	201974	443632
Chamarajanagar	31619	359696
Chickmagalur	22877	215946
Chikkaballapura	164121	316560
Chitradurga	44317	391781
Dakshina Kannada	87795	147628
Davanagere	26168	134614
Dharwad	32126	137541
Gadag	7352	38534
Gulbaraga	30544	7959
Hassan	39356	172467
Haveri	44904	204987
Kodagu	20505	108055
Kolar	154066	649409
Koppal	31620	191257
Mandya	35210	80349
Mysore	56738	266896
Ramanagara	134748	359730
Raichur	9292	42644
Shimoga	42652	288330
Tumkur	100011	324760
Udupi	22470	28466
Uttara Kannada	17861	184472
Yadgir	14473	913

Table 5.4.13. Croplands -total production (tons)

District	2005	2019
Bagalkot	662613	10376890
Bengaluru Rural	270310	414777
Belgaum	9703020	17478205

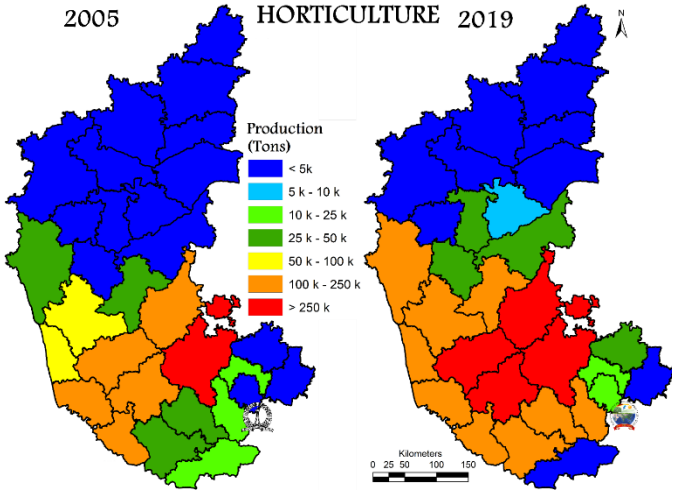
Yadgir shows a 13% decline (Figure 5.4.9, Table 5.4.13).

Figure 5.4.9. Total croplands production in Karnataka during 2005 and 2019



Bellary	1260474	1612653
Bengaluru Urban	207898	203974
Bidar	1979805	2803709
Vijayapura	1926817	4892366
Chamarajanagar	949889	1165755
Chickmagalur	506937	890255
Chikkaballapura	469555	954677
Chitradurga	538895	1283250
Dakshina Kannada	285036	327440
Davanagere	2209847	2252647
Dharwad	598526	1633937
Gadag	569862	1466936
Gulbaraga	1079674	2617410
Hassan	928967	1033599
Haveri	597256	2375348
Kodagu	145130	214895
Kolar	440788	1545833
Koppal	806742	1541518
Mandya	1877200	3940494
Mysore	1821238	1925672
Ramanagara	409715	660470
Raichur	855399	812537
Shimoga	1187482	1471588
Tumkur	597433	966718
Udupi	220163	283306
Uttara Kannada	318615	797156
Yadgir	511592	446315

Figure 5.4.10. Total production of horticulture goods



- Horticulture: 24 districts show an increase in horticulture production, while six districts show a decline in horticulture production. Gadag and Bidar districts show an over 12-fold increase in production (Figure 5.4.10, Table 5.4.14).

Table 5.4.14: Horticulture (tons)

District	2005	2019
Bagalkot	1085	2502
Bengaluru Rural	15373	20573
Belgaum	2008	1642
Bellary	3057	33413
Bengaluru Urban	4816	19568
Bidar	97	1311
Vijayapura	425	2595
Chamarajanagar	17824	1190
Chickmagalur	164620	461123
Chikkaballapura	3515	28820
Chitradurga	109155	523534
Dakshina Kannada	140138	119972
Davanagere	47656	190304
Dharwad	1199	4220
Gadag	1489	48283
Gulbaraga	1253	1420
Hassan	193960	403087
Haveri	3763	41167
Kodagu	160880	107175
Kolar	3300	4993

Koppal	820	8936
Mandya	34253	155408
Mysore	26732	201418
Ramanagara	23301	223501
Raichur	1052	2580
Shimoga	58893	120427
Tumkur	293756	271740
Udupi	68811	219247
Uttara Kannada	34795	190175
Yadgir	594	168

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 (winter crops) and *kharif* crops (monsoon crops), respectively, along with other published literature.

Table 5.4.15 provides the list of crops, MSP, production cost, and net revenue generated for 2005. Table 5.4.16.1 lists crop-wise MSP in 2019, while Table 5.4.16.2 lists the associated production costs (2019) compiled through public interviews, etc.

Table 5.4.15. MSP (Rs/Quintal) and cost of production (CACP 2005a, b; DMI 2020; EANDS 2020; TNAU Agriculture Portal 2020)

Crop	Paddy	Jowar	Bajra	Maize	Ragi	Wheat	Barley	Other Millets
MSP 2005 Rs/Q	600	525	525	540	525	640	495	1172
Cost of production Rs/Q	465	252	317	291	295	431	315	703
Net Rs/Ton	1348	2727	2082	2491	2300	2088	1797	4687

Crop	Ground nut	Castor	Sesamum	Mustard	Linseed	Soybean	Niger seeds	Sunflower	Safflower	Others/ Oilseeds
MSP 2005 Rs/Q	1510	1458	1924	1313	1395	1101	1762	1676	1547	1101
Cost of production Rs/Q	1076	642	734	275	614	661	893	618	497	484
Net Rs/Ton	4340	8165	11902	10379	7815	4393	8695	10585	10502	6163

Crop	Pepper	Rubber	Coffee	Cashew	Coconut (Rs/1000 nuts)	Arecanut	Sugarcane (Rs/tons)	Cotton	Tobacco
MSP 2005 Rs/Q	7345	4072	1856	1896	2732	5298	75	1980	2648
Cost of production Rs/Q	2989	1657	755	772	1319	2156	18	1010	1078
Net Rs/Ton	43554	24144	11005	11246	14131	31415	569	9702	15700

Crop	Mango	Banana	Lemon	Grapes	Pomegranate	Papaya	Guava
MSP 2005 Rs/Q	928	512	1039	649	2041	297	557
Cost of production Rs/Q	399	220	447	279	878	128	239
Net Rs/Ton	5289	2919	5923	3702	11635	1692	3173

Crop	Potato	Tapioca	Sweet Potato	Onion	Green Chillies	Other vegetables	Bengal gram	Tur dal	Others
MSP 2005 Rs/Q	359	359	359	567	675	649	1178	1401	560
Cost of production Rs/Q	101	101	101	328	290	279	489	570	357
Net Rs/Ton	2577	2577	2577	2390	3846	3702	6883	8309	2031

Table 5.4.16.1. MSP Rs/Quintal (Rs per 100 kg) (*Fruits Market Price in Bangalore, Karnataka*, 2019; *Krishi Marata Vahini*, 2019; *AgMarknet*, 2020; *Farmers Portal*, 2020; *MSP for Rabi Crops 2019 - 2020*, 2020; Coffee Board, 2019-2020; Commodities Online, 2019-2020)

Cereals	Paddy	Jowar	Bajra	Maize	Ragi	Wheat	Other millets (barley)	
	1850	2550	2000	1760	3150	1925	3613	
Pulses	Tur Dal	Horse gram	Black gram	Green gram	Avare	Cowpea	Bengal gram	Other pulses
	5800	2317	4924	7050	4688	4567	4875	2317
Oil seeds	Groundnut	Sunflower	Safflower	Castor	Sesamum			
	5090	5650	5215	4915	6485			
	Niger seeds	Soybean	Mustard	Linseed	Others/oilseeds			
	5940	3710	4425	4704	3710			
Commercial crops	Cotton	*Sugarcane (Rs/Tons)	Tobacco	Coffee	*Coconut (Rs/1000 nuts)			
	5335	275	9773	6850	10086			
	Cashew	Coco	Areca	Cardamom	Pepper	Rubber		
	7000	19000	19555	285100	27111	15029		
Fruits	Banana	Mango	Lemon	Pineapple	Guava	Grapes	Sapota	Pomegranate	Papaya
	1380	2500	2800	1000	1500	1750	1000	5500	800
Vegetables	Potato	Tomato	Brinjal	Beans	Cluster Beans	Onion	Green Chillies	Leafy Vegetables	Other Vegetables
	967	532	1058	2000	2200	1527	1818	532	1750

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). Table 5.4.16.2 depicts the cost of production for each crop. Across the grades (based on the quality as A1, A2, B1, B2, C1, C2), only A1 was considered in the analysis.

Table 5.4.16.2. Cost of Production Rs/Quintal (Rs per 100 kg) in 2019

Cereals	Paddy	Jowar	Bajra	Maize	Ragi	Wheat	Other millets (barley)	
	1434	1225	1207	948	1770	1296	2167	
Pulses	Tur Dal	Horse gram	Black gram	Green gram	Avare	Cowpea	Bengal gram	Other pulses
	2360	1476	1476	2765	2668	1476	2025	1476
Oil seeds	Groundnut	Sunflower	Safflower	Castor	Sesamum			
	3627	2081	1675	2162	2473			
	Niger seeds	Soybean	Mustard	Linseed	Others / Oilseeds			
	3009	2229	926	2069	1632			
Commercial crops	Cotton	*Sugarcane (Rs/Tons)	Tobacco	Coffee	*Coconut (Rs/1000 nuts)			
	2721	65	3977	2787	4870			
	Cashew	Coco	Areca	Cardamom	Pepper	Rubber		
	2849	7733	7958	116035	11034	6116		
Fruits*	Banana	Mango	Lemon	Pineapple	Guava	Grapes	Sapota	Pomegranate	Papaya
	593	1075	1204	430	645	752	430	2365	344
Vegetables	Potato	Tomato	Brinjal	Beans	Cluster Beans	Onion	Green Chillies	Leafy Vegetables	Other Vegetables
	272	228	454	860	946	882	781	228	752

Table 5.4.17 depicts the district-wise share of crops (based on MSP and production) in the agriculture ecosystem. Figure 5.4.11 illustrates the district-wise contribution of crops in the agriculture ecosystem (based on Table 5.4.17). Among the districts in

Karnataka, Belgaum contributes about 85.2 billion rupees, of which commercial crops contribute 55.79%, followed by cereals with 20.56%. This is followed by Bagalkot (54.2 billion rupees), Vijayapura (50.87 billion rupees), while the districts of Chitradurga, Davanagere, Kalaburagi contributed 43.7 to 44.3 billion rupees each. The least was contributed by Bengaluru Urban with revenue of 4.5 billion, of which 51.9% is contributed by cereals, followed by fruits (21.85%). In the dry belts, particularly in northern Karnataka, the assessment indicates that pulses are extensively grown, followed by fruits in the south-eastern portions (Kolar and Chikkaballapura). Commercial crops and cereals cropping are practiced in transition zones as well as dry belts with managed water resources and also in the zones close to the Western Ghats.

Table 5.4.17. District wise contribution by agricultural sector (million rupees)

District	Cereals	Pulses	Oil Seeds	Fruits	Vegetables	Commercial	∑Agriculture
Belgaum	17534	2198	4564	5475	7917	47568	85257
Bagalkot	8267	5116	2933	3354	9612	24945	54229
Vijayapura	11116	15097	2737	10442	798	10682	50871
Chitradurga	5938	1895	4371	11481	6598	14067	44351
Davanagere	26147	569	776	2395	2620	11628	44133
Kalaburagi/	6398	22237	2072	149	115	12797	43767
Chickmagalur	6302	550	796	3602	1951	21848	35048
Mysore	11496	2004	494	4006	1596	14436	34033
Tumkur	7941	600	1723	7710	1508	13639	33120
Bellary	13686	1327	4549	6056	4861	1894	32373
Shimoga	10732	49	134	4212	70	16346	31543
Haveri	6492	213	1025	3227	8520	10497	29975
Koppal	12825	2453	4383	3927	4925	1154	29667
Gadag	4466	4773	2886	676	2962	11327	27090
Dharwad	3644	4247	3133	3044	4330	8297	26694
Bidar	2929	10003	5140	979	1312	6092	26455
Hassan	7286	1880	212	2992	3093	9662	25125
Kolar	3975	1254	341	13466	5621	308	24965
Dakshina Kannada	2797	75	16	1984	304	16846	22022
Mandya	5247	426	153	1291	1725	11513	20355
Raichur	9581	4972	3617	818	1199	26	20212
Udupi	3989	118	237	407	268	14760	19780
Uttara Kannada	3381	44	193	2947	41	12211	18817
Chikkaballapura	6573	886	908	6216	2598	427	17608
Ramanagar	4423	553	213	7399	719	3206	16512
Yadgiri	4602	2588	1008	22	35	5900	14154
Chamarajanagar	3428	697	804	4987	2456	1417	13788
Kodagu	1912	1	4	2230	39	7344	11529
Bangalore Rural	3505	175	22	3058	1186	631	8577
Bangalore Urban	2387	152	6	1005	691	356	4598
KARNATAKA	**218999**	**87153**	**49449**	**119555**	**79670**	**311824**	**866649**

Crop-wise assessment of revenue generated reveals that Davanagere has the highest revenue in cereal crops (26.1 billion rupees), followed by Belgaum (17.5), and Bellary, Koppal, Mysore, Vijayapura (Bijapur), and Shimoga, range between 10 to 15 billion rupees each. Similarly, Kalaburagi contributed the highest for pulses (22.3 billion), followed by Vijayapura (Bijapur) (15 billion) and Bidar (10 billion rupees). Bidar,

Belgaum, Bellary, Koppal, Chitradurga contributed to oilseeds with 4.3 to 5.1 billion rupees each. Districts Kolar, Chitradurga, and Vijayapura (Bijapur) contribute to fruits with a 10.4 to 13.4 billion rupees revenue each. Vegetables contributed by Bagalkot, Haveri, and Belgaum amounted to between 7.9 billion to 9.6 billion rupees each. Belgaum contributes about 47.5 billion rupees through commercial crops, followed by Bagalkot (21.8), Chickmagalur (24.9 billion rupees), followed by Dakshina Kannada and Shimoga, each with 16 billion rupees.

The annual revenue (in 2019) from the cropland ecosystem in Karnataka State amounts to 866 billion (Figure 5.4.12). Commercial crops contribute to 36.1% (311.8 billion), followed by cereal crops (25.3%, 218.9 billion), fruits (13.8%, 119.5 billion), pulses (10.1%, 87.1 billion), vegetables (9.2%, 79.6 billion) and oilseeds (5.7%, 49.4 billion).

Total revenue (based on the crop production and MSP) generated in a district was compared with the GDDP (Gross District Domestic product) to understand the agriculture sector's contribution to the State economy. Table 5.4.18 lists district-wise GDDP obtained from the Economic Survey of Karnataka, 2018-19. Figure 5.4.13 indicates district-wise total revenue generated through agriculture, GDDP, and the proportion of revenue generated from the agriculture sector compared to the GDDP. The total GSDP (Gross State Domestic Product) of Karnataka State is 10128 billion rupees. The revenue generated from croplands is 866 billion rupees, which is 8.5% of the GSDP. Among districts, Bangalore urban has the highest GDDP of 3535.6 billion rupees (agriculture share is 0.13%), followed by Dakshina Kannada with GDDP of 587 billion rupees (agriculture contributes 3.75%). Agriculture contributes 27% in GDDP of Vijayapura district, followed by Chitradurga (26%), Koppal (25%), Gadag (25%), Kalaburagi (22%), Davanagere (22%), and Bagalkot (20%).

Figure 5.4.11. District wise share of crops (2019), Karnataka

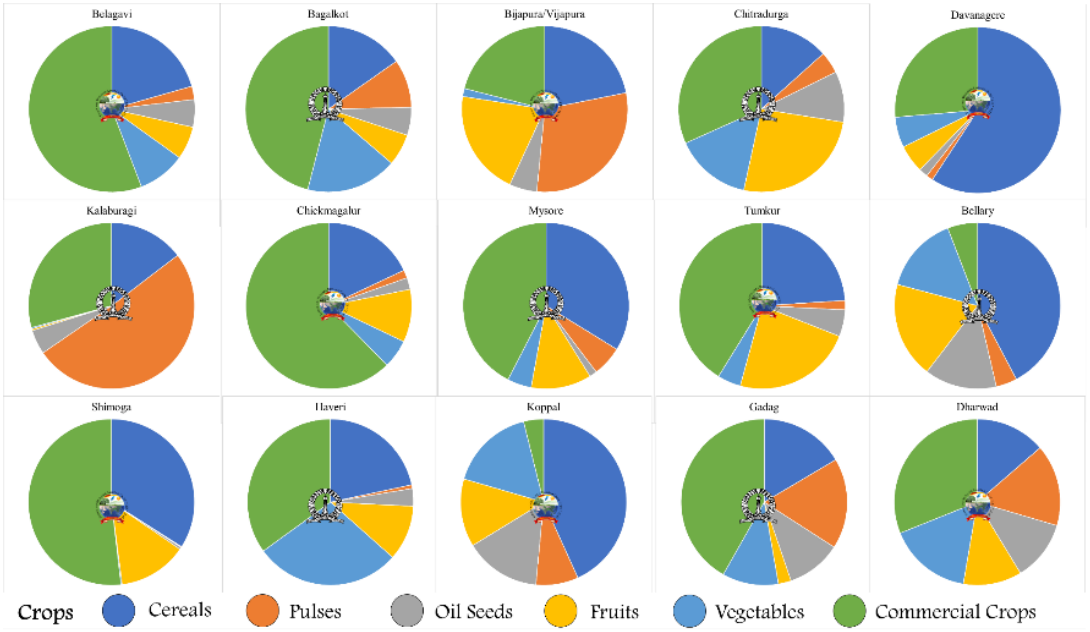
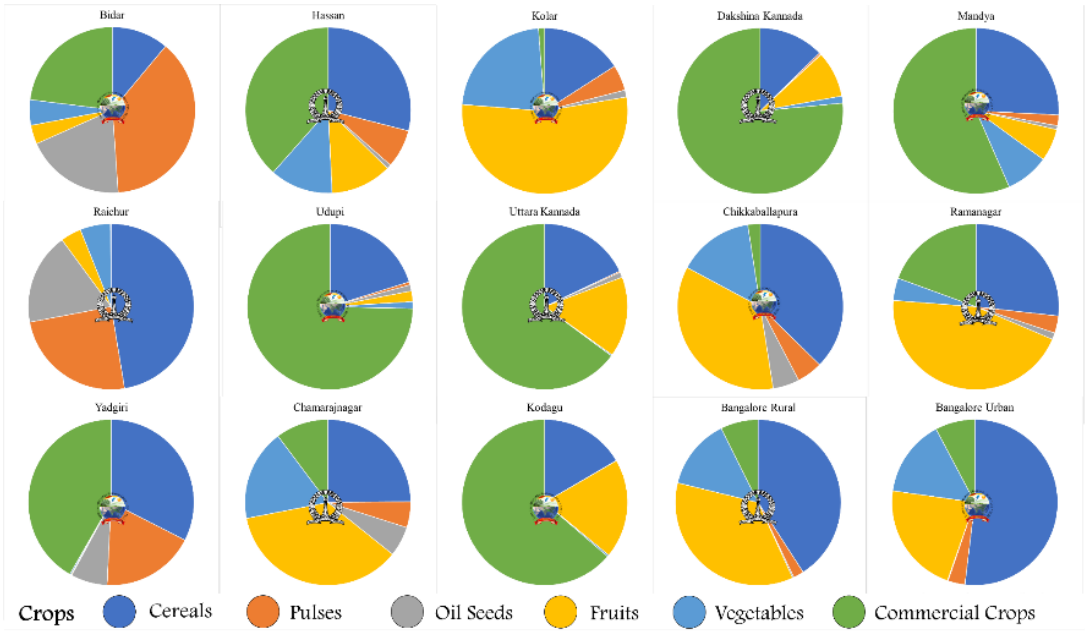


Figure 5.4.12. The relative share of crops in the total revenue of 866 billion (2019)



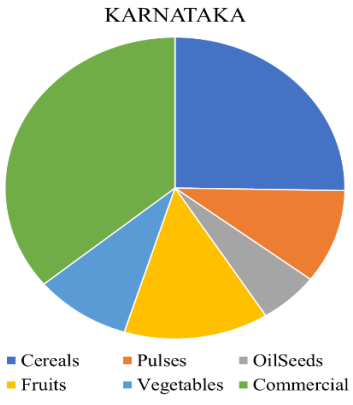
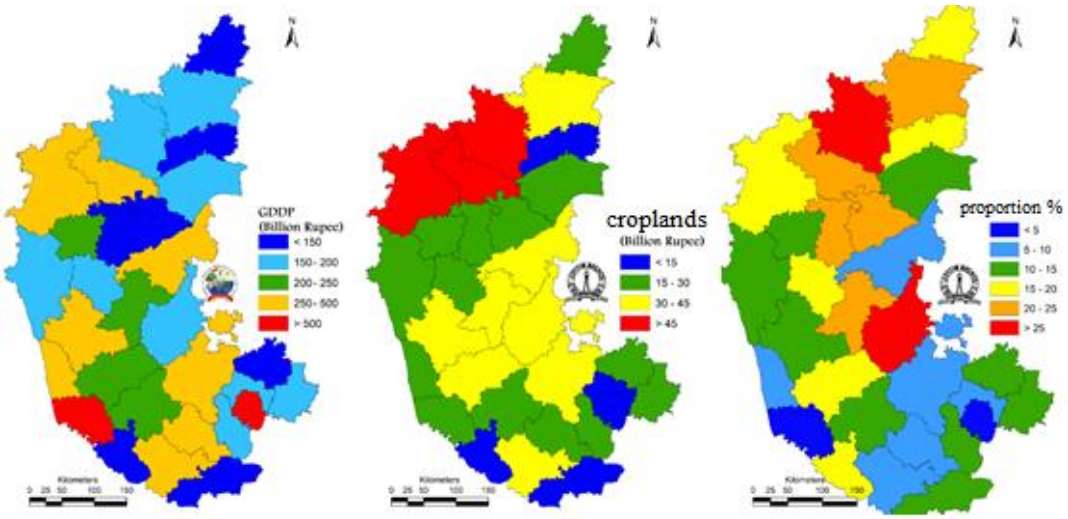


Table 5.4.18. District wise GDDP, and revenue from croplands (billion rupees)

District	GDDP	Agriculture	Proportion (%)
Bagalkot	265.5	54.2	20.43
Bengaluru (Urban)	3635.6	4.6	0.13
Bengaluru (Rural)	162.5	8.6	5.28
Belgaum	454.6	85.3	18.76
Bellary	334.8	32.4	9.67
Bidar	144.9	26.5	18.26
Vijayapura	188.1	50.9	27.04
Chamarajanagar	117.0	13.8	11.79
Chikkaballapura	144.4	17.6	12.20
Chikkamagaluru	230.2	35.0	15.23
Chitradurga	169.6	44.4	26.16
Dakshina Kannada	587.2	22.0	3.75
Davanagere	202.1	44.1	21.84
Dharwad	244.7	26.7	10.91
Gadag	109.1	27.1	24.82
Kalaburagi	195.1	43.8	22.44
Hassan	236.4	25.1	10.63
Haveri	155.3	30.0	19.31
Kodagu	61.6	11.5	18.73
Kolar	176.6	25.0	14.14
Koppal	118.9	29.7	24.96
Mandya	267.3	20.4	7.61
Mysuru	352.1	34.0	9.67
Raichur	173.5	20.2	11.65
Ramanagara	159.6	16.5	10.34
Shimoga	300.5	31.5	10.50
Tumkur	385.3	33.1	8.60
Udupi	276.3	19.8	7.16
Uttara Kannada	186.2	18.8	10.10
Yadgir	93.4	14.2	15.16
KARNATAKA	10128.1	866.6	8.56

Figure 5.4.13. District wise GDDP, revenue generated from croplands and its relative proportion in the GDDP



Ecosystem services of agriculture ecosystem: Table 5.4.19 provide details of various ecosystem goods and services and their monetary value across different major crop types.

