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ARTICLE

Ecosystem Services Demand and Supply in a City Region: Implications for Regional Spatial Planning in Mekelle City

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Abstract
The provision of ecosystem services is determined by three factors: supply, demand, and flow**.** The study looked into both the demand and supply sides, as well as the spatial and temporal variations between supply and demand, from the perspective of a city region. To investigate the mismatch between demand and supply both quantitative and qualitative sources of data were employed. Landsat data, expert knowledge, document review, and qualitative data including key informant interview was utilized. The land-use patterns analyses show that ecosystem services flow in the city surroundings are higher than those within Mekelle city's administrative boundary. Land use/land cover dynamics were the main drivers of ecosystem services supply decline in the Mekelle city region. Those changes negatively affected the capacity of ecosystems to provide goods and services to the growing urban and rural populations. This supply of bundles of ecosystem services did not match the demands of the society which endangered the sustainable utilization of natural capital. The results disclose land-use patterns over time and space as well as the capacities of different ecosystems to provide sustainable ecosystem services supply are declining. On the contrary, demands for these services are increasing due to the growth of the population and economic activities. The study can support spatial planners in addressing the sustainable use of watershed ecosystem services.

Key words: Demand, Supply, Flow, Ecosystem services, City region.

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1. Introduction

Research on ecosystem services (ESs) has increased substantially in recent decades, but the findings have been slow to affect actual management, perhaps because most studies to date have neglected ESs supply and demand coupling mechanisms. Human reliance on ESs is due to the capacity of the landscape to supply services, but also to a societal need for these services. Sustainable land management requires supply and demand mismatches to be reconciled and the needs of different stakeholders to be balanced. Explicit spatial mapping of ESs supply and demand associated with land-use changes can provide relevant insights for enhancing land management in urban areas. The emphasis is now shifting to enhancing sustainable land use, to ensure that supply meets or exceeds demand(**Chen, Jiang, Bai, Xu, & Alatalo, 2019**).

The application of the ecosystem services (ES) framework in landscape planning has become particularly relevant in rural-urban gradients since it allows for the integration of the complex interactions between ES supply and demand(**Palomo-Campesino, Palomo, Moreno, & González, 2018**). Spatial planning is a key policy instrument for decision-making that drives future changes to land systems, and subsequently to the quality, quantity, and spatial distribution of ecosystem services (ES). Supply and demand for ES vary from local to regional and global scales affecting a wide range of stakeholders(**Rozas-Vásquez, Fuerst, Geneletti, &**

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Almendra, 2018). This study has assessed both ecosystem services supply and demand comprehensively. Therefore, it is important to study this problem to raise the awareness of policymakers for improved decision-making.

In the Mekelle city region, ecosystem services supply is decreasing. Despite, this fact there is an increase in demand. The scenario shows likely decreasing trends in ES supply and the population growth projection shows the demand likely increasing trends in ES demand. The need and demand for water in Mekelle city are becoming acute with the growing population(Oyedotun, 2017)and (Meisina, 2015). Growing water demand poses severe problems to the population in the Mekelle Outlier, Northern Ethiopia(Meisina, 2015, p. 64) (Asgedom, 2014, p. 1922) and (Aregawi, 2010, p. 2). There is strong competition to get ecosystem services that aggravate their ultimate deterioration. Demand for cultural ecosystem services is increasing and putting pressure, particularly on the urban and peri-urban space for nearby recreation and landscape amenities in the study area.

In the core city of the region i.e., Mekelle city cultural services are inadequate. Mekelle city has relatively little green space. The economic benefits they provide are rarely captured by the people who own and manage them. The Population projection of the Mekelle city region has shown that the population is expected to double by 2040 that can demand more bundles of ecosystem services. As a result of the unsustainable consumption of ecosystems are consumed, the gaps between the supply and demand of ecosystem services are rapidly widening. Ecosystem service flows or supply-side that affect the demand of Mekelle city residents are poorly understood. However, relatively little is known about the supply and demand of ecosystem services at the city-region scale and the effects of land-use dynamics on ecosystem service values. A study by (Abreha, 2014)on hydrogeochemical and water quality investigation on irrigation and drinking water supplies in the Mekelle region shows depletion of the water ecosystem.

This problem impacts the ecosystem services and the well-being of society in the city region. Vulnerability extends to urban populations that depend on the ecosystem services provided by or flowing through peri-urban areas. Degradation of these ecosystems results in the loss of ecosystem services that support urban and peri-urban populations. Accelerated urban expansion not only influences socioeconomic change, but also influences farmland loss, impacts ecology and the environment, and often threatens sustainable urban development(Rimal, 2018).