Table 5.4.19. 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)

Table 5.4.20 lists ecosystem services district-wise for agriculture and horticulture ecosystems. The agriculture ecosystem 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). The district-wise assessment indicates that Belgaum has the highest ecosystem services value of 25.1 billion rupees (13.5 billion rupees from provisioning services, 10.89 billion rupees from regulating services, and 0.6 billion rupees from cultural services). Vijayapura (Bijapur) district has an agriculture ecosystem service value of 19.8 billion rupees (8.9 billion rupees from provisioning, 10.2 billion rupees from regulating, and 0.6 billion rupees from cultural services). The lowest values are in Bengaluru Urban and Bengaluru Rural districts, with the agriculture ecosystem service value of 1.4 billion Rs each.

Similar to agriculture, 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). A district-wise assessment indicates Tumkur has the highest value of 9.7 billion rupees (8.3 billion rupees from provisioning, 1.2 billion rupees from regulating services, and 0.6 billion rupees from cultural services), followed by Hassan (5.5 billion rupees) and Dakshina Kannada (4.3

billion rupees). Districts with the lowest values include Bidar (3 million rupees), Chikkaballapura (14 million rupees), and Vijayapura (Bijapur) (14 million rupees).

Figures 5.4.14 and 5.4.15 provide the monetary value of agriculture (croplands and horticulture) ecosystem services in 2005. The ecosystem services of agriculture are about 266 billion rupees. Belgaum contributes the highest at 25.1 billion rupees, followed by Hassan (21 billion rupees) and Tumkur (21 billion rupees), and Vijayapura (Bijapur) (19.8 billion rupees).

Table 5.4.20. Monetary value of agriculture - croplands and horticulture ecosystems services (million Rs)

District	Croplands				Horticulture				TESV (Agriculture) = croplands +horticulture
	Provisioning	Regulating	Cultural	TESV	Provisioning	Regulating	Cultural	TESV	
Bagalkot	4479	5702	361	10542	31	5	0	36	10577
Bengaluru Rural	999	391	25	1414	437	88	6	530	1944
Belgaum	13542	10894	689	25125	45	12	1	57	25182
Bellary	5103	5150	326	10579	87	13	1	100	10680
Bengaluru Urban	831	602	38	1472	137	27	2	166	1638
Bidar	4599	4425	280	9305	2	1	0	3	9307
Vijayapura (Bijapur)	8968	10240	648	19856	12	2	0	14	19870
Chamarajanagar	1979	1899	120	3998	483	134	8	625	4623
Chickmagalur	1739	1931	122	3792	2807	1186	75	4068	7860
Chikkaballapura	1558	789	50	2397	12	2	0	14	2411
Chitradurga	2618	1629	103	4351	3136	580	37	3753	8103
Dakshina Kannada	2167	4306	272	6745	3477	829	52	4358	11103
Davanagere	4105	730	46	4881	1418	341	22	1781	6662
Dharwad	3450	4231	268	7949	32	6	0	38	7986
Gadag	3861	4617	292	8770	42	6	0	49	8819
Gulbaraga	5613	3757	238	9608	35	5	0	41	9649
Hassan	5520	9507	601	15629	4465	1031	65	5561	21190
Haveri	2820	3362	213	6394	109	19	1	129	6524
Kodagu	1811	4160	263	6234	2414	903	57	3374	9608
Kolar	1619	214	14	1847	69	22	1	92	1939
Koppal	3021	1529	97	4647	23	3	0	27	4674
Mandya	3571	4963	314	8848	966	194	12	1173	10021
Mysore	3939	2629	166	6735	756	203	13	972	7707
Ramanagara	1514	593	37	2144	662	133	8	803	2947
Raichur	5033	5323	337	10692	30	4	0	34	10727
Shimoga	1986	1491	94	3571	1792	387	24	2203	5775
Tumkur	4244	6656	421	11321	8380	1276	81	9736	21057
Udupi	1148	2029	128	3306	1549	411	26	1986	5292
Uttara Kannada	2118	4564	289	6971	999	207	13	1219	8190
Yadgir	2660	1780	113	4553	17	2	0	19	4572
KARNATKTA	106615	110093	6965	223676	34424	8032	505	42961	266637

Figure 5.4.14. Services from croplands ecosystem (2005)

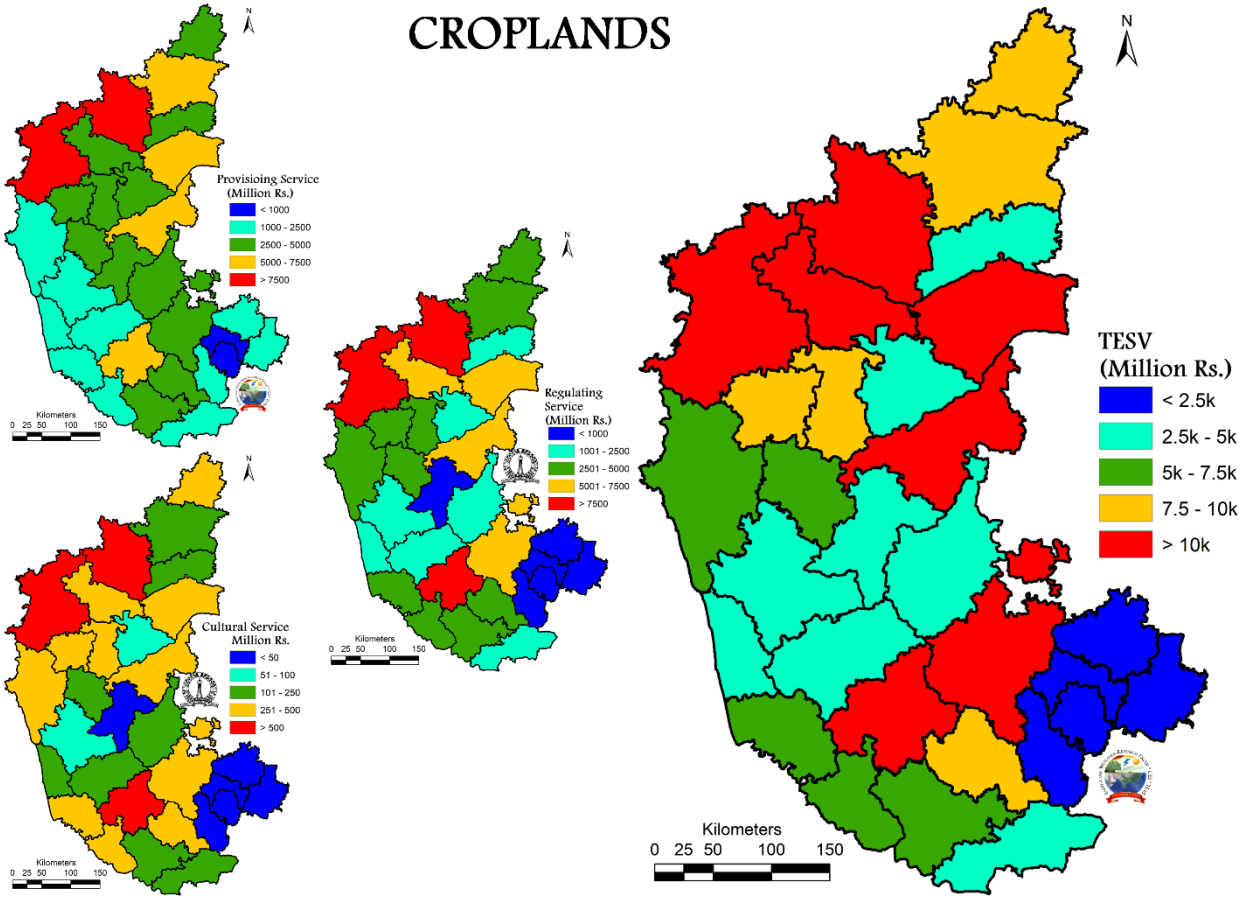
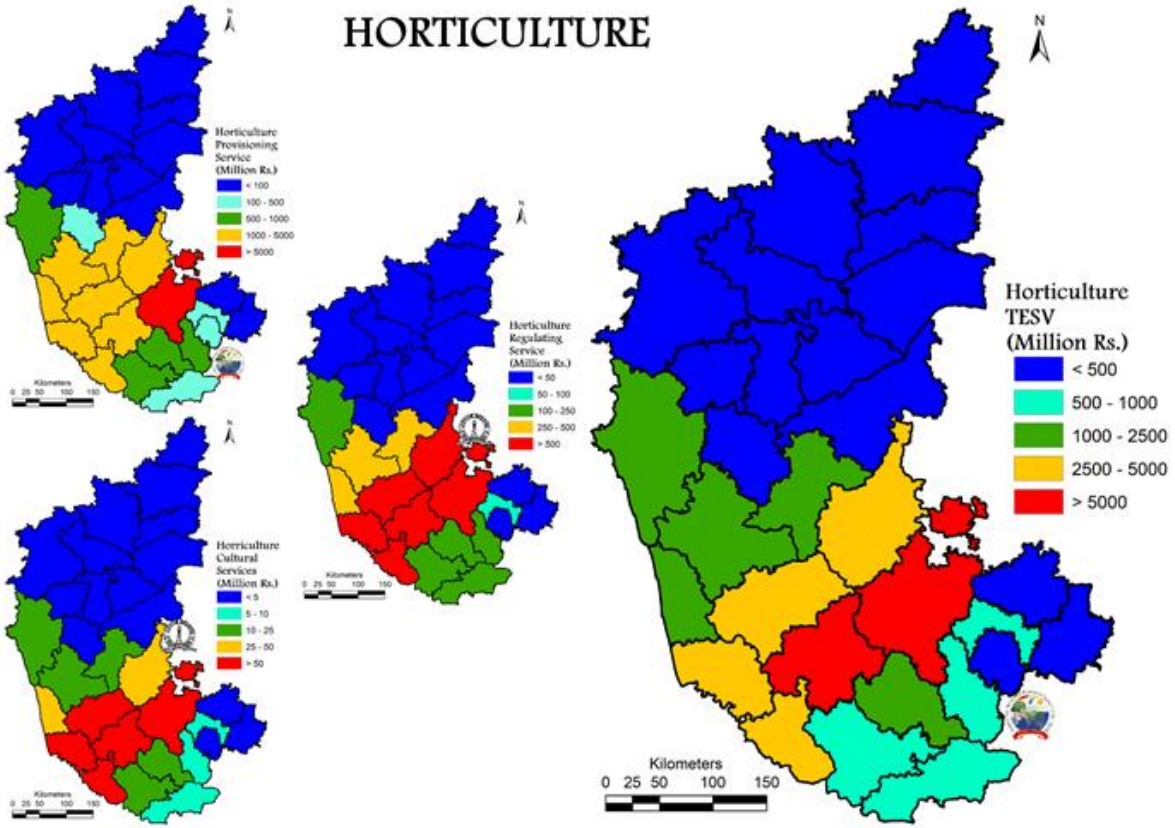
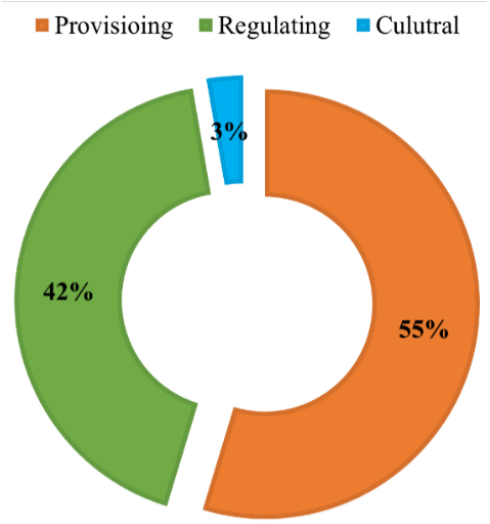


Figure 5.4.15. Services from horticulture ecosystem (2005)



Valuation of agriculture ecosystem services (2019): Services of agriculture ecosystem in Karnataka state with diverse cropping patterns amount to 1,077.6 billion rupees, with 55% from provisioning services, 42% from regulating services, and 3% from cultural services (Figure 5.4.16). The net present value (NPV) of the agriculture ecosystem is 27.72 trillion rupees.

Figure 5.4.16. Agriculture ecosystem services distribution – Karnataka State, 2019

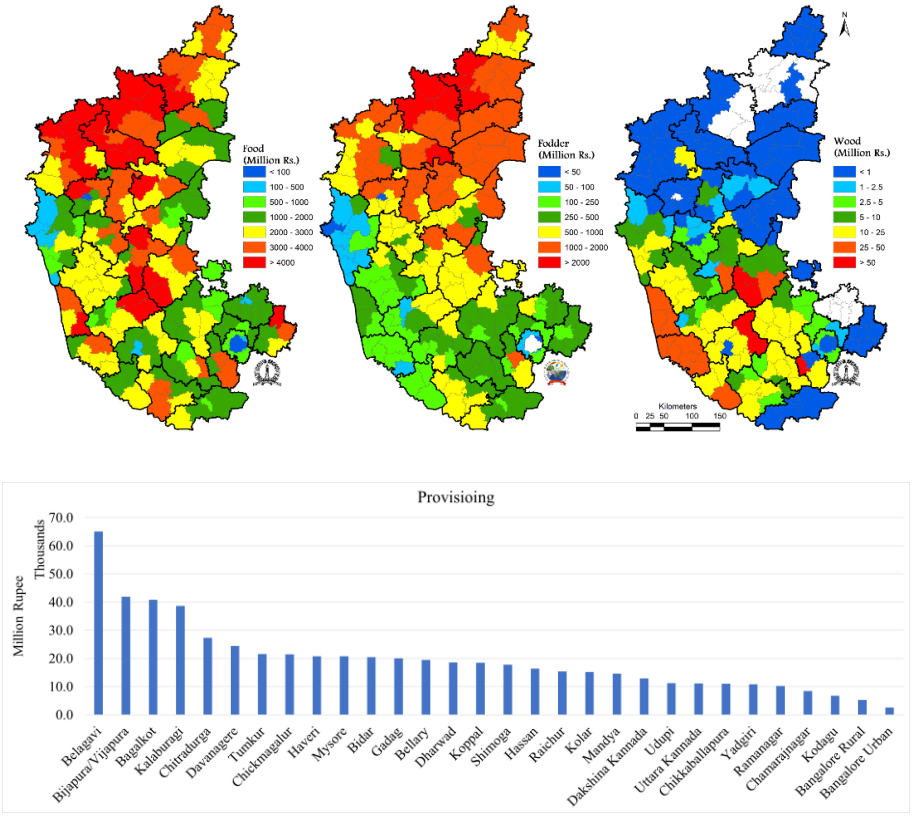


District-wise agriculture ecosystem services are listed in Tables 5.4.21.1, 5.4.21.2, and 5.4.22. The annual provisioning services amount to 589 billion rupees (food: 462 billion, fodder:125 billion, and wood 1.5 billion rupees), regulating services amount to 459 billion rupees (air quality: 42 billion, 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 107 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.

Provisioning services: In the current study, provisioning services include food, fodder, and wood derived from agriculture (croplands and horticulture) ecosystems for 2019 (Table 5.4.21.1). District-wise variability in ecosystem services from the agriculture ecosystem is depicted in Figure 5.4.17.

Belgaum contributes the highest of 64.99 billion rupees/year (Table 5.4.21.1, Figure 5.4.17), followed by Vijayapura (41.9 billion) and Kalaburagi (38.6 billion rupees). The lowest is in Bengaluru Urban (2.5 billion rupees), followed by Bengaluru Rural (5.2 billion rupees).

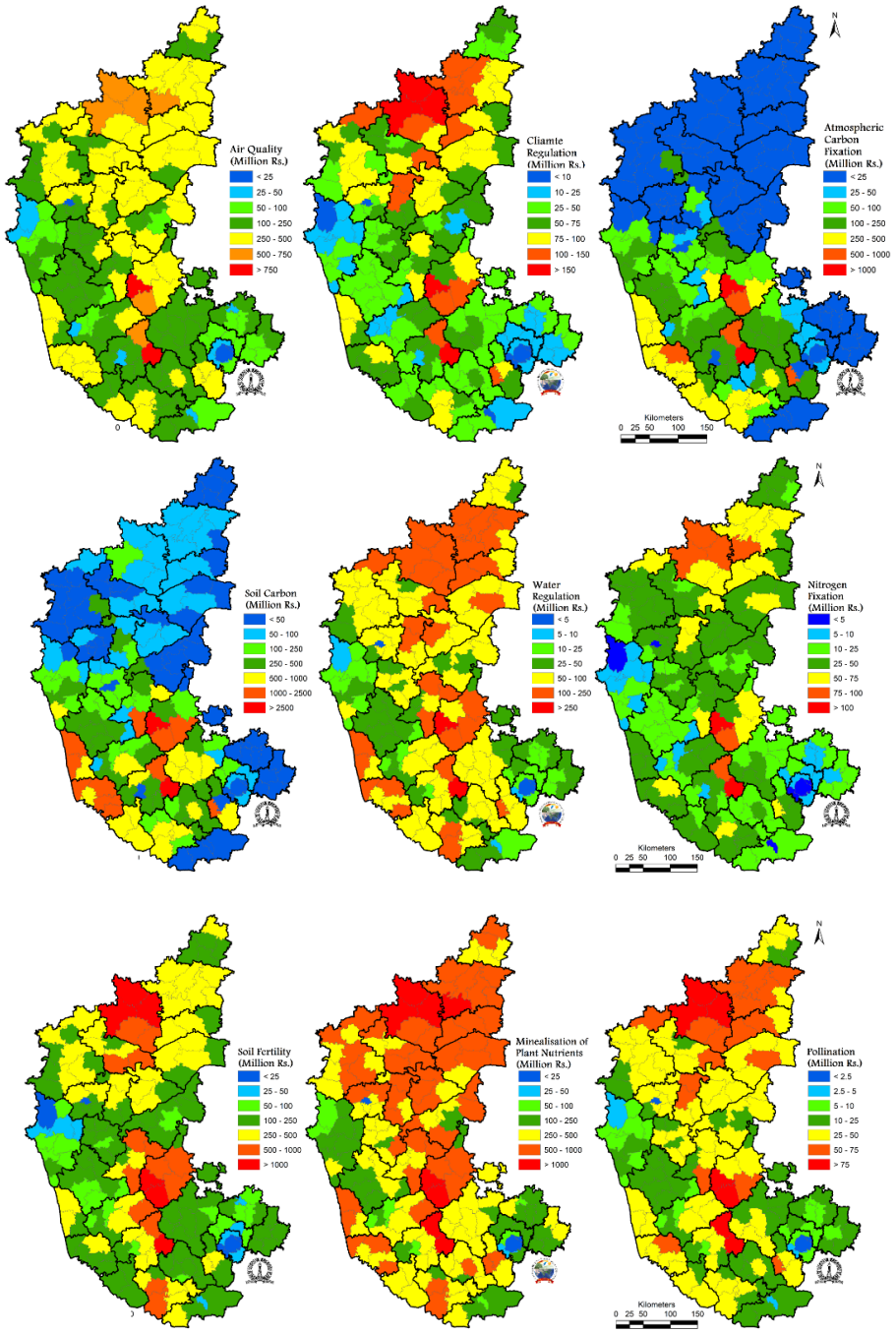
Figure 5.4.17. Provisioning services (food, fodder, wood) during 2019 - Agriculture

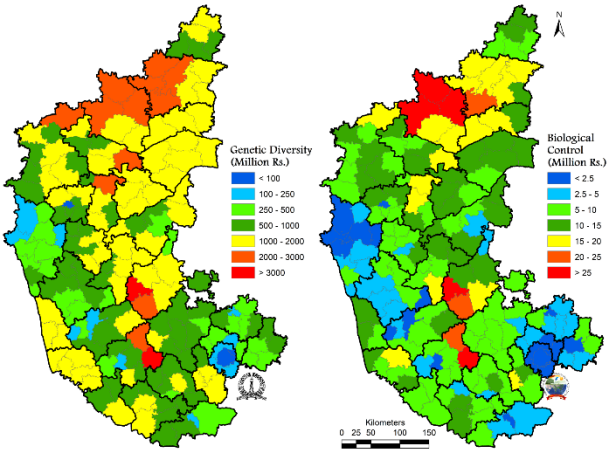


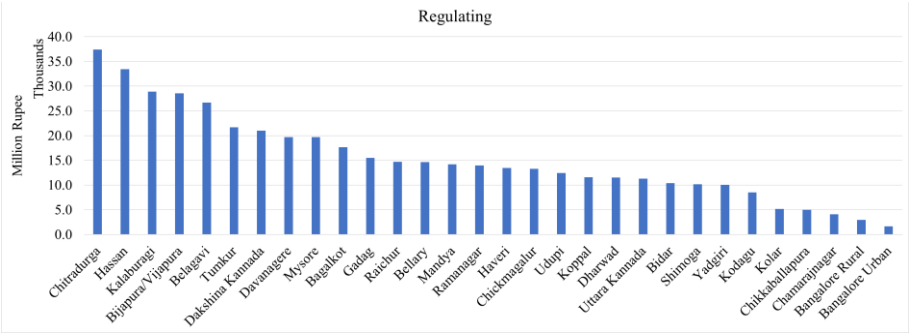
Regulating services: Regulating services considered (Table 5.4.21.1 and 5.4.21.2) are air quality, climate regulation, atmospheric carbon fixation, soil carbon, water regulation, nitrogen fixation, soil fertility, remediation – organic and inorganic materials (mineralization of plant nutrients), pollination, genetic diversity, and biological control. Figure 5.4.18 depicts the variability in regulating services across districts in Karnataka.

Chitradurga contributes the highest with 37.3 billion rupees/year (961.7 billion rupees - NPV) followed by Hassan with 33.4 billion rupees/year, and Kalaburagi, Vijayapura, and Belgaum with 25 to 28 billion rupees/year each (Table 5.4.21.1 and Table 5.4.21.2, Figure 5.4.18). Bengaluru Urban, Bengaluru rural, Chamarajanagar and Chikkaballapura contributed the lowest ranging between 1.6 to 4.9 billion rupees each.

Figure 5.4.18. Regulating services (air quality, climate regulation, atmospheric carbon fixation, soil carbon, water regulation, nitrogen fixation, soil fertility, remediation – organic and inorganic materials, pollination, genetic diversity, biological control) – agriculture ecosystem

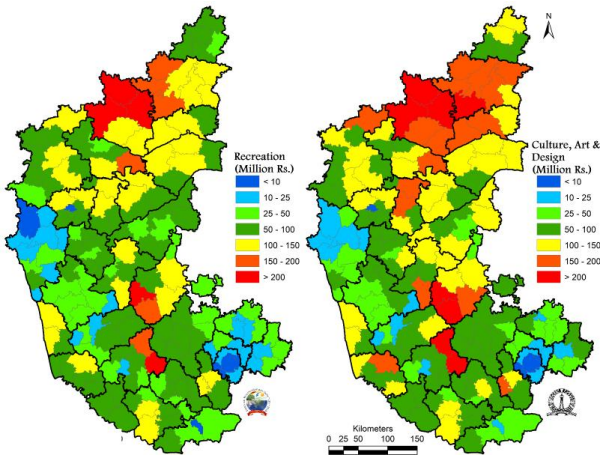


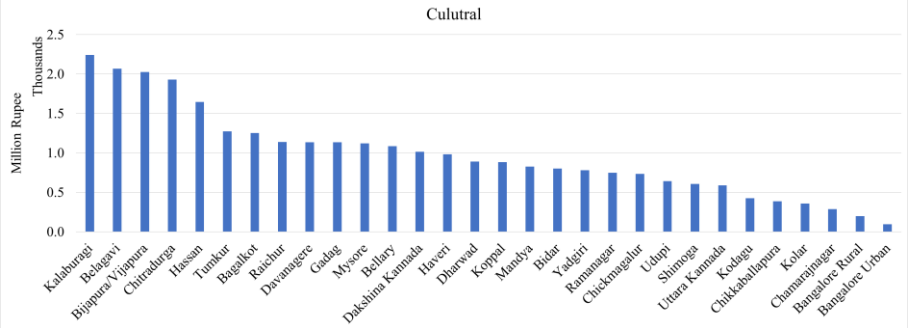




Cultural Services: Cultural services (Table 5.4.21.2) include i) recreation and tourism and ii) culture and art. The relative share of cultural services is depicted in Figure 5.4.17. Kalaburagi contributed the highest with 2.2 billion rupees (57.6 billion rupees NPV), followed by Belgaum and Vijayapura (Bijapur) with 2 billion rupees /year each (Table 5.4.21.2, Figure 5.4.19). The lowest values were observed in Bengaluru Urban and Bengaluru Rural districts with 96.4 million rupees/year and 199.1 million rupees/year, respectively.

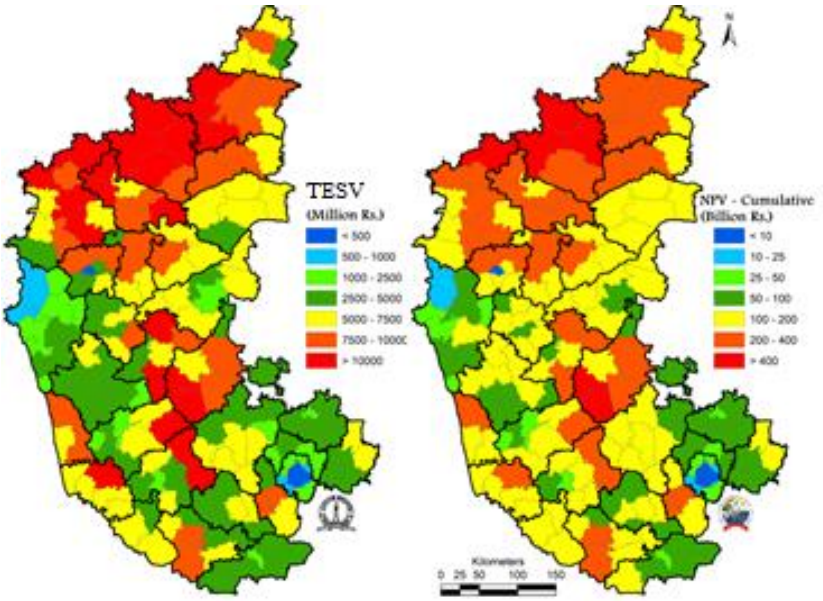
5.4.19. Cultural services (recreation, culture) from the agriculture ecosystem

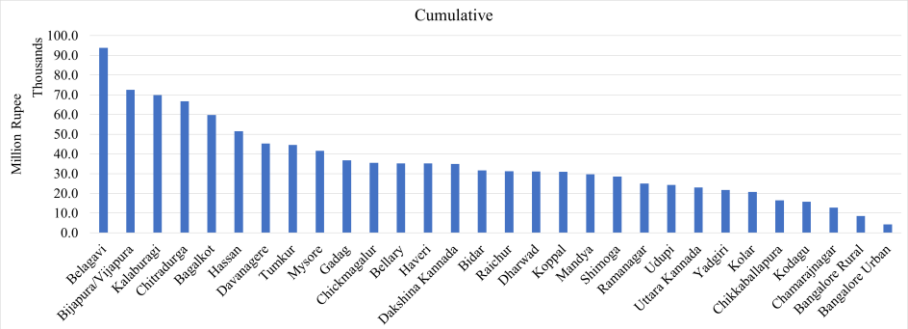




Total ecosystem supply value [TESV] of agriculture ecosystem: Provisioning, regulating, and cultural services were aggregated to compute TESV – total ecosystem supply value of agriculture ecosystem in Karnataka State, India, which are listed in Table 5.4.22. Belgaum District provides 93.7 Billion Rs./year (2.4 trillion rupees NPV); this was followed by Vijayapura, Kalaburagi, and Chitradurga, with services ranging between 66.6 billion rupees to 72.4 billion rupees/year (Figure 5.4.20). The lowest was 4.3 billion rupees /year in the district of Bengaluru Urban, followed by Bengaluru Rural with 8.4 billion rupees/year.

Figure 5.4.20. Agriculture ecosystem TESV –Karnataka, 2019





Temporal comparison of agriculture ecosystem services: Monetary values of ecosystem services (provisioning, regulating, cultural services, and TSEV) 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 to 2019 values by considering the GDP deflator (MoSPI 2020) of an inflation rate of 2.92 times (*Inflation Calculator - Indian Rupee*, 2019). Tables 5.4.23 and 5.4.24 list district-wise comparative assessments of various goods and services of 2005 (at 2019 price) with goods and services of 2019 for agriculture and horticulture ecosystems.

Croplands Ecosystem: Tables 5.4.23 indicates that there has been an increase in the provisioning goods of 193 billion rupees (311 billion rupees in 2005 (at 2019 price) increased to 505 billion rupees in 2019, an increase of 62%), a decline in regulating services of 31 billion rupees (321 billion rupees in 2005 declined to 290 billion rupees in 2019, a drop of 10%), a marginal increase in cultural services of 1.5 billion rupees (20.3 billion rupees in 2005 increased to 21.8 billion rupees, an increase of 8%) and an increase in TESV of 164 billion rupees (653 billion rupees in 2005 increased to 817 billion rupees in 2019, an increase of 25%). However, a TESV decline of 24% to 80% is noticed during 2005 to 2019 in Mandya, Bengaluru Urban, Tumkur, Udupi, Hassan, Raichur, Uttara Kannada, Dakshina Kannada, and Kodagu districts, due to the conversion of agriculture lands to commercial plantations, built-up areas, etc. On the other hand, there has been an increase in TESV of 125% in Ramanagara, Kolar, Chitradurga, Kalaburagi (Gulbarga), Chikkaballapura, and Koppal districts, owing to an increase in the spatial extent of cropland.

Horticulture ecosystem: There has been a decline of 19 billion rupees (Tables 5.4.24) in provisioning services (100 billion rupees in 2005 (at 2019 price), decreased to 80.9 billion rupees in 2019, a decline of 19%), an increase in regulating services of 15 billion rupees (23 billion rupees in 2005 increased to 38 billion rupees in 2019, an increase of 65%), 0.2 billion rupees increase in cultural services (1.5 billion rupees in 2005 increased to 1.7 billion rupees in 2019, an increase of 16%) and decline of 4 billion rupees in TESV (125 billion in 2005 declined to 121 billion rupees in 2019, a drop of 3%). An increase in TESV is noticed in 14 districts, while the rest showed a declining trend. About a 125% increase in TESV is seen in the Uttara Kannada, Gadag, Chikkaballapura, and Bidar districts, while a 78% decline in the districts of Raichur, Chamarajanagar, Bagalkot, Yadgir, and Kalaburagi (Gulbarga) was seen during 2005 to 2019.

Table 5.4.21.1. Ecosystem services of agriculture ecosystem (million rupees/year), district wise, Karnataka

District	Provisioning services			Regulating services				
	Food	Fodder	Wood	Air quality	Climate regulation	Atmospheric carbon fixation	Soil carbon	Water flow
Bagalkot	33577	7194	1	1805	430	34	253	475
Bangalore Rural	4439	847	9	287	68	106	323	84
Bangalore Urban	2283	292	8	139	33	100	291	45
Belgaum	53017	11982	1	2983	712	44	383	783
Bellary	13620	5865	14	1565	373	186	658	425
Bidar	15761	4704	1	1158	276	20	158	304
Vijayapura	30162	11738	1	2920	696	48	388	767
Chamarajanagar	6865	1585	1	413	99	11	66	109
Chickmagalur	18961	2391	65	1058	252	765	2237	342
Chikkaballapura	8970	2093	0	559	133	7	67	147
Chitradurga	22411	4667	226	2784	664	2653	7684	956
Dakshina Kannada	11981	747	176	1465	349	2056	5894	560
Davanagere	20116	4237	82	1637	390	972	2868	512
Dharwad	13515	5065	2	1286	307	33	205	339
Gadag	14048	5962	21	1635	390	259	869	450
Hassan	13139	3058	227	2375	566	2658	7661	850
Haveri	15505	5207	18	1419	338	224	751	390
Kalaburagi	25491	13134	1	3231	771	46	409	848
Kodagu	6140	530	68	612	146	792	2275	228
Kolar	13556	1590	2	519	124	31	133	138
Koppal	13502	5007	4	1275	304	60	279	338
Mandya	11935	2562	78	1193	285	922	2689	391
Mysore	16609	4034	87	1614	385	1026	3020	510
Raichur	8779	6643	1	1642	392	32	234	432
Ramanagar	8617	1523	97	1079	257	1131	3267	380
Shimoga	15691	2036	52	875	209	613	1796	282
Tumkur	17411	4011	117	1838	438	1382	4036	600
Udupi	10083	1028	93	928	221	1083	3118	336
Uttara Kannada	9933	1082	82	851	203	962	2772	305
Yadgiri	6233	4588	0	1125	268	14	138	295
KARNATAKA	462348	125401	1534	42271	10081	18268	54920	12623

Table 5.4.21.2. Ecosystem services of agriculture ecosystem (million rupee/year), district wise, Karnataka

District	Regulating services						Cultural services	
	Nitrogen fixation	Soil fertility	Mineralisation of soil nutrient	Pollination	Genetic diversity	Biological control	Recreation	Culture
Bagalkot	237	2984	3444	234	7711	69	563	689
Bangalore Rural	38	233	548	37	1227	11	90	110
Bangalore Urban	18	113	265	18	594	5	43	53
Belgaum	391	2419	5692	386	12745	114	930	1138
Bellary	205	1269	2986	203	6686	60	488	597
Bidar	152	939	2210	150	4948	44	361	442
Vijayapura	383	4827	5570	378	12473	111	910	1114
Chamarajanagar	54	683	789	54	1766	16	129	158
Chickmagalur	139	1748	2018	137	4518	40	330	404
Chikkaballapura	73	454	1067	72	2390	21	174	213
Chitradurga	365	4602	5311	361	11892	106	868	1062
Dakshina Kannada	192	1188	2795	190	6257	56	457	559
Davanagere	215	2706	3123	212	6992	62	510	625
Dharwad	169	1043	2453	167	5493	49	401	491
Gadag	214	1325	3119	212	6983	62	510	624
Hassan	312	3926	4531	308	10146	91	740	906
Haveri	186	1150	2707	184	6060	54	442	541
Kalaburagi	424	2620	6165	419	13805	123	1007	1233
Kodagu	80	496	1168	79	2615	23	191	234
Kolar	68	858	990	67	2216	20	162	198
Koppal	167	1034	2433	165	5448	49	398	487
Mandya	157	968	2277	155	5098	46	372	455
Mysore	212	2669	3080	209	6897	62	503	616
Raichur	215	1331	3133	213	7014	63	512	627
Ramanagar	141	875	2058	140	4608	41	336	412
Shimoga	115	710	1669	113	3738	33	273	334
Tumkur	241	1490	3507	238	7851	70	573	701
Udupi	122	752	1770	120	3963	35	289	354
Uttara Kannada	112	690	1624	110	3635	32	265	325
Yadgiri	148	913	2147	146	4807	43	351	429
KARNATAKA	5545	47015	80649	5475	180578	1613	13175	16130

Table 5.4.22. Ecosystem services of agriculture ecosystem - district wise TESV and NPV

District	Total services (million Rupees/Year)				Net present value (billion rupees)			
	Provisioning	Regulating	Cultural	TESV	Provisioning	Regulating	Cultural	NPV
Bagalkot	40771.9	17674.7	1251.4	59697.9	1049.1	454.8	32.2	1536.0
Bangalore Rural	5295.1	2963.1	199.1	8457.3	136.2	76.2	5.1	217.6
Bangalore Urban	2582.5	1621.7	96.4	4300.6	66.4	41.7	2.5	110.7
Belgaum	64999.6	26654.1	2068.4	93722.1	1672.4	685.8	53.2	2411.4
Bellary	19500.0	14616.4	1085.1	35201.5	501.7	376.1	27.9	905.7
Bidar	20464.8	10359.8	802.9	31627.5	526.6	266.6	20.7	813.8
Vijayapura	41900.9	28561.3	2024.1	72486.4	1078.1	734.9	52.1	1865.1
Chamarajanagar	8450.5	4059.8	286.6	12796.9	217.4	104.5	7.4	329.3
Chickmagalur	21416.9	13254.0	733.2	35404.1	551.1	341.0	18.9	910.9
Chikkaballapura	11062.6	4992.2	387.9	16442.7	284.6	128.4	10.0	423.1
Chitradurga	27304.2	37377.0	1929.9	66611.0	702.5	961.7	49.7	1713.9
Dakshina Kannada	12904.6	21001.9	1015.5	34921.9	332.0	540.4	26.1	898.5
Davanagere	24435.3	19688.8	1134.7	45258.8	628.7	506.6	29.2	1164.5
Dharwad	18581.4	11541.7	891.4	31014.4	478.1	297.0	22.9	798.0
Gadag	20030.4	15518.0	1133.3	36681.7	515.4	399.3	29.2	943.8
Hassan	16424.1	33423.0	1646.5	51493.6	422.6	860.0	42.4	1324.9
Haveri	20730.0	13463.0	983.5	35176.5	533.4	346.4	25.3	905.1
Kalaburagi	38625.6	28861.5	2240.3	69727.4	993.8	742.6	57.6	1794.1
Kodagu	6737.0	8516.2	424.4	15677.6	173.3	219.1	10.9	403.4
Kolar	15148.6	5163.8	359.7	20672.1	389.8	132.9	9.3	531.9
Koppal	18512.7	11553.4	884.1	30950.2	476.3	297.3	22.7	796.3
Mandya	14575.4	14179.7	827.4	29582.5	375.0	364.8	21.3	761.2
Mysore	20729.9	19684.2	1119.2	41533.4	533.4	506.5	28.8	1068.6
Raichur	15422.5	14700.1	1138.3	31260.9	396.8	378.2	29.3	804.3
Ramanagar	10236.2	13976.5	747.8	24960.5	263.4	359.6	19.2	642.2
Shimoga	17779.2	10153.5	606.6	28539.3	457.5	261.2	15.6	734.3
Tumkur	21539.9	21690.4	1274.2	44504.4	554.2	558.1	32.8	1145.1
Udupi	11202.8	12447.0	643.1	24292.9	288.2	320.3	16.5	625.1
Uttara Kannada	11097.6	11296.0	589.9	22983.6	285.5	290.6	15.2	591.4
Yadgiri	10820.7	10044.5	780.2	21645.4	278.4	258.4	20.1	556.9
KARNATAKA	**589283.0**	**459037.2**	**29305.2**	**1077625.4**	**15162.1**	**11810.9**	**754.0**	**27727.0**

Table 5.4.23. Monetary value of goods and services, agriculture ecosystem -comparative assessment 2005 and 2019 (million Rs)

District	Opening stock 2005 (at 2019 price)				Closing stock 2019				% Change			
	Provisioning	Regulating	Cultural	TESV	Provisioning	Regulating	Cultural	TESV	Provisioning	Regulating	Cultural	TESV
Bagalkot	13077	16651	1053	30781	40758	17552	1246	59556	212%	5%	18%	93%
Bengaluru Rural	2916	1142	72	4130	4935	2009	156	7099	69%	76%	116%	72%
Belgaum	39542	31811	2012	73365	64964	26575	2065	93604	64%	-16%	3%	28%
Bellary	14902	15038	951	30891	19291	13066	1015	33372	29%	-13%	7%	8%
Bengaluru Urban	2428	1759	111	4298	2377	714	55	3146	-2%	-59%	-50%	-27%
Bidar	13430	12921	817	27169	20448	10299	800	31547	52%	-20%	-2%	16%
Vijayapura (Bijapur)	26186	29902	1891	57979	41886	28434	2019	72339	60%	-5%	7%	25%
Chamarajanagar	5777	5546	351	11674	8399	4002	284	12686	45%	-28%	-19%	9%
Chickmagalur	5079	5637	357	11073	9025	5898	419	15342	78%	5%	17%	39%
Chikkaballapura	4550	2303	146	6999	10849	4992	388	16229	138%	117%	166%	132%
Chitradurga	7645	4757	301	12704	20192	11749	834	32775	164%	147%	177%	158%
Dakshina Kannada	6329	12572	795	19696	2743	2096	163	5002	-57%	-83%	-80%	-75%
Davanagere	11985	2133	135	14253	17209	10373	736	28319	44%	386%	446%	99%
Dharwad	10075	12353	781	23210	18505	11376	884	30765	84%	-8%	13%	33%
Gadag	11273	13483	853	25609	19713	13296	1033	34042	75%	-1%	21%	33%
Gulbaraga	16391	10971	694	28056	38618	28796	2237	69651	136%	162%	222%	148%
Hassan	16118	27761	1756	45635	11859	7701	547	20107	-26%	-72%	-69%	-56%
Haveri	8234	9817	621	18671	20281	11544	897	32722	146%	18%	44%	75%
Kodagu	5288	12146	768	18202	2316	1239	96	3651	-56%	-90%	-87%	-80%
Kolar	4728	626	40	5394	14965	4919	349	20234	217%	686%	782%	275%
Koppal	8821	4466	283	13570	18462	11139	865	30466	109%	149%	206%	125%
Mandya	10427	14493	917	25837	13444	5765	448	19657	29%	-60%	-51%	-24%
Mysore	11503	7676	486	19665	19240	9831	698	29769	67%	28%	44%	51%
Ramanagara	4420	1731	109	6260	15408	14580	1133	31121	249%	743%	935%	397%
Raichur	14696	15542	983	31221	8514	3605	280	12399	-42%	-77%	-72%	-60%
Shimoga	5799	4354	275	10428	9079	4563	355	13997	57%	5%	29%	34%
Tumkur	12393	19436	1229	33058	13762	9079	705	23546	11%	-53%	-43%	-29%
Udupi	3352	5926	375	9653	2490	2508	195	5193	-26%	-58%	-48%	-46%
Uttara Kannada	6184	13328	843	20355	4626	2470	192	7288	-25%	-81%	-77%	-64%
Yadgir	7767	5198	329	13294	10820	10037	780	21636	39%	93%	137%	63%
KARNATAKA	311315	321479	20334	653130	505178	290207	21874	817260	62%	-10%	8%	25%

Table 5.4.24. Monetary value of goods and services of horticulture ecosystem - comparative assessment 2005 and 2020 (million Rs)

District	Opening stock 2005 (at 2019 price)				Closing stock 2020				% Change			
	Provisioning	Regulating	Cultural	TESV	Provisioning	Regulating	Cultural	TESV	Provisioning	Regulating	Cultural	TESV
Bagalkot	90	13	1	104	13	9	0	22	-85%	-34%	-56%	-79%
Bengaluru Rural	1275	256	16	1548	353	120	5	478	-72%	-53%	-67%	-69%
Belgaum	131	34	2	167	35	36	2	72	-74%	7%	-24%	-57%
Bellary	253	38	2	293	196	115	5	315	-23%	202%	116%	8%
Bengaluru Urban	401	80	5	486	198	83	4	285	-51%	4%	-26%	-41%
Bidar	6	2	0	8	17	15	1	32	174%	826%	560%	313%
Vijayapura (Bijapur)	35	5	0	41	14	9	0	23	-61%	74%	18%	-43%
Chamarajanagar	1409	391	25	1825	51	18	1	69	-96%	-95%	-97%	-96%
Chickmagalur	8195	3464	219	11878	12379	5949	254	18582	51%	72%	16%	56%
Chikkaballapura	35	5	0	40	215	92	4	310	514%	1666%	1159%	667%
Chitradurga	9157	1695	107	10959	6913	3000	128	10041	-25%	77%	20%	-8%
Dakshina Kannada	10152	2421	153	12725	10034	5154	232	15420	-1%	113%	52%	21%
Davanagere	4141	997	63	5201	5196	1956	84	7236	25%	96%	33%	39%
Dharwad	92	16	1	110	75	32	1	108	-19%	95%	39%	-1%
Gadag	123	18	1	143	298	159	7	464	142%	768%	519%	226%
Gulbaraga	104	15	1	119	7	5	0	12	-93%	-68%	-77%	-90%
Hassan	13039	3010	190	16240	4370	3546	152	8068	-66%	18%	-20%	-50%
Haveri	319	55	3	378	433	186	8	627	36%	237%	140%	66%
Kodagu	7050	2636	167	9853	4421	7278	328	12027	-37%	176%	97%	22%
Kolar	202	63	4	269	183	193	8	384	-9%	206%	107%	43%
Koppal	68	10	1	79	47	30	1	78	-31%	194%	110%	-1%
Mandya	2822	568	36	3425	1059	658	30	1748	-62%	16%	-17%	-49%
Mysore	2208	594	38	2839	1410	775	33	2218	-36%	31%	-12%	-22%
Ramanagara	1933	389	25	2346	1633	834	38	2505	-16%	115%	53%	7%
Raichur	87	13	1	101	14	9	0	22	-84%	-34%	-53%	-78%
Shimoga	5233	1130	71	6434	8667	2029	92	10787	66%	80%	28%	68%
Tumkur	24469	3725	236	28429	7681	2168	98	9947	-69%	-42%	-59%	-65%
Udupi	4523	1200	76	5799	8644	2578	116	11339	91%	115%	53%	96%
Uttara Kannada	2916	605	38	3560	6406	1776	80	8263	120%	194%	109%	132%
Yadgir	49	7	0	56	1	1	0	1	-98%	-92%	-94%	-97%
KARNATAKA	100517	23455	1482	125455	80963	38813	1712	121483	-19%	65%	16%	-3%

5.5 TESV - TOTAL ECOSYSTEM SUPPLY VALUE, GEP- GROSS ECOSYSTEM PRODUCT, KARNATAKA [DISTRICT-WISE] STATE, INDIA

Ecosystem services (provisioning, regulating, and cultural services) were aggregated to compute the 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*** (Ouyang et al., 2020). The ecosystem monetary asset account also records the changes in the monetary value of ecosystem assets from 2005 to 2019 (accounting period).

Table 5.5.1 lists district-wise provisioning services, regulating services, cultural services, and TESV for 2005 (at 2019 monetary values). TESV for Karnataka state is about 3,620 billion rupees 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 agriculture and horticulture contribute 778 billion rupees (21.5%) in TESV. Figure 5.5.1 depicts the district-wise share and also the share of provisioning, regulating, and cultural services in TESV of 2005 (in 2019 rupees). Similarly, Table 5.5.2 lists district-wise provisioning services, regulating services, cultural services, and TESV for 2019. TESV or GEP for Karnataka state is about 2913 billion rupees 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 5.5.2 depicts the district-wise share and share of provisioning, regulating, and cultural services in TESV of 2019.

Changes in the ecosystem services (provisioning, regulating, and cultural services) are illustrated in Figure 5.5.3. The greatest changes in provisioning services are in Kalaburagi district (48%); the greatest changes in regulating services are in Chitradurga district (54%); and tge greatest changes in cultural services is in Kalaburagi (136%). Overall, Karnataka State has witnessed a 28% decline in provisioning services, 14% in regulating services, and 20% in TESV. TESV has shown a decreasing trend in the majority of districts (25). District-wise changes in the provisioning, regulating, cultural services, and TESV are listed in Table 5.5.3.

Table 5.5.4 lists district-wise TESV (forest, agriculture and total) and GDDP (Gross district domestic product) for Karnataka State, India. The GDP of Karnataka is about 10,128 billion rupees, and estimates of TESV indicate 2,912 billion rupees, of which 1835 billion rupees is derived from forest ecosystems and 1,077 billion rupees from the agricultural ecosystem. TESV of forest ecosystem contribute 18.12% of the GDP, and TESV from agriculture contributes about 10.6% of GDP in Karnataka.

Figure 5.5.4 compares the TESV of 2005 with that of 2019 and Figure 5.5.5 illustrates percentage changes in TESV during 2005 (in 2019 rupees) and 2019. The majority of

districts reveal declining TESV, except districts Kalaburagi (48%), Bangalore urban (10%), Ramnagara (6%), Chitradurga (4%), and Haveri (2%), which show an increase in TESV.

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 5.5.6 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 5.5.5 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.

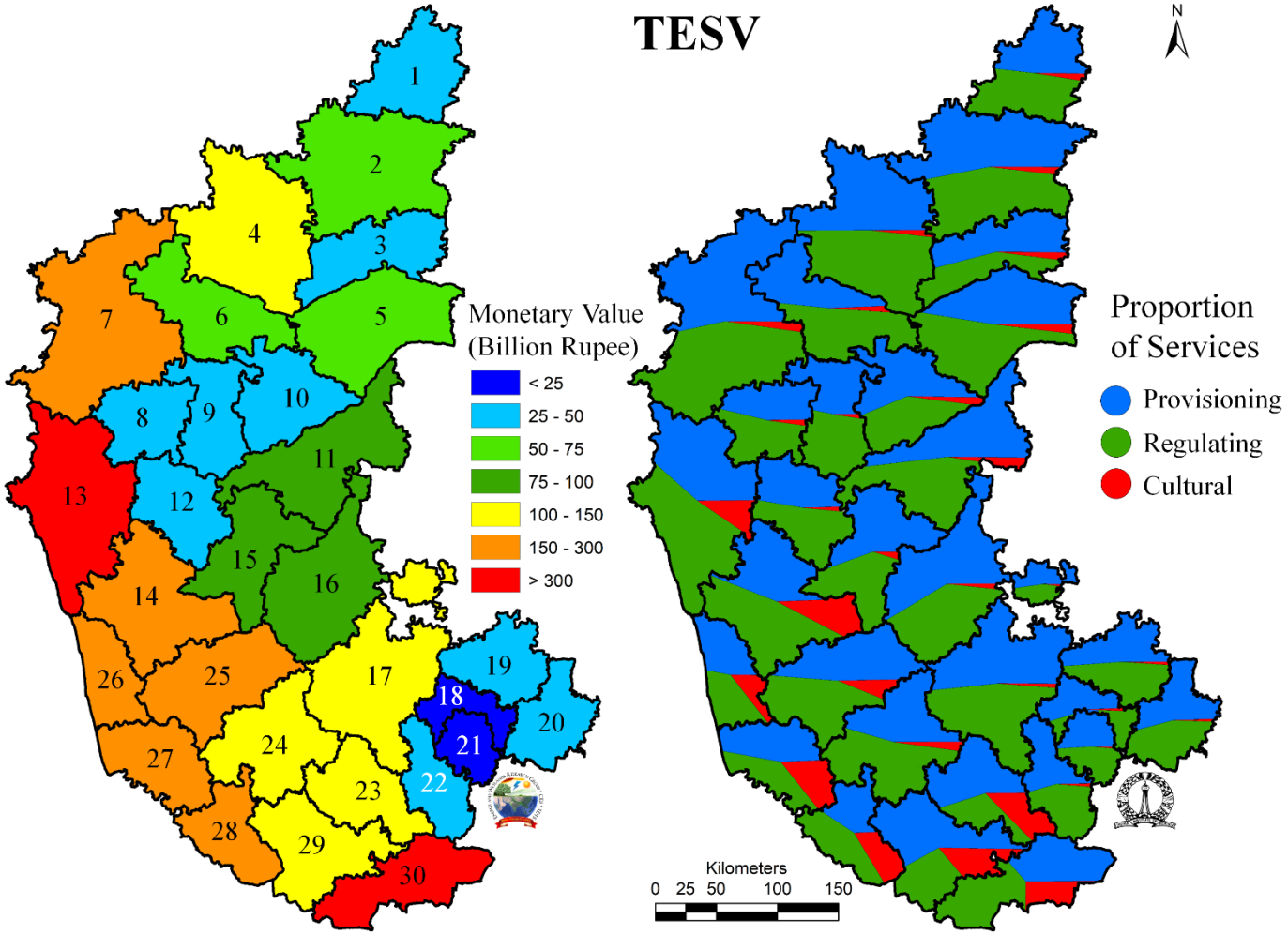
The decline of TESV highlights the degradation of forest ecosystem assets from 2005 to 2019 due to the reduction of ecosystem extent and condition. The decrease in value is also demonstrated by a fall in the net present value of expected future returns of the ecosystem services supplied by forest ecosystem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

Table 5.5.1: District wise ecosystem services – 2005 (in 2019 rupees) Million rupees

	Forest ecosystem			Agriculture Croplands and Horticulture			Cumulative (Forest and agriculture)			Proportion			Total billion rupees
District	**Prov**	**Reg**	**Cult**	**Prov**	**Reg**	**Cult**	**Prov**	**Reg**	**Cult**	**Prov**	**Reg**	**Cult**	**TESV**
Bagalkot	21928	18958	455	13167	16664	1054	35096	35622	1509	49%	49%	2%	72
Bangalore Rural	7862	8295	275	4191	1398	88	12053	9694	363	55%	44%	2%	22
Bangalore Urban	7504	7918	262	2829	1839	116	10332	9757	379	50%	48%	2%	20
Belagavi	44747	38685	928	39673	31845	2014	84420	70530	2942	53%	45%	2%	158
Bellary	28430	23929	1060	15155	15076	954	43585	39005	2014	52%	46%	2%	85
Bidar	5616	6280	147	13436	12923	817	19052	19203	964	49%	49%	2%	39
Vijayapura (Bijapur)	35106	30350	728	26221	29907	1892	61327	60258	2620	49%	49%	2%	124
Chamarajnagar	114986	122387	80745	7187	5937	376	122173	128324	81120	37%	39%	24%	332
Chickmagalur	114990	107946	17615	13274	9101	576	128264	117047	18191	49%	44%	7%	264
Chikkaballapura	14522	15323	508	4585	2309	146	19107	17632	654	51%	47%	2%	37
Chitradurga	28485	24003	1079	16802	6452	408	45287	30455	1487	59%	39%	2%	77
Dakshina Kannada	86601	73233	29544	16480	14993	948	103082	88225	30492	46%	40%	14%	222
Davanagere	31117	30915	3596	16126	3130	198	47243	34045	3794	56%	40%	4%	85
Dharwad	10897	10739	277	10167	12370	782	21064	23109	1060	47%	51%	2%	45
Gadag	11904	11732	303	11396	13501	854	23300	25233	1157	47%	51%	2%	50
Hassan	18499	23163	459	29157	30772	1946	47656	53935	2406	46%	52%	2%	104
Haveri	12316	12137	313	8553	9872	625	20869	22009	938	48%	50%	2%	44
Kalaburagi	11312	12649	295	16495	10985	695	27806	23635	990	53%	45%	2%	52
Kodagu	82098	87168	32948	12338	14783	935	94436	101950	33883	41%	44%	15%	230
Kolar	13621	14373	476	4930	689	44	18551	15062	520	54%	44%	2%	34
Koppal	18693	15733	697	8889	4476	283	27582	20209	980	57%	41%	2%	49
Mandya	50148	23302	13702	13249	15061	953	63397	38363	14655	54%	33%	13%	116
Mysore	64083	29777	17509	13711	8270	523	77794	38047	18032	58%	28%	13%	134
Raichur	8730	9763	228	14783	15555	984	23514	25318	1212	47%	51%	2%	50
Ramanagar	12057	12722	422	6353	2119	134	18409	14841	556	54%	44%	2%	34
Shimoga	106724	122829	20995	11032	5483	347	117756	128313	21342	44%	48%	8%	267
Tumkur	28798	36057	715	36862	23161	1465	65659	59218	2180	52%	47%	2%	127
Udupi	63597	53780	21696	7876	7126	451	71473	60906	22147	46%	39%	14%	155
Uttara Kannada	206709	280344	54914	9101	13933	881	215810	294277	55795	38%	52%	10%	566
Yadgiri	5449	6093	142	7816	5205	329	13265	11298	472	53%	45%	2%	25
KARNATAKA	**1267528**	**1270583**	**303034**	**411834**	**344933**	**21819**	**1679361**	**1615516**	**324854**	**46%**	**45%**	**9%**	**3620**

Note: Prov: provisioning services, Reg: regulating services, Cul: cultural services

Figure 5.5.1: TESV, with the proportion of services (provisioning, regulating and cultural), 2005



Sl.no	District
1	Bidar
2	Kalburgi/Gulburga
3	Yadgir
4	Bijapur
5	Raichur
6	Bagalkot
7	Belagavi
8	Dharwad
9	Gadag
10	Koppala
11	Ballari
12	Haveri
13	Uttara Kannada
14	Shimoga
15	Davanagere
16	Chitradurga
17	Tumkuru
18	Bengaluru Rural
19	Chickkaballura
20	Kolar
21	Bengaluru Urban
22	Ramanagara
23	Mandya
24	Hassan
25	Chickmagaluru
26	Udupi
27	Dakshina Kannada
28	Kodagu
29	Mysore
30	Chamarajanagara

Table 5.5.2: District wise goods and services - 2019 (million Rs unless otherwise noted)

	Forest Ecosystem			Agriculture Ecosystem Croplands and Horticulture			Cumulative (forest and agriculture)				Proportion			Billion	Billion
District	Prov	Reg	Cult	Prov	Reg	Cult	Prov	Reg	Cult	Total	Prov	Reg	Cult	TESV	NPV
Bagalkot	8117	11320	256	40772	17675	1251	48889	28995	1507	79391	62%	37%	2%	79	2043
Bangalore Rural	2233	4991	184	5295	2963	199	7528	7954	383	15865	47%	50%	2%	16	408
Bangalore Urban	2131	4764	175	2582	1622	96	4713	6386	271	11371	41%	56%	2%	11	293
Belagavi	16564	23101	522	65000	26654	2068	81564	49755	2590	133909	61%	37%	2%	134	3445
Bellary	2789	9393	609	19500	14616	1085	22289	24009	1694	47992	46%	50%	4%	48	1235
Bidar	1005	2372	44	20465	10360	803	21470	12732	847	35049	61%	36%	2%	35	902
Vijayapura	12996	18123	410	41901	28561	2024	54897	46684	2434	104015	53%	45%	2%	104	2676
Chamarajnagar	47814	87131	79943	8451	4060	287	56265	91191	80230	227685	25%	40%	35%	228	5858
Chickmagalur	80547	95068	17313	21417	13254	733	101964	108322	18046	228332	45%	47%	8%	228	5875
Chikkaballapura	4126	9220	340	11063	4992	388	15189	14212	728	30129	50%	47%	2%	30	775
Chitradurga	2852	9467	628	27304	37377	1930	30156	46844	2558	79558	38%	59%	3%	80	2047
Dakshina Kannada	67619	70283	29453	12905	21002	1015	80524	91285	30468	202277	40%	45%	15%	202	5205
Davanagere	10175	17758	3260	24435	19689	1135	34610	37447	4395	76452	45%	49%	6%	76	1967
Dharwad	2794	5690	150	18581	11542	891	21375	17232	1041	39648	54%	43%	3%	40	1020
Gadag	3053	6216	164	20030	15518	1133	23083	21734	1297	46115	50%	47%	3%	46	1187
Hassan	5246	11818	188	16424	33423	1646	21670	45241	1834	68746	32%	66%	3%	69	1769
Haveri	3158	6431	169	20730	13463	983	23888	19894	1152	44934	53%	44%	3%	45	1156
Kalaburagi	2026	4779	90	38626	28861	2240	40652	33640	2330	76622	53%	44%	3%	77	1971
Kodagu	33203	63203	32523	6737	8516	424	39940	71719	32947	144607	28%	50%	23%	145	3721
Kolar	3870	8648	318	15149	5164	360	19019	13812	678	33508	57%	41%	2%	34	862
Koppal	1834	6176	400	18513	11553	884	20347	17729	1284	39360	52%	45%	3%	39	1013
Mandya	13000	17797	13564	14575	14180	827	27575	31977	14391	73944	37%	43%	19%	74	1903
Mysore	16612	22743	17332	20730	19684	1119	37342	42427	18451	98220	38%	43%	19%	98	2527
Raichur	1563	3688	69	15423	14700	1138	16986	18388	1207	36581	46%	50%	3%	37	941
Ramanagar	3425	7655	282	10236	13976	748	13661	21631	1030	36323	38%	60%	3%	36	935
Shimoga	60258	87520	20412	17779	10153	607	78037	97673	21019	196729	40%	50%	11%	197	5062
Tumkur	8167	18398	292	21540	21690	1274	29707	40088	1566	71361	42%	56%	2%	71	1836
Udupi	49657	51613	21629	11203	12447	643	60860	64060	22272	147192	41%	44%	15%	147	3787
Uttara Kannada	146073	238678	54193	11098	11296	590	157171	249974	54783	461928	34%	54%	12%	462	11885
Yadgiri	976	2302	43	10821	10045	780	11797	12347	823	24966	47%	49%	3%	25	642
KARNATAKA	**613883**	**926346**	**294955**	**589283**	**459037.2**	**29305.17**	**1203166**	**1385383**	**324260.2**	**2912809**	**41%**	**48%**	**11%**	**2913**	**74946**

Figure 5.5.2: TESV with the proportion of services (provisioning, regulating and cultural), and NPV 2019-20

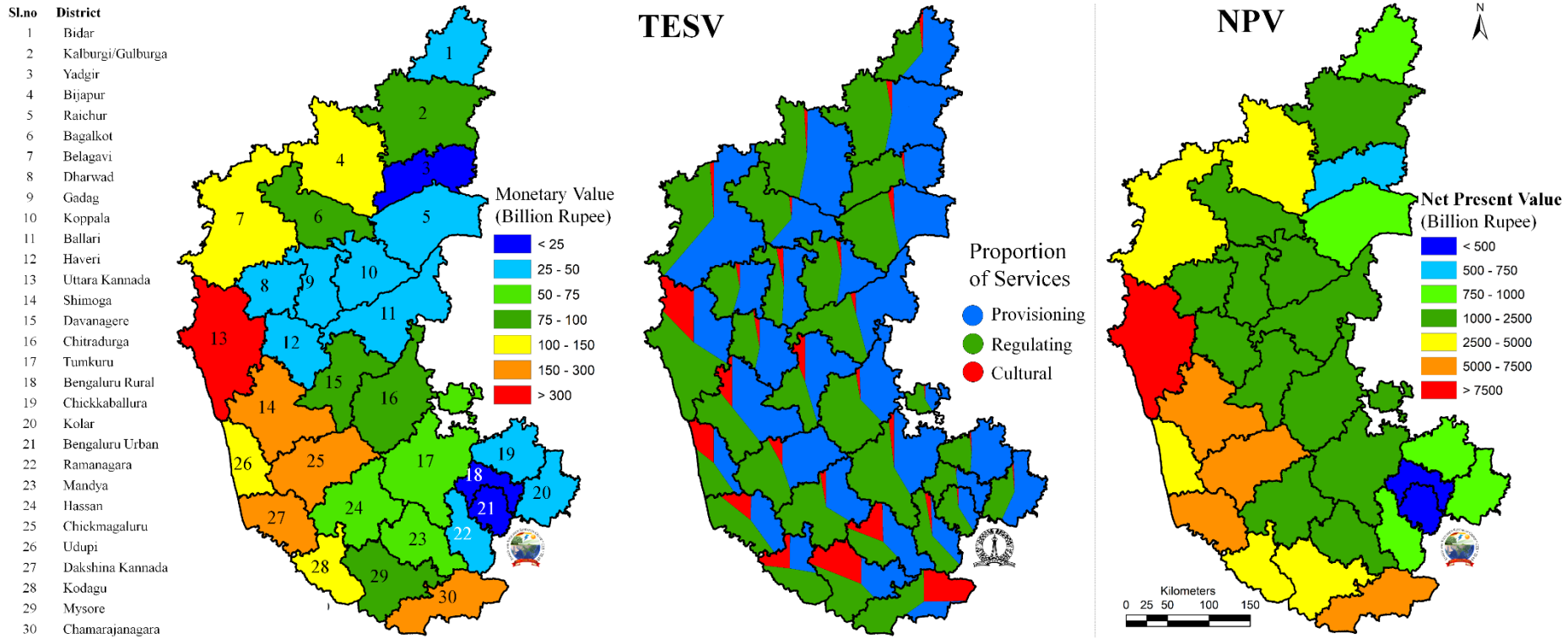


Figure 5.5.3. Changes in ecosystem services (provisioning, regulating and cultural) during 2005 to 2019

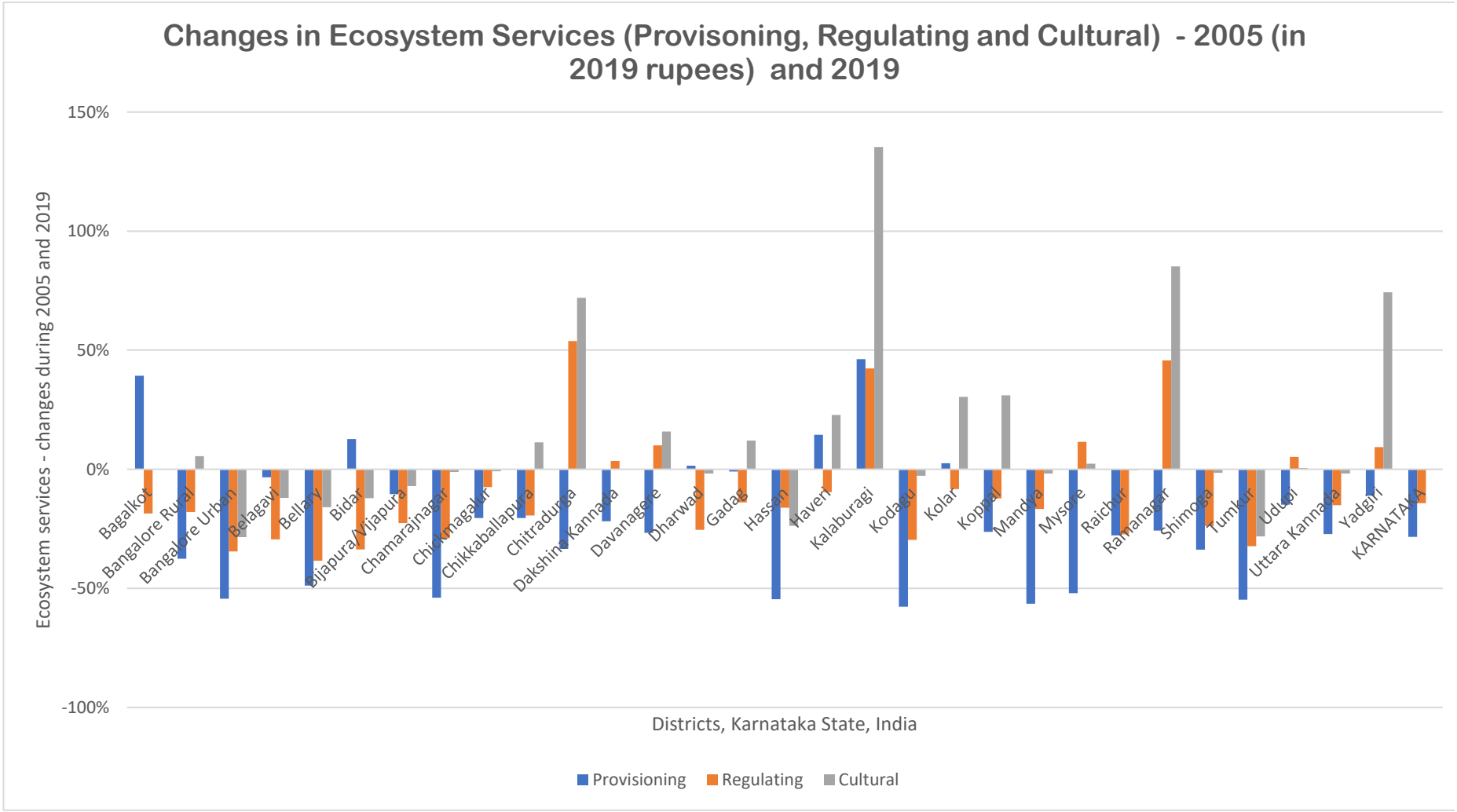


Table 5.5.3: Changes in the provisioning, regulating, cultural services and TESV (monetary values) in Karnataka from 2005 to 2019

District	Ecosystem services			TESV
	Provisioning	Regulating	Cultural	Billions of rupees
Bagalkot	39%	-19%	0%	10%
Bangalore Rural	-38%	-18%	6%	-27%
Bangalore Urban	-54%	-35%	-28%	-45%
Belagavi	-3%	-29%	-12%	-15%
Bellary	-49%	-38%	-16%	-44%
Bidar	13%	-34%	-12%	-10%
Vijayapura	-10%	-23%	-7%	-16%
Chamarajnagar	-54%	-29%	-1%	-31%
Chickmagalur	-21%	-7%	-1%	-14%
Chikkaballapura	-21%	-19%	11%	-19%
Chitradurga	-33%	**54%**	72%	4%
Dakshina Kannada	-22%	3%	0%	-9%
Davanagere	-27%	10%	16%	-11%
Dharwad	1%	-25%	-2%	-11%
Gadag	-1%	-14%	12%	-8%
Hassan	-55%	-16%	-24%	-34%
Haveri	14%	-10%	23%	2%
Kalaburagi	**46%**	42%	**135%**	**48%**
Kodagu	-58%	-30%	-3%	-37%
Kolar	3%	-8%	30%	0%
Koppal	-26%	-12%	31%	-20%
Mandya	-57%	-17%	-2%	-36%
Mysore	-52%	12%	2%	-27%
Raichur	-28%	-27%	0%	-26%
Ramanagar	-26%	46%	85%	6%
Shimoga	-34%	-24%	-2%	-26%
Tumkur	-55%	-32%	-28%	-44%
Udupi	-15%	5%	1%	-5%
Uttara Kannada	-27%	-15%	-2%	-18%
Yadgiri	-11%	9%	74%	0%
KARNATAKA	-28%	-14%	0%	-20%

Figure 5.5.4. Comparison of TSEV of 2005 (in 2019 rupees) and 2019

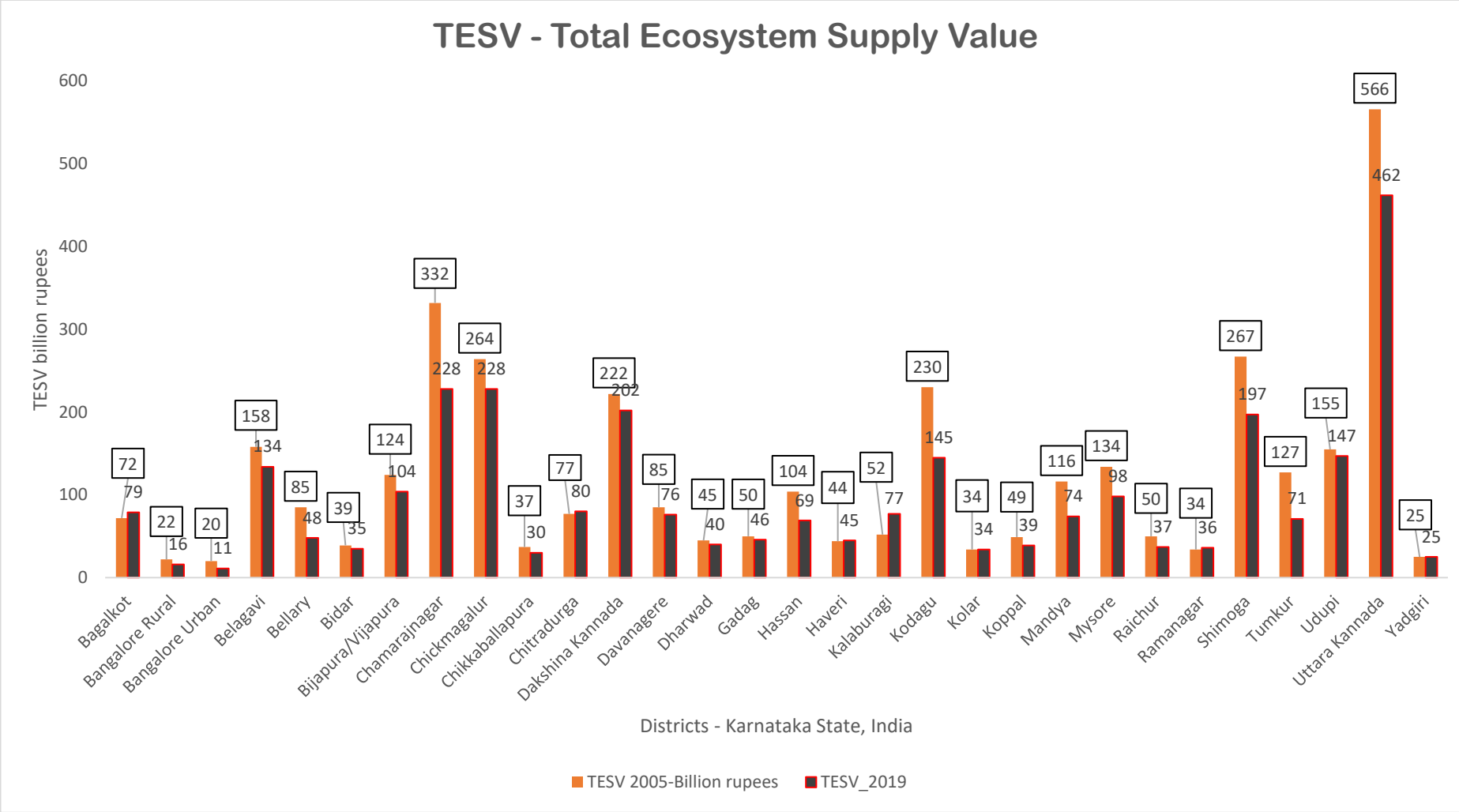


Figure 5.5.5. Percentage changes in TESV – 2005 (in 2019 rupees) and 2019

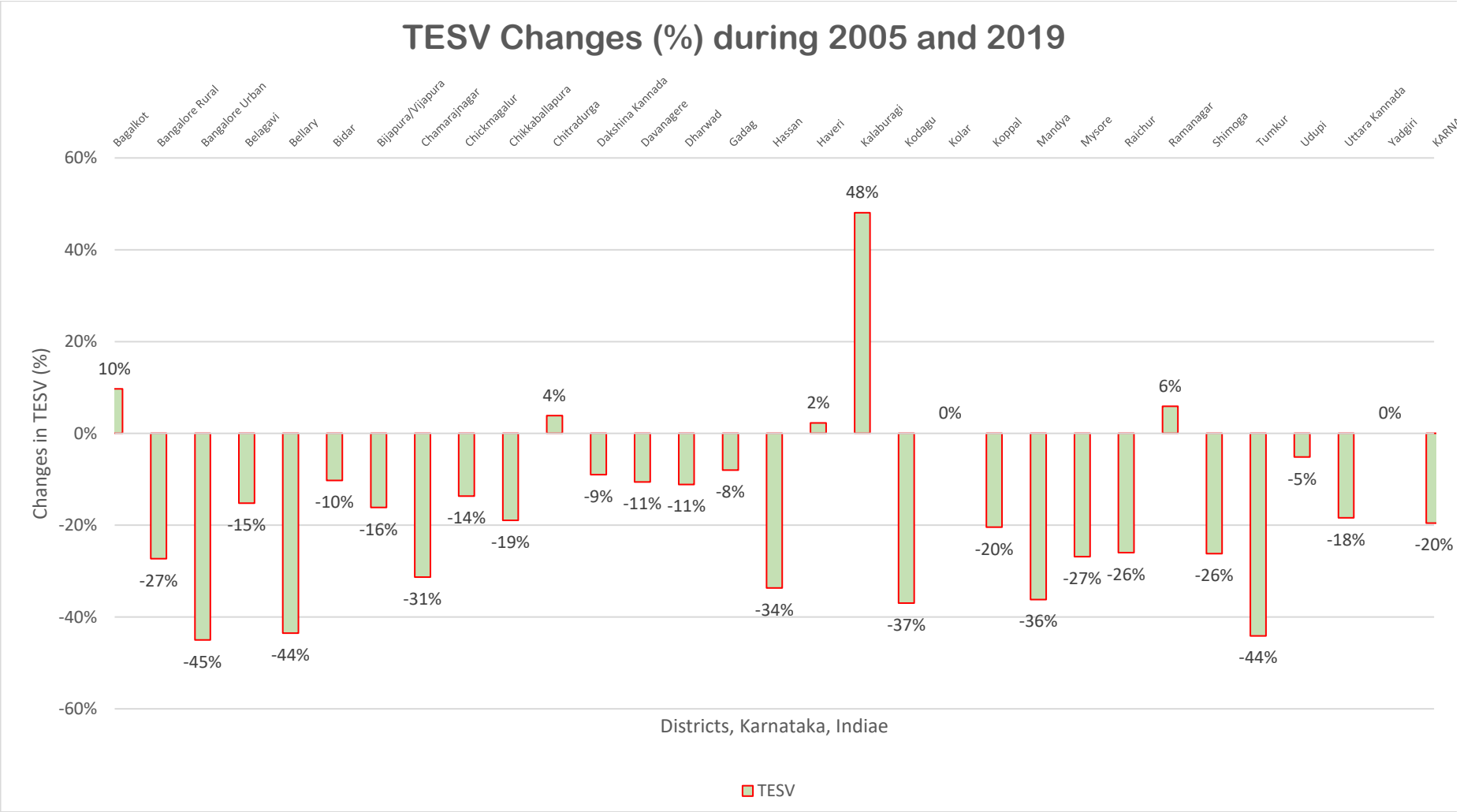


Table 5.5.4: TESV and share of TESV in GDDP (2019)

District	Revenue billion rupee				Ratio of TESV to GDDP		
	TESV-forest	TESV- agriculture	TESV-total	GDDP	Forest	Agriculture	Total
Bagalkot	19.7	59.7	79.4	265.5	7.4	22.5	29.9
Bangalore Rural	7.4	8.5	15.9	162.5	4.6	5.2	9.8
Bangalore Urban	7.1	4.3	11.4	3635.6	0.2	0.1	0.3
Belagavi	40.2	93.7	133.9	454.6	8.8	20.6	29.5
Bellary	12.8	35.2	48.0	334.8	3.8	10.5	14.3
Bidar	3.4	31.6	35.0	144.9	2.4	21.8	24.2
Vijayapura	31.5	72.5	104.0	188.1	16.8	38.5	55.3
Chamarajnagar	214.9	12.8	227.7	117.0	183.7	10.9	194.6
Chickmagalur	192.9	35.4	228.3	230.2	83.8	15.4	99.2
Chikkaballapura	13.7	16.4	30.1	144.4	9.5	11.4	20.9
Chitradurga	12.9	66.6	79.6	169.6	7.6	39.3	46.9
Dakshina Kannada	167.4	34.9	202.3	587.2	28.5	5.9	34.4
Davanagere	31.2	45.3	76.5	202.1	15.4	22.4	37.8
Dharwad	8.6	31.0	39.6	244.7	3.5	12.7	16.2
Gadag	9.4	36.7	46.1	109.1	8.6	33.6	42.3
Hassan	17.3	51.5	68.7	236.4	7.3	21.8	29.1
Haveri	9.8	35.2	44.9	155.3	6.3	22.7	28.9
Kalaburagi	6.9	69.7	76.6	195.1	3.5	35.7	39.3
Kodagu	128.9	15.7	144.6	61.6	209.3	25.5	234.8
Kolar	12.8	20.7	33.5	176.6	7.3	11.7	19.0
Koppal	8.4	31.0	39.4	118.9	7.1	26.0	33.1
Mandya	44.4	29.6	73.9	267.3	16.6	11.1	27.7
Mysore	56.7	41.5	98.2	352.1	16.1	11.8	27.9
Raichur	5.3	31.3	36.6	173.5	3.1	18.0	21.1
Ramanagar	11.4	25.0	36.3	159.6	7.1	15.6	22.8
Shimoga	168.2	28.5	196.7	300.5	56.0	9.5	65.5
Tumkur	26.9	44.5	71.4	385.3	7.0	11.6	18.5
Udupi	122.9	24.3	147.2	276.3	44.5	8.8	53.3
Uttara Kannada	438.9	23.0	461.9	186.2	235.7	12.3	248.1
Yadgiri	3.3	21.6	25.0	93.4	3.6	23.2	26.7
KARNATAKA	1835.2	1077.6	2912.8	10128.4	18.12	10.64	28.76

Figure 5.5.6: TESV to GDDP ratio

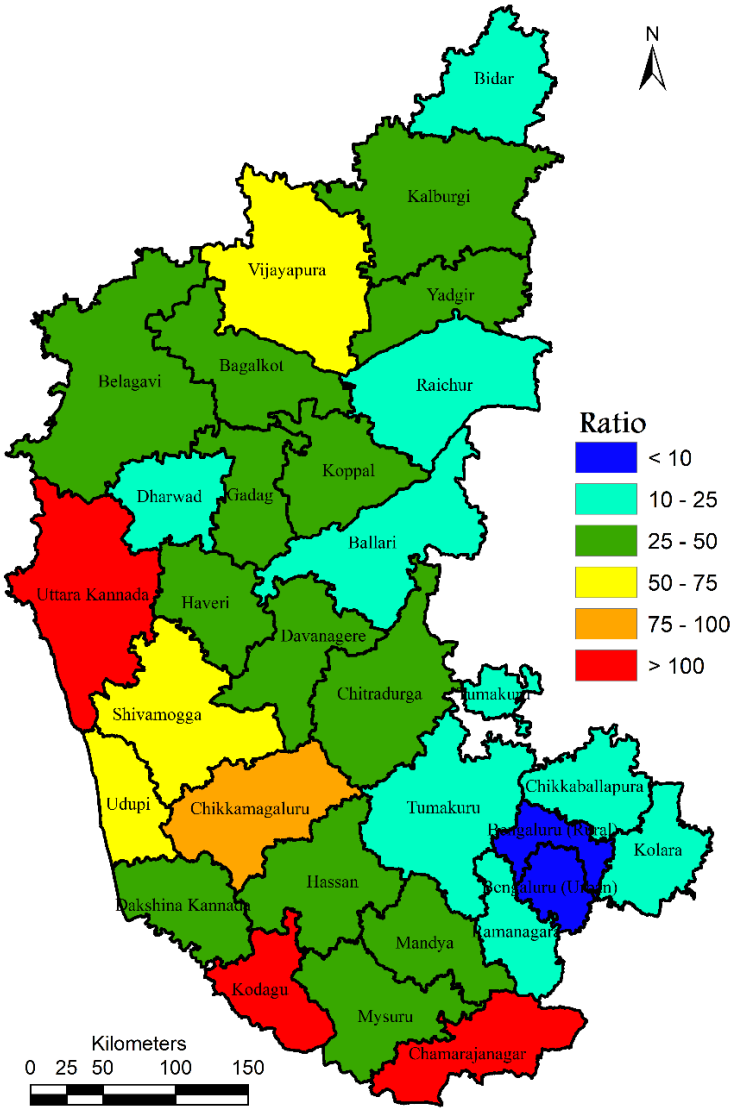


Table 5.5.5. Comparison of provisioning, regulating, and cultural services and TESV during 2005 (in 2019 rupees) and 2019

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

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 5.5.6 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 is 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%.

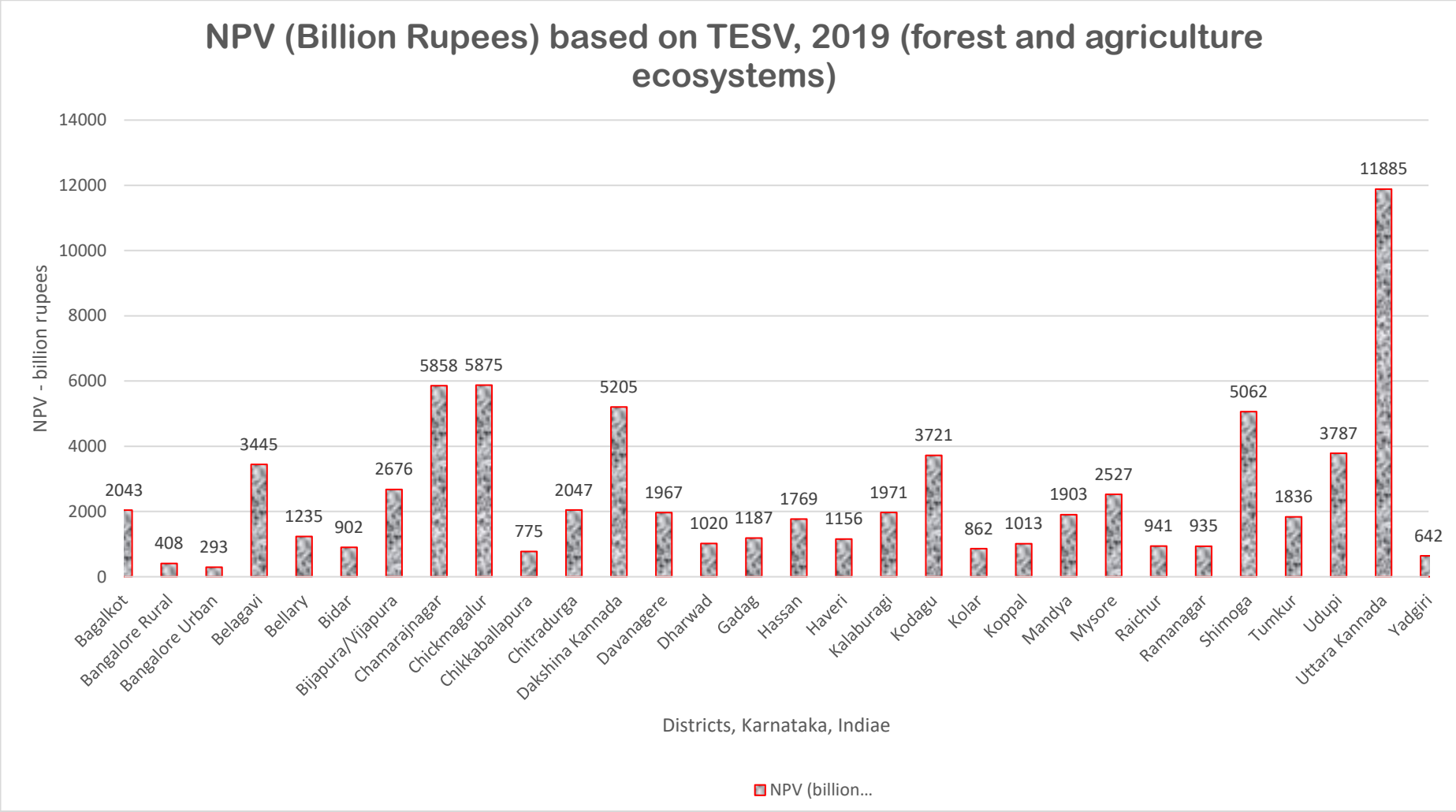
Table 5.5.6. Monetary asset account (2005-2019)

	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**

Figure 5.5.7 presents district-wise NPV of forest and agriculture ecosystems based on the 2019 TESV, which totals about **74,938** billion rupees for Karnataka. This shows a decline 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.

Figure 5.5.7. NPV of ecosystem assets (forest and agriculture) based on TESV of 2019



6.0 Conclusion

The compilation of ecosystem extent, service, and asset accounts using the SEEA EA has enabled a 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 relationship between the SEEA EA and the System of National Accounts also means that TESV can be compared to GDP. 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, restoring 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 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 has been an uneven implementation of these policies and programs. Thus, ecosystem accounting can play a role in two ways. First, ecosystem accounts can help policymakers factor in ecosystem service benefits when making economic policies that 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 a 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. The SEEA EA 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. Developing 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 replicating 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.

The exercise of compiling physical and monetary SEEA EA could be replicated in any region (of 10000 to 20000 sq. km) in a period of 15 months, with a team of multidisciplinary expertise. It requires (i) all para-state agencies sharing biophysical data, as primary data collection is a time-consuming endeavor, (ii) Training programmes and workshops - orientation programs, (iii) hands-on training to enhance the capability of the team to undertake spatial analyses, (iv) collecting biophysical data from the government agencies and in the field, (v) performing data integration and validation, and conducting analyses of the data and interpretation, and (vi) addressing gaps in existing biophysical models (i.e., adapting them to the local context).

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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Annexures

3.1 Socio-economic survey: agriculture

3.2 Horticulture (areca/coconut/..)

3.3 Valuation of ecosystem services of Sacred Grooves in Karnataka

3.4 Tourism and recreational services of forest ecosystems in Karnataka

4.1 Global climate regulation service – carbon storage in forest ecosystems

(Note: this service is not accounted in the valuation of ecosystem services)

5.3 Valuation of forest ecosystem services (provisioning, regulating and cultural) at the district level

Annexure 3.1

SOCIO-ECONOMIC SURVEY: AGRICULTURE (use separate questionnaire for each crop)

NAME OF THE INVESTIGATOR _____ DATE: _____

NAME OF THE RESPONDENT: _____ AGE: _____ M/F _____

VILLAGE: _____ TALUK: _____ DISTRICT: _____

DEMOGRAPHIC INFORMATION

TOTAL NUMBER OF PERSONS IN HOUSEHOLD: ___

AGE 0-15 YEARS: ___ AGE 16-25 YEARS: ___ AGE 26-50 YEARS: ___ AGE 50+ YEARS: ___

OCCUPATION(S) OF HOUSEHOLD MEMBERS:

TOTAL HOUSEHOLD INCOME (Rs./yr):

AGRICULTURE CROP:

LAND (AREA) ACRE		
LAND PREPARATION	LABOUR No: Amount:	ANIMALS (cattle/Bullock): No MECHANISED: Type Capacity Cost:
SEASON		

SEED	TYPE	QUANTITY COST
SOWING	LABOUR AMOUNT:	ADDITIONAL WORK – DEWEEDING LABOUR AMOUNT
TRANSPLANTATION (FOR PADDY)	LABOUR TYPE	COST
MANURE /Fertiliser	Frequency: Type:	Quantity Cost:
IRRIGATION	TYPE: Frequency Electricity	Motor (HP) Duration Cost
PESTS PROTECTION (WILD PIG, BANDICOT, MONKEY, …)	PEST Type DAMAGE EXTENT	PROTECTION TYPE Cost
PESTICIDE /	Type	Labour

HERBICIDE	Frequency	Cost
HARVESTING	LABOUR	QUANTITY COST
PRODUCTION	QUANTITY	VALUE
PROCESSING	TYPE WATER QUANTITY	FUEL - TYPE FUEL – QUANTITY COST
END PRODUCT	TYPE	QUANTITY VALUE
DO YOU PROCESS FURTHER IF YES TYPE (END PRODUCT) QUANTITY		

VALUE		
FARM RESIDUES		
TYPE	QUANTITY	IF SOLD, VALUE:
1.		
2.		
3.		
PROBLEMS (IF ANY) FACED WHILE PRACTICING AGRICULTURE		
MARKET		
TYPE	QUANTITY	VALUE

Date Collected by:

Signature

Annexure 3.2

SOCIO-ECONOMIC SURVEY: HORTICULTURE (ARECA/COCONUT/..)

NAME OF THE INVESTIGATOR _____ DATE: _____

NAME OF THE RESPONDENT: _____ AGE: _____ M/F _____

VILLAGE: _____ TALUK: _____ DISTRICT: _____

DEMOGRAPHIC INFORMATION

TOTAL NUMBER OF PERSONS IN HOUSEHOLD: ___

AGE 0-15 YEARS: ___ AGE 16-25 YEARS: ___ AGE 26-50 YEARS: ___ AGE 50+ YEARS: ___

OCCUPATION(S) OF HOUSEHOLD MEMBERS:

TOTAL HOUSEHOLD INCOME (Rs./yr):

HORTICULTURE CROP:

LAND (AREA) ACRE		
LAND PREPARATION	LABOUR No: Amount:	ANIMALS (cattle/Bullock): No MECHANISED: Type Capacity

		Cost:
PLANTING	LABOUR AMOUNT:	ADDITIONAL WORK- SHADIING AMOUNT
MANURE /Fertiliser	Frequency: Type:	Quantity Cost:
INTERCROP	TYPE COST (SEED/SAPLING)	**PRODUCTION** QUANTITY VALUE
IRRIGATION	TYPE: Frequency Electricity	Motor (HP) Duration Cost
MULCHING	Qty Type	Labour Cost
PESTS PROTECTION	PEST Type	PROTECTION

(WILD PIG, BANDICOT, MONKEY, …)	DAMAGE EXTENT	TYPE Cost
PESTICIDE / HERBICIDE	Type Frequency	Labour Cost
HARVESTING	LABOUR	QUANTITY COST
PRODUCTION	QUANTITY	VALUE
PROCESSING	TYPE WATER QUANTITY	FUEL - TYPE FUEL – QUANTITY COST
END PRODUCT	TYPE	QUANTITY VALUE
DO YOU PROCESS FURTHER IF YES		

TYPE (END PRODUCT) QUANTITY VALUE		
FARM RESIDUES TYPE 1. 2. 3.	QUANTITY	IF SOLD, VALUE:
PROBLEMS (IF ANY) FACED WHILE PRACTICING HORTICULTURE		
MARKET TYPE	QUANTITY	VALUE

Date Collected by:

Signature

Annexure 3.3

Valuation of ecosystem services of Sacred Grooves in Karnataka

Date: / /20….

Name of the Groove:_____

Village Name:_____Panchayat:_____

Taluk: _____District:_____

Forest Division:_____Circle: _____Range: _____

Area (Ha): _____Age of the grove (approx.)_____

Deities worshipped:_____

Name of the plants symbolized as abode of deities_____

Communities present:_____

Water Source (River/ Lake/ Pond):_____

Water Availability (in months): _____

Legal status (Managed by Forest Department / Community) **……**

If manage by community then,

Administrative committee members:

Name:_____

Contact Number:_____

Rituals performed (Festivals/ Religious functions/ Birthday/ Anniversary): _____

_____

Amount collected per year (INR):

2018:_____

2019:_____

2020:_____

Number of visitors for performing rituals per year:_____

Name: _____Address:_____

Name: _____Address:_____

Name: _____Address:_____

Name: _____Address:_____

Age group of the visitors (approx.)

Age 0-15 Years: Age 16-25 Years: Age 26-50 Years: Age 50+ Years:

Amount received by post/bank transfer per year (from the devotees/villagers without visiting grooves)
INR: _____

Nature of expenses in the groove (INR):

1. Performing rituals: _____
2. Salary of priests: _____
3. Management, Maintenance of the grove:_____
4. Miscellaneous:_____

Revenue as per records (after deducting the expenses) in INR:

2018: _____

2019: _____

2020: _____

Any other observations:

Unique cultural significance:

Status of the grove (Intact/Fragmented): _____

Data collected by: ……

Annexure 3.4

Tourism & recreational services of forest ecosystems in Karnataka

Date: / /20....

Name of the Tourism Centre:_____

Type of the recreational place *(Beach/ River front/ Forest area/ Park/ Water body/ National parks/Waterfalls)*:.....

Village Name:_____Panchayat:_____

_____Taluk: _____District:_____

Forest Division:_____Circle: _____Range: _____

Area (Ha): _____

Legal status (Managed by_Forest Department / Tourism/ Community)

.....

Entry fee (if any-INR):_____

Number of tourists (From India):_____

Number of tourist (from Abroad): _____

Age group of the visitors (approx.)

Age 0-15 Years: Age 16-25 Years: Age 26-50 Years: Age 50+ Years:

If recreation facility is manage by community then,

Administrative committee members:

Name:_____

Contact Number:_____

Accommodation status:…….

If available then,

Type of the accommodation:……

Price per day (INR):……

Peak season of tourism activities (Monsson/Summer): …….

Gross Revenue generated per year (INR):

2018:_____

2019:_____

2020:_____

Nature of expenses (INR):

1. Maintenance of the location: _____
2. Salary of the employers: _____
3. Miscellaneous:_____

Revenue as per records (after deducting the expenses) in INR:

2018: _____

2019: _____

2020: _____

Any other observations:

Uniqueness of the region:

Status of the environment: _____

Data collected by: ……

Annexure 4.1 Global climate regulation service – carbon storage in forest ecosystems

(Note: this service is not accounted in the valuation of ecosystem services)

Method:

Forest ecosystems are the large repositories of terrestrial carbon and play a crucial role in the carbon cycle (C-cycle) through sequestration of atmospheric carbon in the above-ground biomass (AGB), below-ground biomass (BGB), and soil organic carbon (SOC). The quantification of carbon storage of **forest ecosystems and plantations** has been done through (i) assessing biomass accumulated based on field measurements of girth and height, and (ii) published literature based on the standard biomass experiments. The study region (Karnataka State) was divided into 2597 grids of 5' × 5' (or 9 km x 9 km) grids corresponding to 5' × 5' grids of 1:50000 topographic maps of the Survey of India. Select grids corresponding to agro-climatic zones were chosen for biomass and carbon estimation through field investigations. The basal area, height, vegetation type (evergreen, deciduous, semi-evergreen, moist deciduous, scrub forests), diversity, biomass, carbon, etc., were computed based on the collected field data. The field estimations were done across the forest types with about 424 transects in Uttara Kannada, Shimoga, Chikmagalur, Kodagu, Dakshina Kannada, Udupi, and Dharwad districts. The number of quadrats per transect varied between 3 and 5 depending on species occurrence in the sampling locality. The biomass was estimated using GBH (girth at breast height) for the trees >30 cm. The transect data and standard literature data were used for biomass quantification. The carbon for above-ground vegetation is computed as 50% of the AGB value. Table 4.3.1 lists the carbon quantification method depending on forest type. Above ground biomass quantified for various forest types and plantation is listed in the Table 4.3.2. The carbon is stored in the soil (SOC) as soil organic matter in both organic and inorganic forms. SOC is calculated based on the field estimations in top 30 cm soil for different forests (Table 4.3.3) and average values of soil carbon reported in the literature (Ravindranath et al. 1997; Nair et al. 2009; Ramachandra and Bharath 2019b).

Table 4.3.1. Biomass and sequestered carbon based on forest types

Index	Forest type	Equation	Quantification
Biomass (T/Ha)	Evergreen	$(\text{Forest cover}) \times 485.67$	Above ground biomass content
	Deciduous	$(\text{Forest cover}) \times 258.12$	
	Scrub	$(\text{Forest cover}) \times 74.25$	
	Plantations	$(\text{Extent}) \times 45.25$	
Carbon stored (T/Ha)	All	$(\text{Estimated biomass}) \times 0.5$	Sequestered carbon
Carbon sequestration of soil (T/Ha)	Evergreen	$(\text{Forest cover}) \times 132.8$	Carbon stored in the soil
	Deciduous	$(\text{Forest cover}) \times 58$	
	Scrub	$(\text{Forest cover}) \times 44$	

	Agriculture	(Extent) × 2.43	(Ravindranath et al. 1997; Dadhwal et al. 2009; Rajan et al. 2010)
	Plantations	(Extent) × 55	

Table 4.3.2. Above ground Biomass for various forest types and plantations

Sno	Forest Type	Standing Biomass (T/ha)	Source
1	Dense Evergreen to Semi evergreen	486 to 834	Field based transect cum quadrat method; (Rai SN, Proctor J 1986; Ramachandra et al. 2000c, d, 2010; Rao et al. 2013; Ramachandra and Bharath 2019a)
2	Low evergreen	226	
3	Dense Deciduous	258	
4	Degraded Deciduous	130	
5	Savanna Woodlands	75 to 90	
6	Thorn degraded	40	
7	Littoral and swamp	215	
8	Plantations	45 to 126	

Table 4.3.3. Soil carbon storage in different forest types and agriculture filed

Sno	Forest Types	Mean SOC in top 30 cm (t/ha)	Source
1	Tropical Wet Evergreen Forest	132.8	(Swamy 1992; Ravindranath et al. 1997; Ravindranath and Ostwald 2008; Ramachandra and Bharath 2019b)
2	Tropical Semi Evergreen Forest	171.75	
3	Tropical Moist Deciduous Forest	57.14	
4	Littoral and Swamp Forest	34.9	
5	Tropical Dry Deciduous Forest	58	
6	Tropical Thorn Forest	44	
7	Tropical Dry Evergreen Forest	33	
8	Agriculture Fields	4	
9	Plantations	55	

InVEST Carbon model: The InVEST 3.9 Carbon model has been used to validate the results of 2005 and 2019. The Invest model takes the land use map and associated carbon values in Mg or tons per hectare to extrapolate for entire regions. The land use maps of 2005 and 2019 have been provided as input to the Invest Carbon model to quantify the carbon storage across the Karnataka region. The social cost of carbon is considered for representing the carbon sequestration service as suggested by MoSPI (MoSPI 2020).

Results

The field data and literature information have been integrated to account per hectare biomass computation across various types of forests in Karnataka. The analyses of the above-ground biomass show that the grids in the Western Ghats part of Karnataka have higher AGB >1000 Gg (Giga gram). The grids of evergreen forested areas represent the greater values of biomass compared to the other forest types. The total

AGB of forests is about 1013.7 Tg (Teragram) with stored carbon of 506.8 Tg (in 1985), which is now reduced to 678 Tg and 339 Tg, respectively (2019). The temporal decline of AGB values in the districts of Kodagu, Shimoga, Uttara Kannada, and Dakshina Kannada are due to anthropogenic pressure (Figure 4.3.1). The Mysore Chamarajanagar a and Ballari districts also reflect a decline in AGB values during 2005-2019. Uttara Kannada, Kodagu, Udupi, and Chikmagalur with relatively higher forest cover have higher carbon sequestration than the other parts of the State. The temporal decline in carbon sequestration is due to deforestation and land degradations due to the sustained anthropogenic pressures (Figure 4.3.2).

Figure 4.3.1. Temporal AGB in forest areas of Karnataka

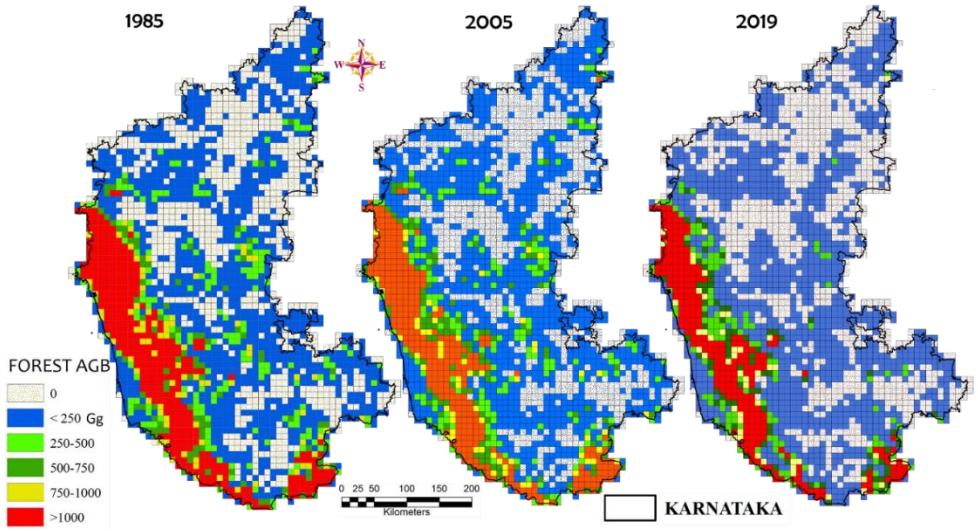
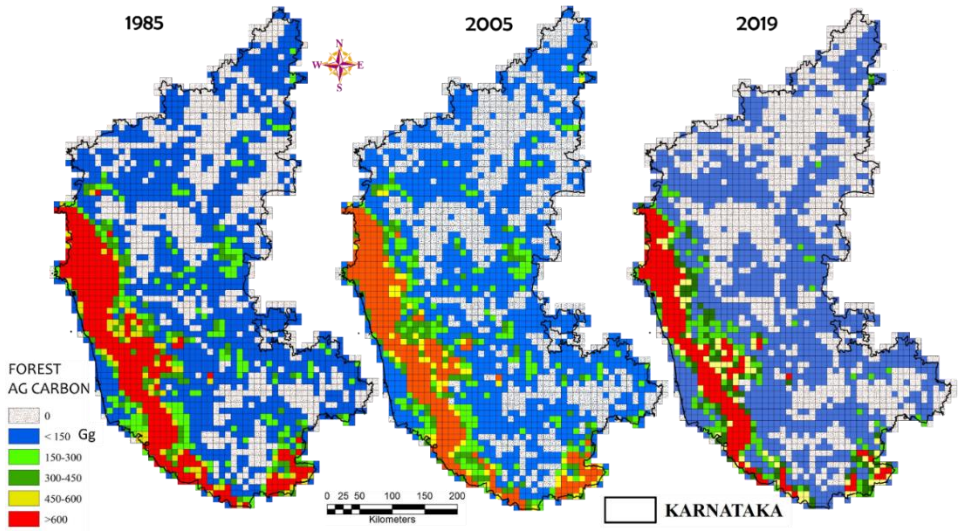


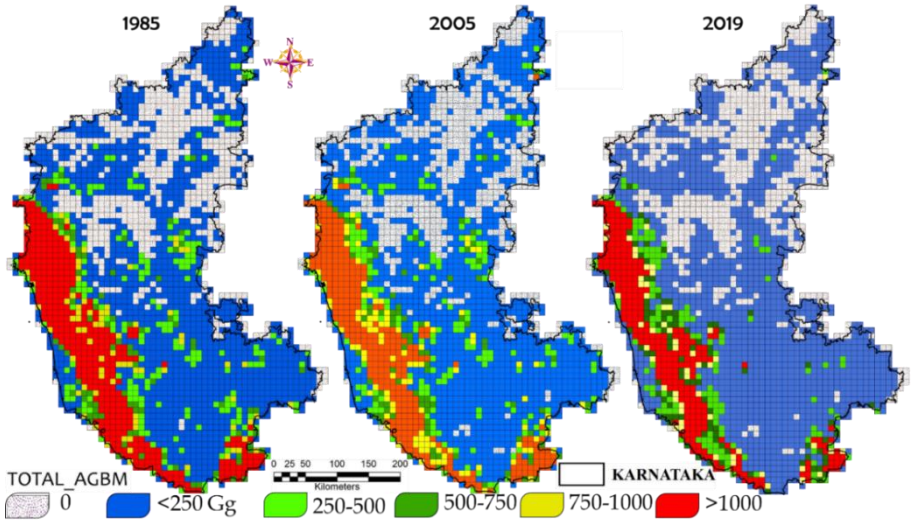
Figure 4.3.2. Temporal variation in carbon storage for forest areas of Karnataka.



Temporal BGB highlights the decline from 275 Tg (1989) to 180 Tg (2019). The grids consisting of evergreen forests (of Western Ghats) show higher values of >600 Gg SOC, while other regions are with relatively lower values (Figure 4.3.3). The loss of forest cover has degraded the SOC potential, and the region is exposed to the sunlight resulting in emissions.

In order to protect the land under greening initiatives and to sustain market demand for timber Karnataka forest department has implemented monoculture plantations in Karnataka State. The AGB, BGB, and their carbon values were accounted to understand the role of plantations in carbon sequestration apart from arresting land degradations. The total carbon has been estimated based on the AGB and BGB values as a sum of forest and forest plantation biomass. Figures 4.3.4 and 4.3.5 show the AGB for forest and plantations accounted for 1056.90 Tg with carbon sequestration of 528.45 Tg (in 1985), which is now reduced to 732.83 Tg and 366.41Tg, respectively. Figure 4.3.6 shows BGB from forest plantation and agriculture areas across Karnataka State accounted for 275.43 (1985), which is now reduced to 180.54 Tg. The plantations did not significantly contribute to ecosystem services compared to the forest but supported sequestration. The Uttara Kannada grids have significant AGB and BGB values.

Figure 4.3.3. Total AGB of Karnataka from 1985-2019



Total AGB and BGB from forests are about 782.1 Tg (1985), which is reduced to 519.36 Tg (2019) due to LU conversions (Figure 4.3.6). The total carbon sequestration from forest plantation and agriculture areas together is about 803.9 Tg (1985) and 546.96 Tg (2019) due to changes in LU with the burgeoning anthropogenic pressures. The grids covered in Ballari, Mysore, Chamarajanagar, Uttara Kannada, Kodagu have witnessed higher transitions in carbon sequestration potential.

Table 4.3.4 lists the carbon storage as per InVEST model and the same is presented in Figure 4.3.7. The comparison with gridded data quantification and model shows the accuracy as 97%. The limitations of Invest are it does not account for incremental carbon per year along with storage. The model does not allow to include a range of values for a single land use class. It takes for each carbon category (AGB or BGB) per hectare unique value.

Figure 4.3.4. Total carbon from AGB of Karnataka from 1985-2019

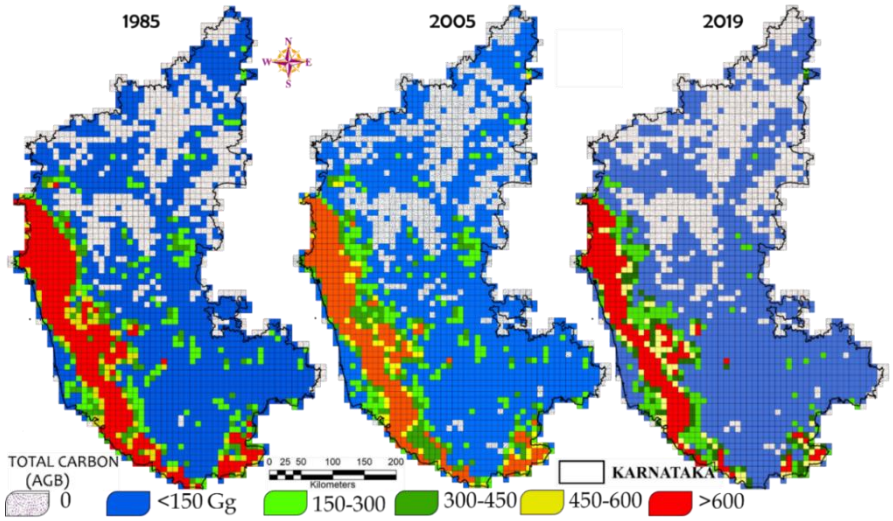


Figure 4.3.5. Total carbon from BGB of Karnataka from 1985-2019

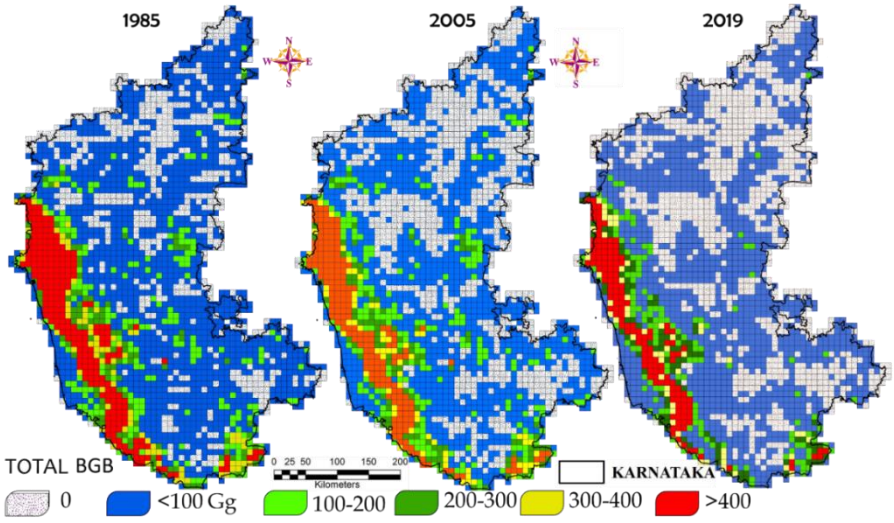


Figure 4.3.6. Total carbon from AGB & BGB of Karnataka from 1985-2019

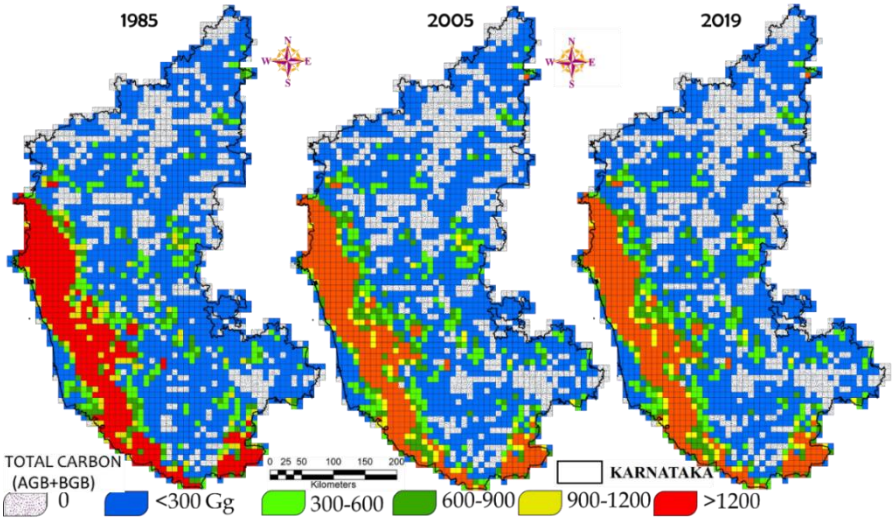


Figure 4.3.7: Total carbon storage quantified with InVEST model (2005 -2019)

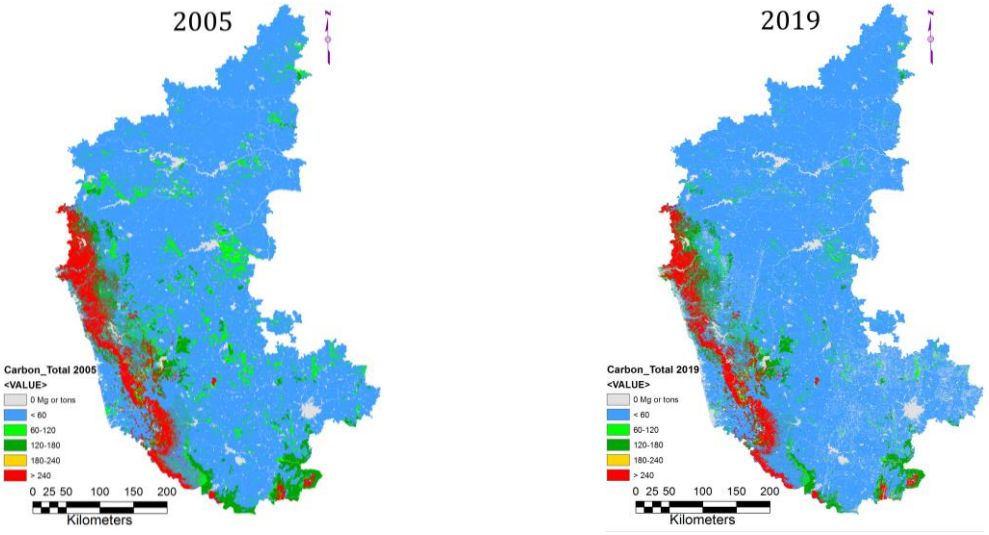


Table 4.3.4. Quantification of carbon storage using Invest

Year	Total Carbon Storage (Mg or ton)	Tg
2005	1053345477.95	1053.35
2019	831528751.17	831.53

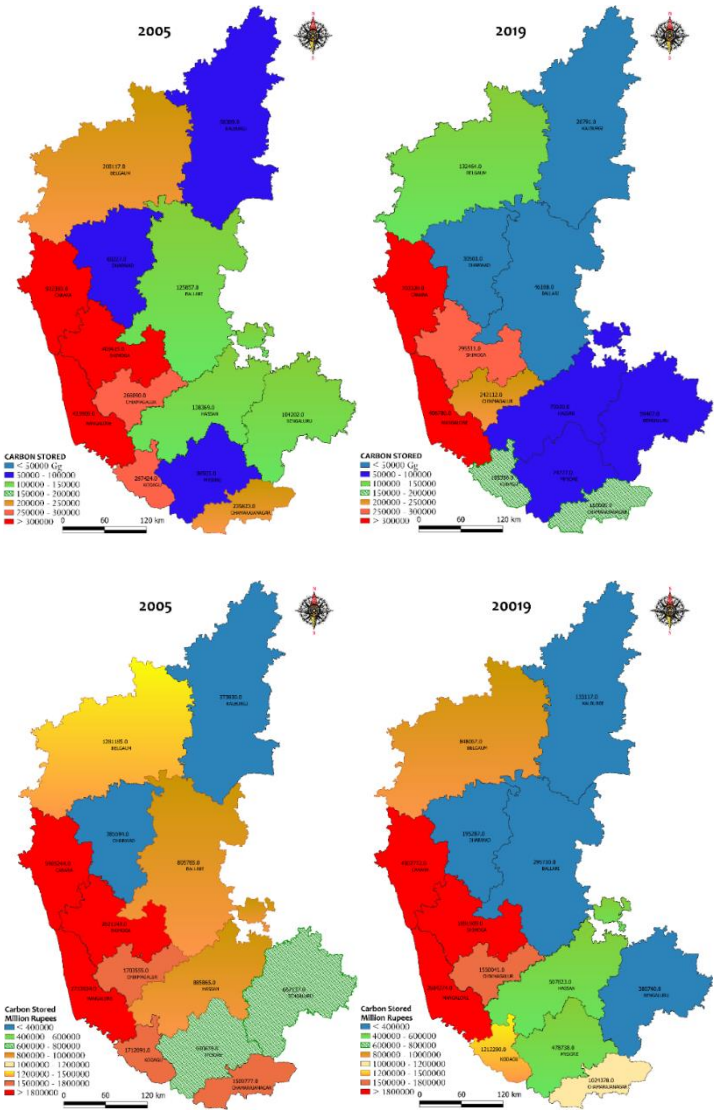
The ecosystem value of storage is computed as a function of the amount of carbon stored, the monetary value of each unit of carbon, a monetary discount rate, and the change in the value of carbon storage over time. Based on the social cost of Carbon dioxide, the ecosystem value of CO_2 storage is computed at circle wise and are listed in Table 4.3.5 The social cost of a tonne of CO_2 is taken as US$ 80 using the GDP deflator (MoSPI 2020). The circles having evergreen forest cover represent the greater values of biomass compared to the other forest types. The Karnataka forests have been providing regulating services evident from the carbon sequestration of 21,195,755 (2005), 156,25,146 (2019) million rupees. Canara and Mangalore circles have higher carbon forests due to rich forest cover, and Dharwad, Hassan, and Kalburgi depict the least values due to lesser forest cover (Figure 4.3.8).

Table 4.3.5. Ecosystem value of stored carbon in forest ecosystems of Karnataka

Sno	Circle	CO_2 Storage (Gg)		CO_2 Storage (Gg)	
		2005	2019	2005	2019
1	Bengaluru	104202	59467	667137	380740
2	Belgaum	200117	132464	1281185	848067
3	Ballari	125857	46188	805765	295710
4	Chamarajanagar	235823	160005	1509777	1024378
5	Chikmagalur	266090	242112	1703555	1550041
6	Dharwad	60227	30501	385594	195287

7	Kalburgi	58389	20791	373830	133117
8	Hassan	138369	79320	885865	507823
9	Canara	922383	703320	5905244	4502772
10	Kodagu	267424	189356	1712091	1212290
11	Mangalore	423909	406780	2713934	2604274
12	Mysore	98503	74777	630635	478738
13	Shimoga	409415	295511	2621143	1891909
Total		3310708	2440592	21195755	15625146

Figure 4.3.8. ecosystem service - Carbon storage (physical and monetary value)



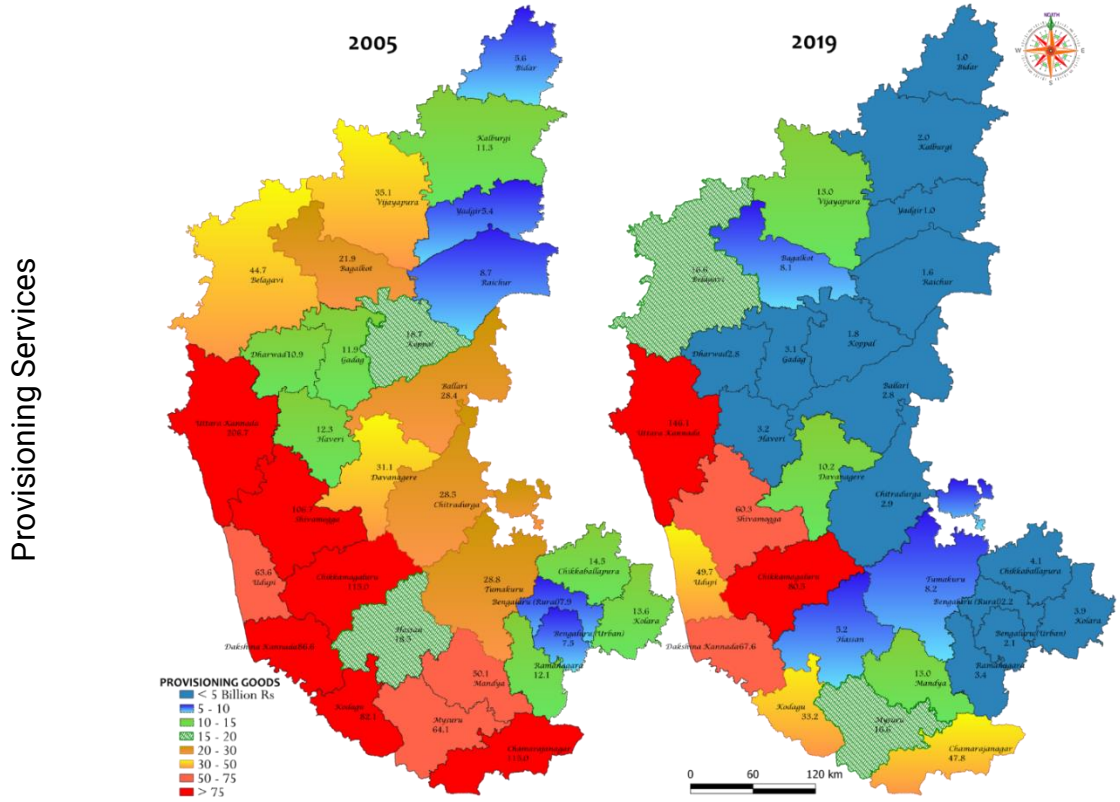
Annexure 5.3

Valuation of forest ecosystem services (provisioning, regulating and cultural) at the district level

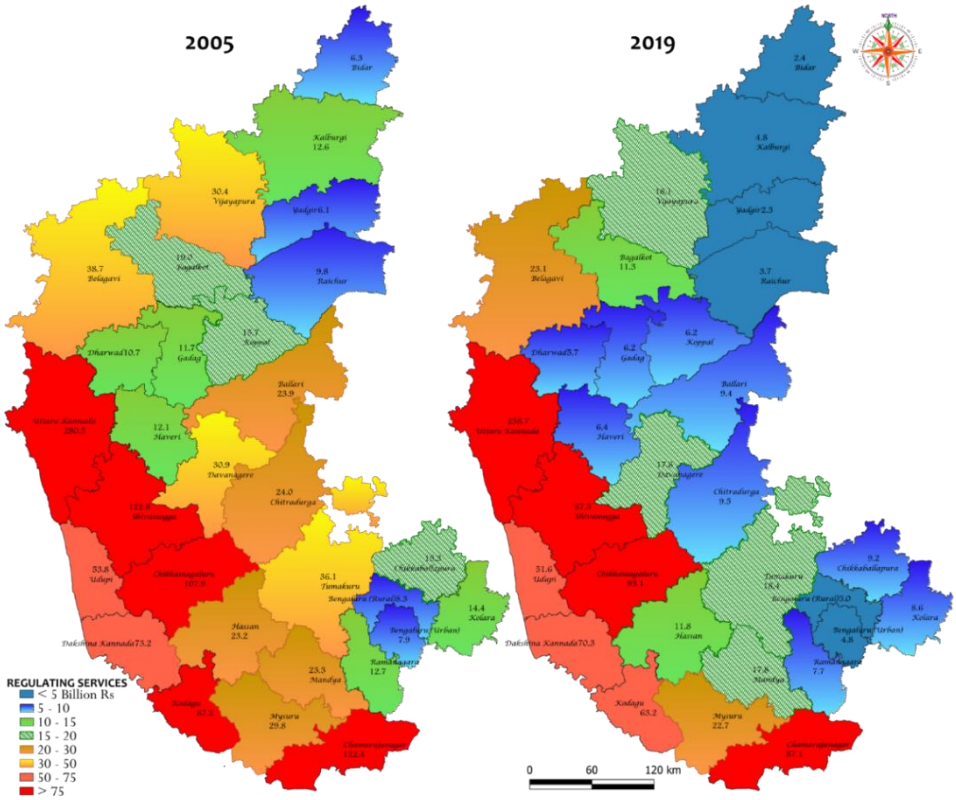
Ecosystem services (Provisioning services, regulating services, and cultural services) were computed district-wise by extracting the statistics at the district level by overlaying the district boundaries over the circle-wise layers. Tables 5.3.28 to 5.3.30 list the provisioning, regulating, and cultural services of 2005. Similarly, Table 5.3.31 to 5.3.33 provisioning, regulating, and cultural services during 2019. The spatial variations in the provisioning, regulating, and cultural services district-wise during 2005 and 2019 are depicted in Figure 5.3.31.

Total Ecosystem Supply Value (TESV) is computed by aggregating provisioning services, regulating, and cultural services, which accounts for 2841 billion INR in 2005 and 1835 billion INR in 2019. The decline of 35% in TSEV is mainly due to the degradation of the ecosystem (spatial extent as well as conditions. Provisioning services have declined from 1268 (2005) to 614 (2004) billion INR; regulating services declined from 1271 (2005) to 926 (2019) and cultural services from 303 (2005) to 295 (2019). Figure 5.3.32 illustrates the variability across the region. Districts such as Uttara Kannada, Chikmagalur, Dakshina Kannada, Shimoga, Kodagu, and Chamarajanagar contribute significantly to TESV. The district-wise assessment indicates Uttara Kannada has the highest TESV, over 439 billion rupees, followed by Chamarajanagar (215 billion), Chickmagalur (193 billion), Shimoga (168 billion), and Dakshina Kannada (167 billion). The lowest was observed in Yadgir, Bidar, Raichur districts.

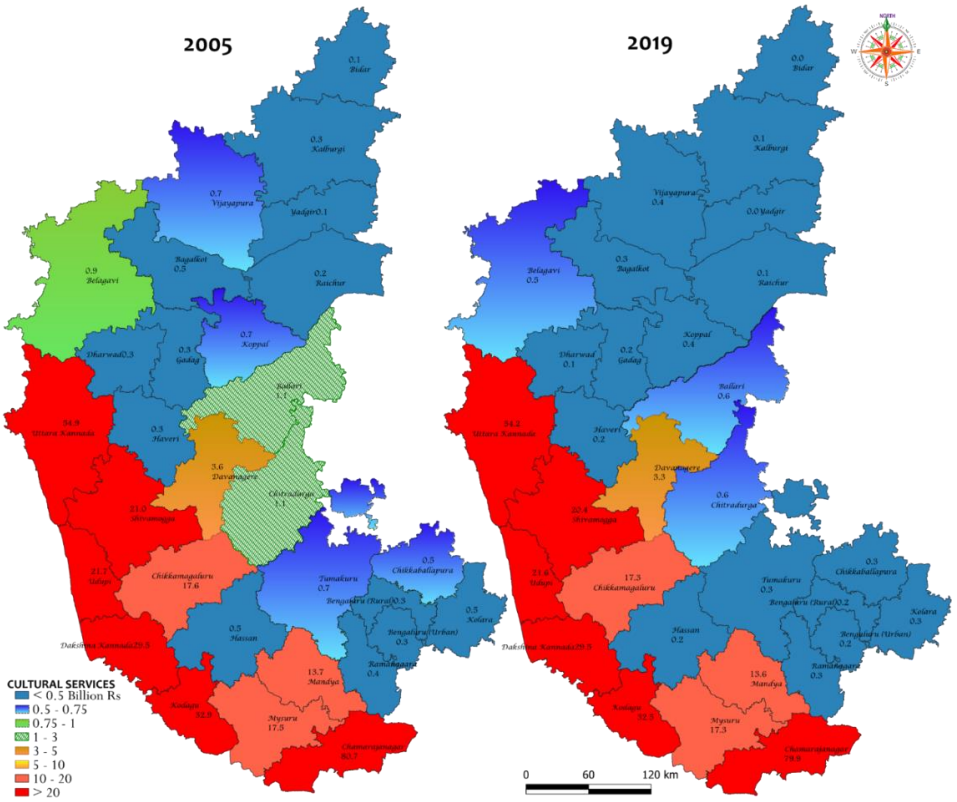
Figure 5.3.31. District wise, forest ecosystem services (provisioning, regulating and cultural) Karnataka state, India



Regulating Services



Cultural Services



TESV

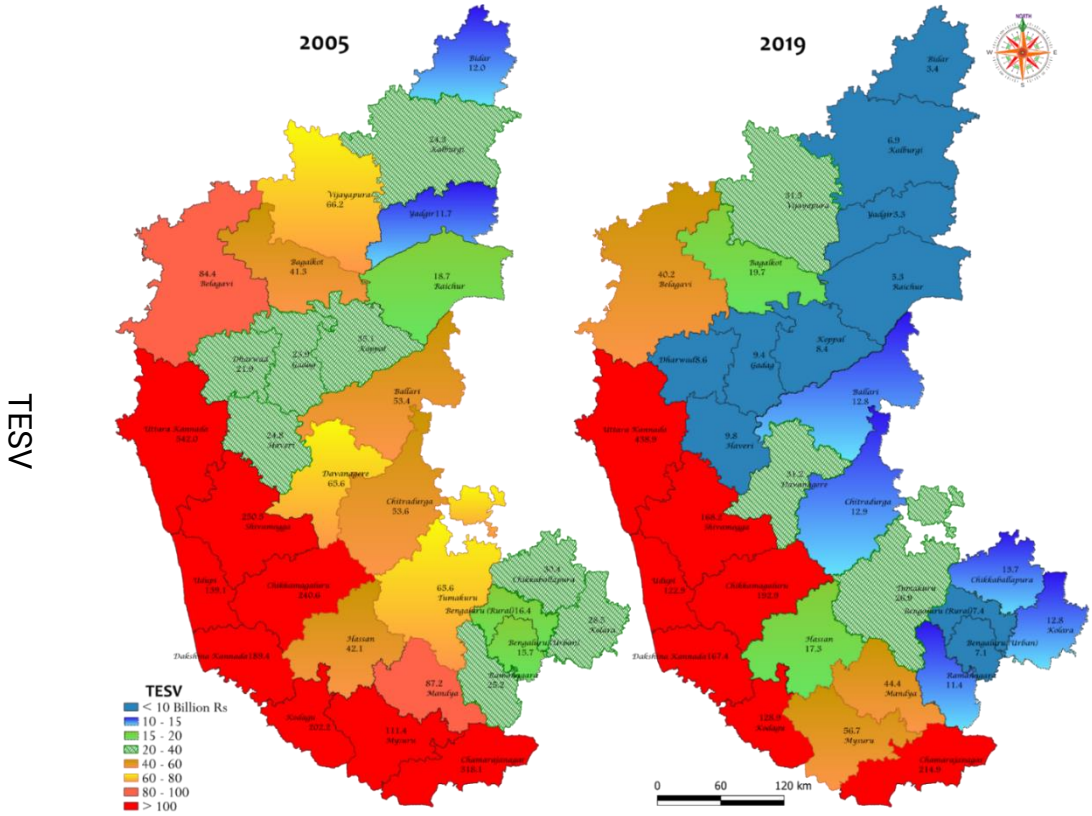


Figure 5.3.32. District-wise TESV (Total Ecosystem Supply Value) of forest ecosystem in Karnataka, India

Table 5.3.28. Provisioning services of forest ecosystem (district wise) 2005

Sno	District	Provisioning services (Million Rupees)										
		Timber	Bamboo	Canes	NTFP	Fish	Fuelwood	Fodder	Medicine	Water Supply	Genetic Material	Total
1	Bagalkot	5.6	2.6	0.0	462.9	71.3	908.7	1292.4	13.3	11362.6	7811.6	21928.5
2	Ballari	1.0	0.0	0.0	2.8	420.9	995.3	1436.3	21.6	20285.7	5266.4	28430.0
3	Belgaum	11.5	5.3	0.0	944.6	145.5	1854.2	2637.3	27.2	23186.4	15940.2	44747.0
4	Bengaluru (Rural)	1.9	0.0	0.0	62.0	136.9	369.1	545.4	5.7	5351.5	1389.3	7861.8
5	Bengaluru (Urban)	1.8	0.0	0.0	59.2	130.6	352.3	520.6	5.4	5107.7	1326.0	7503.6
6	Bidar	1.7	0.0	0.0	3.3	119.3	321.7	419.2	5.2	3767.1	978.0	5615.5
7	Chamarajanagar	0.1	0.0	0.0	4754.3	224.5	3911.9	6330.4	63.6	71235.5	28465.9	114986.1
8	Chikkaballapura	3.5	0.0	0.0	114.5	252.8	681.9	1007.5	10.5	9885.2	2566.3	14522.1
9	Chikmagalur	139.1	3.8	0.0	3596.0	327.5	4151.3	6026.3	59.5	54016.8	46673.1	114989.6
10	Chitradurga	1.4	0.0	0.0	19.0	420.4	998.2	1439.6	21.6	20289.6	5295.1	28485.0
11	Dakshina Kannada	53.5	0.5	0.0	7072.8	113.0	2482.1	3717.2	40.1	39225.6	33897.1	86601.4
12	Davanagere	77.5	2.7	0.0	2960.5	285.8	1268.7	1668.7	22.3	16988.9	7844.1	31116.5
13	Dharwad	47.6	2.0	0.0	19.9	165.0	463.0	665.7	7.5	6807.9	2720.4	10896.9
14	Gadag	52.0	2.2	0.0	21.7	180.2	505.8	727.2	8.2	7437.0	2971.8	11903.9
15	Hassan	32.8	0.0	0.0	110.7	560.9	1225.7	1643.5	16.7	10652.5	4256.8	18499.5
16	Haveri	53.8	2.2	0.0	22.5	186.4	523.3	752.3	8.5	7694.3	3074.6	12315.8
17	Kalburgi	3.5	0.0	0.0	6.6	240.3	648.0	844.3	10.5	7588.4	1970.0	11311.7
18	Kodagu	273.9	0.2	0.0	29517	76.5	2985.0	3513.6	48.5	24506.2	21177.2	82098.0
19	Kolara	3.2	0.0	0.0	107.4	237.1	639.6	945.0	9.9	9272.0	2407.1	13621.3
20	Koppal	0.7	0.0	0.0	1.8	276.8	654.4	944.4	14.2	13337.7	3462.6	18692.6
21	Mandya	54.7	0.9	0.0	28711	418.4	875.3	1349.9	13.2	13379.0	5346.3	50148.2
22	Mysore	69.9	1.1	0.0	36689	534.6	1118.6	1724.9	16.8	17096.6	6831.8	64082.5
23	Raichur	2.7	0.0	0.0	5.1	185.5	500.1	651.6	8.1	5856.7	1520.5	8730.4
24	Ramanagara	2.9	0.0	0.0	95.1	209.9	566.1	836.4	8.7	8206.9	2130.6	12056.6
25	Shimoga	537.4	18.7	0.0	20664	357.4	4988.8	6067.3	71.8	39722.1	34314.9	106723.7
26	Tumkur	51.1	0.0	0.0	172.3	873.1	1907.9	2558.4	25.9	16582.5	6626.4	28797.6
27	Udupi	39.3	0.3	0.0	5194.1	83.0	1822.8	2729.8	29.4	28806.1	24893.0	63597.4
28	Uttara Kannada	488.2	18.6	0.3	401.4	380.4	9365.8	11434	152.3	98965.3	85521.5	206709.4
29	Vijayapura	9.0	4.2	0.0	741.1	114.2	1454.7	2069.1	21.4	18190.9	12505.9	35106.2
30	Yadgir	1.7	0.0	0.0	3.2	115.8	312.1	406.7	5.1	3655.3	949.0	5448.8
Total		**2023**	**65**	**0.3**	**142,537**	**7844**	**48,852**	**66,906**	**772**	**6,18,460**	**3,80,133**	**12,67,528**

Table 5.3.29. Regulating services of forest ecosystem (district wise) 2005

Sno	District	Regulating Services (Million Rupees)									
		Air filtration	Local Climate Regulation	Global Climate Regulation /Carbon Seq.	Pollination	Erosion Prevention	Soil Fertility	Water Purification	Waste Treatment	Ground Water	Total
1	Bagalkot	1373.9	2925.7	11477.9	727.6	965.8	852.0	178.1	252.1	204.7	18957.8
2	Ballari	2220.1	4727.6	12907.9	991.7	1262.3	947.7	287.7	407.3	176.7	23929.1
3	Belgaum	2803.6	5970.1	23421.7	1484.8	1970.7	1738.7	363.4	514.4	417.7	38685.1
4	Bengaluru Rural	585.9	1247.6	5244.3	261.7	333.1	392.8	75.9	107.5	46.6	8295.5
5	Bengaluru Urban	559.2	1190.8	5005.4	249.8	317.9	374.9	72.5	102.6	44.5	7917.5
6	Bidar	539.1	1147.9	3448.2	240.8	284.7	410.3	69.9	98.9	39.9	6279.6
7	Chamarajanagar	6550.1	13948	77250.3	3035.5	5952.0	12785.1	848.9	1201.8	815.6	122387.4
8	Chikkaballapura	1082.2	2304.5	9687.3	483.4	615.3	725.5	140.3	198.6	86.1	15323.2
9	Chikmagalur	6130.0	13054	72554.8	3206.7	4804.5	5210.2	794.5	1124.7	1067.6	107946.3
10	Chitradurga	2222.8	4733.4	12959.9	993.5	1264.9	955.1	288.1	407.8	177.5	24003.0
11	Dakshina Kannada	4127.4	8789.1	47077.7	2159.2	3310.1	5739.1	534.9	757.3	737.7	73232.5
12	Davanagere	2295.9	4889.0	18167.4	1106.5	1437.5	2041.3	297.6	421.2	258.8	30915.2
13	Dharwad	773.9	1648.1	6528.7	358.7	657.5	438.7	100.3	142.0	91.3	10739.2
14	Gadag	845.5	1800.4	7132.1	391.8	718.2	479.3	109.6	155.1	99.7	11731.6
15	Hassan	1715.5	3653.0	13954.7	766.3	880.8	1531.8	222.3	314.7	123.4	23162.7
16	Haveri	874.7	1862.6	7378.8	405.4	743.1	495.9	113.4	160.5	103.1	12137.4
17	Kalburgi	1085.9	2312.4	6945.8	485.1	573.5	826.5	140.7	199.2	80.3	12649.4
18	Kodagu	4998.2	10643	52770.8	2614.7	3404.7	10429.2	647.8	917.0	741.9	87167.8
19	Kolara	1015.1	2161.6	9086.3	453.4	577.1	680.5	131.6	186.2	80.8	14372.7
20	Koppal	1459.7	3108.4	8486.9	652.0	830.0	623.1	189.2	267.8	116.2	15733.3
21	Mandya	1355.8	2887.1	14232.8	628.3	1193.1	2416.1	175.7	248.8	164.5	23302.2
22	Mysore	1732.5	3689.3	18187.6	802.9	1524.6	3087.5	224.5	317.9	210.2	29777.0
23	Raichur	838.1	1784.7	5360.8	374.4	442.6	637.9	108.6	153.8	62.0	9762.8
24	Ramanagara	898.5	1913.3	8042.6	401.3	510.8	602.3	116.5	164.8	71.5	12721.6
25	Shimoga	7396.3	15750	76679.9	3869.1	5128.6	10569.6	958.6	1357.0	1120.4	122829.4
26	Tumkur	2670.5	5686.6	21722.9	1192.9	1371.1	2384.5	346.1	490.0	192.2	36056.7
27	Udupi	3031.1	6454.5	34572.4	1585.6	2430.8	4214.6	392.8	556.1	541.8	53779.7
28	Uttara Kannada	15682.3	33395	182897.2	8203.9	11262.1	21520.9	2032.6	2877.3	2473.1	280343.9
29	Vijayapura	2199.6	4683.9	18375.5	1164.9	1546.1	1364.1	285.1	403.6	327.7	30350.3
30	Yadgir	523.1	1113.9	3345.8	233.7	276.2	398.1	67.8	96.0	38.7	6093.2
Total		79,587	1,69,475	7,94,904	39,525	56,589	94,873	10,315	14,601	10,712	127,058

Table 5.3.30. Cultural services of forest ecosystem (district wise) 2005

Sno	District	Cultural Services (Million Rupees)					
		Aesthetic	Tourism & Recreational	Spiritual	Art & Cultural	Education, scientific and research	Total
1	Bagalkot	65.2	70.9	0.0	29.0	289.7	454.8
2	Ballari	116.4	428.9	0.0	46.8	468.2	1060.4
3	Belgaum	133.1	144.7	0.0	59.1	591.2	928.1
4	Bengaluru (Rural)	30.7	108.3	0.0	12.4	123.6	274.9
5	Bengaluru (Urban)	29.3	103.3	0.0	11.8	117.9	262.4
6	Bidar	21.6	0.0	0.0	11.4	113.7	146.7
7	Chamarajanagar	408.8	78816.2	0.0	138.1	1381.3	80744.5
8	Chikkaballapura	56.7	200.0	0.0	22.8	228.2	507.8
9	Chikmagalur	310.0	15864.3	19.2	129.3	1292.7	17615.5
10	Chitradurga	116.4	446.8	0.1	46.9	468.8	1079.0
11	Dakshina Kannada	225.1	28346.1	15.1	87.0	870.4	29543.8
12	Davanagere	97.5	2953.4	12.2	48.4	484.2	3595.7
13	Dharwad	39.1	58.7	0.0	16.3	163.2	277.3
14	Gadag	42.7	64.2	0.0	17.8	178.3	303.0
15	Hassan	61.1	0.0	0.0	36.2	361.8	459.1
16	Haveri	44.2	66.4	0.0	18.4	184.5	313.5
17	Kalburgi	43.6	0.0	0.0	22.9	229.0	295.5
18	Kodagu	140.6	31629.7	18.0	105.4	1054.1	32947.8
19	Kolara	53.2	187.6	0.0	21.4	214.1	476.3
20	Koppal	76.5	282.0	0.0	30.8	307.8	697.2
21	Mandya	76.8	13310.7	0.0	28.6	285.9	13702.0
22	Mysore	98.1	17009.3	0.0	36.5	365.4	17509.3
23	Raichur	33.6	0.0	0.0	17.7	176.7	228.0
24	Ramanagara	47.1	166.0	0.0	18.9	189.5	421.6
25	Shimoga	228.0	18966.1	85.2	156.0	1559.8	20995.1
26	Tumkur	95.2	0.0	0.0	56.3	563.2	714.7
27	Udupi	165.3	20816.5	11.1	63.9	639.2	21696.1
28	Uttara Kannada	568.0	50669.9	38.2	330.7	3307.2	54914.0
29	Vijayapura	104.4	113.5	0.0	46.4	463.9	728.2
30	Yadgir	21.0	0.0	0.0	11.0	110.3	142.3
Total		**3,549**	**280,824**	**199**	**1,679**	**16,784**	**3,03,034**

Table 5.3.31. Provisioning services of forest ecosystem (district wise) 2019

Sno	District	Provisioning services (Million Rupees)										
		Timber	Bamboo	Canes	NTFP	Fish	Fuelwood	Fodder	Medicine	Water Supply	Genetic Material	Total
1	Bagalkot	3.2	0.0	0.0	17.7	184.6	1341.8	824.3	6.9	3400.6	2337.8	8117.6
2	Ballari	0.0	0.0	0.0	0.3	466.7	607.5	325.0	7.1	1097.5	284.6	2789.4
3	Belgaum	6.6	0.0	0.0	36.1	376.8	2738.1	1682.1	14.1	6939.2	4770.5	16564.7
4	Bengaluru (Rural)	1.8	0.0	0.0	5.4	142.5	330.7	180.6	3.0	1245.9	323.4	2233.7
5	Bengaluru (Urban)	1.8	0.0	0.0	5.1	136.0	315.6	172.3	2.8	1189.2	308.7	2131.9
6	Bidar	1.3	0.0	0.0	0.2	319.5	193.3	107.2	1.8	303.5	78.7	1005.7
7	Chamarajanagar	0.0	0.0	0.0	1394.0	131.0	5918.0	5023.1	41.0	25225.0	10080.0	47814.0
8	Chikkaballapura	3.4	0.0	0.0	9.9	263.2	610.8	333.5	5.5	2301.5	597.5	4126.0
9	Chikmagalur	129.1	0.6	0.0	1248.0	427.0	4978.1	3435.1	50.5	37697.9	32576.8	80547.0
10	Chitradurga	0.3	0.0	0.0	6.6	466.5	611.2	327.9	7.2	1123.7	308.6	2852.6
11	Dakshina Kannada	53.6	0.5	0.0	2.3	140.7	2710.5	2019.3	37.5	33609.3	29044.0	67619.4
12	Davanagere	45.9	0.0	0.0	1158.3	385.8	1011.8	672.9	11.3	3893.5	2994.6	10174.8
13	Dharwad	22.0	0.0	0.0	1.2	230.6	376.7	229.0	3.4	1379.6	551.1	2794.6
14	Gadag	24.1	0.0	0.0	1.4	251.9	411.5	250.1	3.7	1507.1	602.0	3052.9
15	Hassan	24.6	0.0	0.0	0.8	474.8	1672.5	1018.1	7.4	1462.4	584.4	5246.3
16	Haveri	24.9	0.0	0.0	1.4	260.6	425.8	258.8	3.9	1559.3	622.9	3158.5
17	Kalburgi	2.5	0.0	0.0	0.3	643.7	389.5	216.0	3.6	611.3	158.5	2025.9
18	Kodagu	152.0	0.0	0.0	1391.0	252.0	4413.0	2970.0	33.0	12869.0	11120.0	33203.0
19	Kolara	3.2	0.0	0.0	9.3	246.9	572.9	312.8	5.1	2158.7	560.4	3870.0
20	Koppal	0.0	0.0	0.0	0.2	306.9	399.4	213.7	4.7	721.6	187.1	1834.0
21	Mandya	35.1	0.0	0.0	188.3	709.0	1464.5	1154.7	8.8	6743.6	2694.6	13000.3
22	Mysore	44.9	0.0	0.0	240.7	906.0	1871.5	1475.6	11.2	8617.4	3443.4	16612.7
23	Raichur	2.0	0.0	0.0	0.2	496.8	300.6	166.7	2.8	471.8	122.4	1563.6
24	Ramanagara	2.8	0.0	0.0	8.2	218.5	507.1	276.9	4.6	1910.7	496.0	3425.5
25	Shimoga	320.7	0.1	0.0	8087.6	878.2	4704.6	3436.9	51.2	22946.5	19829.2	60257.3
26	Tumkur	38.4	0.0	0.0	1.2	739	2603.5	1584.8	11.6	2276.6	909.6	8166.7
27	Udupi	39.4	0.3	0.0	1.7	103.3	1990.5	1482.9	27.5	24681.7	21329.0	49657.6
28	Uttara Kannada	455.0	3.2	0.0	54.0	1360.0	11499.0	7487.7	130.0	67098.0	57984.0	146073.0
29	Vijayapura	5.2	0.0	0.0	28.3	295.6	2148.1	1319.7	11.0	5444.2	3742.7	12995.8
30	Yadgir	1.2	0.0	0.0	0.1	310.0	187.6	104.1	1.8	294.5	76.4	975.9
Total		**1445**	**4.8**	**0.1**	**13,900**	**12,124**	**57,306**	**39,062**	**514**	**2,80,781**	**2,08,719**	**6,13,890**

Table 5.3.32. Regulating services of forest ecosystem (district wise) 2019

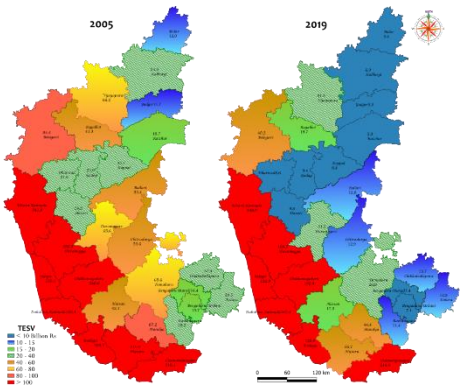
Sno	District	Regulating Services (Million Rupees)									
		Air filtration	Local Climate Regulation	Global Climate Regulation /Carbon Seq.	Pollination	Erosion Prevention	Soil Fertility	Water Purification	Waste Treatment	Ground Water	Total
1	Bagalkot	724.5	1542.8	6934.6	383.7	476.6	937.4	93.7	132.9	93.5	11320.6
2	Ballari	751.0	1599.3	4768.1	335.3	318.2	1340.5	97.3	137.7	44.4	9393.5
3	Belgaum	1478.5	3148.2	14150.6	783.0	972.5	1912.9	191.2	271.3	190.8	23100.7
4	Bengaluru (Rural)	311.4	663.3	3058.2	139.1	146.9	554.3	40.3	57.0	20.5	4991.8
5	Bengaluru (Urban)	297.2	633.1	2918.9	132.7	140.2	529.1	38.5	54.4	19.6	4764.4
6	Bidar	186.1	396.6	1246.5	83.0	79.4	310.7	24.0	34.1	11.0	2372.7
7	Chamarajanagar	4234.0	9017.0	50800.0	1962.0	3255.0	16074.0	548.0	776.0	461.0	87131.0
8	Chikkaballapura	575.2	1225.2	5649.1	256.9	271.3	1024.0	74.5	105.3	37.9	9220.8
9	Chikmagalur	5241.6	11162.5	63289.3	2742.2	3885.4	6246.0	679.4	961.1	856.9	95067.9
10	Chitradurga	755.0	1607.7	4816.5	337.5	321.3	1346.5	97.8	138.4	45.2	9467.6
11	Dakshina Kannada	3886.7	8277.4	44942.0	2033.0	3029.3	6222.4	503.4	712.7	672.3	70282.6
12	Davanagere	1177.1	2506.5	10221.2	583.6	682.5	2083.3	152.5	215.8	134.5	17758.4
13	Dharwad	369.3	786.3	3378.3	171.0	260.3	571.0	47.8	67.6	37.5	5690.4
14	Gadag	403.4	859.0	3690.5	186.8	284.4	623.7	52.2	73.9	41.0	6216.3
15	Hassan	774.4	1649.0	7166.4	345.8	334.4	1258.3	100.1	142.0	46.9	11818.9
16	Haveri	417.3	888.7	3818.2	193.2	294.2	645.3	54.0	76.5	42.4	6431.3
17	Kalburgi	374.9	798.9	2511.0	167.3	160.0	625.8	48.4	68.7	22.2	4779.4
18	Kodagu	3456.0	7361.0	37358.0	1808.0	2247.0	9402.0	448.0	634.0	486.0	63203.0
19	Kolara	539.6	1149.2	5298.7	241.0	254.5	960.5	69.9	98.8	35.5	8648.8
20	Koppal	493.8	1051.5	3135.0	220.4	209.2	881.4	63.9	90.5	29.2	6176.2
21	Mandya	924.6	1969.4	10631.9	428.5	745.9	2701.7	119.8	169.5	104.5	17797.4
22	Mysore	1181.4	2516.6	13586.1	547.5	953.1	3452.3	153.2	216.5	133.5	22742.6
23	Raichur	289.4	616.6	1938.0	129.1	123.5	483.0	37.3	53.0	17.1	3688.7
24	Ramanagara	477.6	1017.2	4690.0	213.3	225.2	850.1	61.8	87.4	31.5	7655.3
25	Shimoga	5300.5	11287.1	52866.1	2772.7	3530.2	9335.1	686.8	972.0	766.7	87520.3
26	Tumkur	1205.6	2567.0	11155.6	538.2	520.6	1958.7	155.9	221.0	73.1	18398.1
27	Udupi	2854.3	6078.6	33004.0	1493.0	2224.7	4569.6	369.6	523.3	493.7	51613.4
28	Uttara Kannada	13416.0	28570.0	151785.0	7018.0	9174.0	22512.0	1738.0	2461.0	2000.0	238678
29	Vijayapura	1160.0	2469.9	11101.8	614.3	763.0	1500.7	150.0	212.8	149.7	18123.6
30	Yadgir	180.6	384.8	1209.5	80.6	77.1	301.5	23.3	33.1	10.7	2302.2
Total		**53,437**	**1,13,801**	**5,71,119**	**26941**	**35,959**	**101,214**	**6921**	**9799**	**7109**	**926,356**

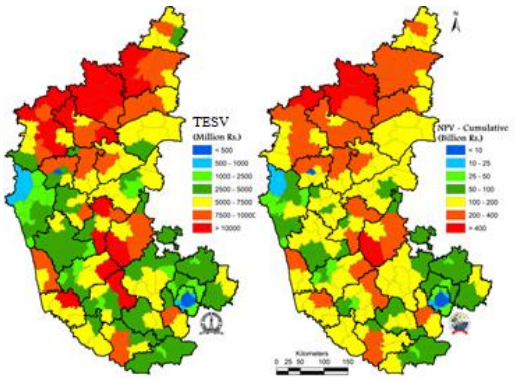
Table 5.3.33. Cultural services of forest ecosystem (district wise) 2019

Sno	District	Cultural Services (Million Rupees)					
		Aesthetic	Tourism & Recreational	Spiritual	Art & Cultural	Education, scientific and research	Total
1	Bagalkot	19.39	68.51	0	15.28	152.80	255.95
2	Ballari	6.21	428.80	0	15.84	158.41	609.33
3	Belgaum	39.57	139.80	0	31.18	311.80	522.29
4	Bengaluru (Rural)	7.07	104.56	0	6.57	65.69	184.07
5	Bengaluru (Urban)	6.75	99.80	0	6.27	62.70	175.69
6	Bidar	1.62	0.00	0	3.93	39.29	44.95
7	Chamarajanagar	144.00	78816.00	0	89.31	893.05	79943.00
8	Chikkaballapura	13.07	193.14	0	12.13	121.35	340.02
9	Chikmagalur	216.04	15863.63	16.53	110.55	1105.51	17312.99
10	Chitradurga	6.36	446.70	0.07	15.92	159.25	628.37
11	Dakshina Kannada	192.58	28345.75	12.68	81.98	819.76	29453.36
12	Davanagere	22.21	2953.28	12.20	24.83	248.26	3260.88
13	Dharwad	7.76	56.48	0	7.79	77.89	150.19
14	Gadag	8.47	61.69	0	8.51	85.09	164.07
15	Hassan	8.21	0.00	0	16.33	163.34	187.74
16	Haveri	8.77	63.83	0	8.80	88.03	169.74
17	Kalburgi	3.27	0.00	0	7.91	79.14	90.55
18	Kodagu	73.00	31629.00	18.00	72.90	729.03	32523.00
19	Kolara	12.26	181.16	0	11.38	113.82	318.93
20	Koppal	4.09	281.93	0	10.42	104.16	400.63
21	Mandya	38.63	13310.72	0	19.51	195.07	13563.59
22	Mysore	49.37	17009.28	0	24.93	249.27	17332.41
23	Raichur	2.53	0.00	0	6.11	61.08	69.88
24	Ramanagara	10.85	160.35	0	10.07	100.75	282.29
25	Shimoga	131.06	18965.96	85.20	111.79	1117.88	20412.40
26	Tumkur	12.79	0.00	0	25.43	254.27	292.26
27	Udupi	141.42	20816.25	9.32	60.20	602.01	21629.64
28	Uttara Kannada	385.00	50669.00	25.00	282.95	2829.46	54193.00
29	Vijayapura	31.04	109.68	0	24.46	244.62	409.76
30	Yadgir	1.58	0	0	3.81	38.12	43.62
Total		**1605**	**2,80,775**	**179**	**1127**	**11271**	**2,94,965**

Table 5.3.34. District wise TESV (aggregation of Provisioning, Regulating and Cultural services) of a forest ecosystem in Karnataka in Billion Rs

Sno	District	PROVG_BRS		REGS_BRS		CULTS_BRS		TESV	
		2005	2019	2005	2019	2005	2019	2005	2019
1	Bagalkot	22	8	19	11	0.5	0.3	41	20
2	Ballari	28	3	24	9	1.1	0.6	53	13
3	Belagavi (Belgaum)	45	17	39	23	0.9	0.5	84	40
4	Bengaluru (Rural)	8	2	8	5	0.3	0.2	16	7
5	Bengaluru (Urban)	8	2	8	5	0.3	0.2	16	7
6	Bidar	6	1	6	2	0.1	0.0	12	3
7	Chamarajanagar	115	48	122	87	80.7	79.9	318	215
8	Chikkaballapura	15	4	15	9	0.5	0.3	30	14
9	Chikkamagaluru (Chikmagalur)	115	81	108	95	17.6	17.3	241	193
10	Chitradurga	28	3	24	9	1.1	0.6	54	13
11	Dakshina Kannada	87	68	73	70	29.5	29.5	189	167
12	Davanagere	31	10	31	18	3.6	3.3	66	31
13	Dharwad	11	3	11	6	0.3	0.2	22	9
14	Gadag	12	3	12	6	0.3	0.2	24	9
15	Hassan	18	5	23	12	0.5	0.2	42	17
16	Haveri	12	3	12	6	0.3	0.2	25	10
17	Kalburgi (Gulbarga)	11	2	13	5	0.3	0.1	24	7
18	Kodagu	82	33	87	63	32.9	32.5	202	129
19	Kolar	14	4	14	9	0.5	0.3	28	13
20	Koppal	19	2	16	6	0.7	0.4	35	8
21	Mandya	50	13	23	18	13.7	13.6	87	44
22	Mysuru (Mysore)	64	17	30	23	17.5	17.3	111	57
23	Raichur	9	2	10	4	0.2	0.1	19	5
24	Ramanagara	12	3	13	8	0.4	0.3	25	11
25	Shivamogga (Shimoga)	107	60	123	88	21.0	20.4	251	168
26	Tumakuru (Tumkur)	29	8	36	18	0.7	0.3	66	27
27	Udupi	64	50	54	52	21.7	21.6	139	123
28	Uttara Kannada	207	146	280	239	54.9	54.2	542	439
29	Vijayapura (Bijapur)	35	13	30	18	0.7	0.4	66	32
30	Yadgir	5	1	6	2	0.1	0.0	12	3
Total		**1268**	**614**	**1271**	**926**	**303**	**295**	**2841**	**1835**





Forest Ecosystem **Agriculture Ecosystem**