The population growth indicates more beneficiaries; an uncertain climate and more demand for ecosystem services. There is an imbalance of ecosystem services supply and demand in Mekelle city. There is a challenge to balance spatial mismatches. The imbalance between socially driven economic growth on the one hand and the naturally limited availability of resources on the other poses one of the biggest challenges: the overuse of resources and the associated losses of natural processes providing the essentials of our life.

Previous studies have not adequately considered the ability to fulfill city residents' demand for ecosystem services. The number of studies using the city residents' demand for ES study is limited. To address this gap, the study used a comprehensive approach to study the demand side. Ecosystem services mapping and modeling has focused more on supply than demand, until recently. Whereas the potential provision of economic benefits from ecosystems to people is often quantified through ecological production functions, the use of and demand for ecosystem services has received less attention, as have the spatial flows of services from ecosystems to people. To fill this gap, the study investigated both the demand and supply side and the spatial and temporal variations between the supply and demand from the city region perspective which is central to sustainable management of the ecosystem.

2. Literature Review

Ecosystem services benefit human beings in different ways. The contributions of nature to the basic needs, in terms of food production, water provisioning, provision of fuel and fiber, and regulation of climate, water, and nutrient cycling and supporting services which produce the conditions for all other provisioning, regulating and cultural service(Carabine, 2015).To meet increasing human needs natural ecosystems have been converted into different land uses since humans first began to manage their environment. However, the changes that have taken place over the last 50 years have been especially important and intense as society is becoming increasingly urbanized, while ecosystems become deteriorated(Martínez, 2009). Land use dynamics significantly change the supply of ecosystem services with resulting negative impacts on human well-being(Quintas-Soriano, Castro, Castro, & García-Llorente, 2016).

The regional supply of ecosystem goods and services is directly determined by the regional ecological integrity which is influenced by human actions and decisions such as land cover change, land use, and technical progress. Human well-being (economic, social, and personal well-being) is based on benefits derived from the people's actual use of ecosystem goods and services. This actual use of ecosystem goods and services is the demand side of this supply and demand chain. The demand side of this supply and demand chain (EEA, 2010). The impacts on the demand side are manifold and can include policies, population dynamics, economic factors, marketing, trends, advertising, cultural norms, and governance(Burkhard, Kroll, Nedkov, & Müller, 2012).

The continuous increase in the number and size of cities and the transformation of landscapes reduce ecosystem services supply, is driven by LULC changes, in particular the conversion of high service-providing ecosystems such as forests, cropland, and water bodies to built-up areas(Haase et al., 2014).On the other hand, increased demand is driven by increases in population, wealth, and changes in spending preferences(Wolff, Schulp, Kastner, & Verburg, 2017). Many studies have shown that land use and land cover changes (e.g. urbanization) can decrease various ESs(Chen et al., 2019). The ecosystem services concept has shifted the paradigm of how nature matters to human well-being. Nevertheless, ecosystem services are becoming increasingly scarce. To halt the trend, the challenge is to provoke society to recognize the value of natural capital and ESV is the method to tackle such an alarming challenge(**Liu, Costanza, Farber, & Troy, 2010**).

The supply of ecosystem services refers to the capacity of a particular area to provide a specific bundle of ecosystem goods and services within a given period. Here, capacity refers to the generation of the used set of natural resources and services. Thus, it is not similar to the potential supply of ecosystem services in a certain ecosystem, which would be the hypothetical maximum yield of selected optimized services. The demand for ecosystem services is the sum of all ecosystem goods and services currently consumed or used in a particular area over a given period (**Burkhard et al., 2012**).

A region is the arena of social processes; territories of control; and spatial formations interacting at different scales(**Terlouw, 2001**). The region works as a system, with flows and movements across the mosaic. Also, the great mosaic changes over time, especially as human pieces expand and natural pieces shrink. This leaves nature further degraded, and the fundamental human dependence on nature's resources riskier, and less sustainable(**Forman, 2008**). The formal region is organized or tied together vertically, while the functional region is generally organized by horizontal relations in space in a form of spatial flows or interactions of various kinds of persons, goods, material, energy, information, etc. between parts of a region(**Pavel Klapka, 2013**). Within a region, the major pressures on catchment systems are through a historical timeline of land use and management, urbanization, and industrialization driven by different cultures. Each of these pressures has direct and indirect consequences on water resources and there are many synergistic interactions between them at local, regional, and global scales(**Ferrier & Jenkins, 2010**)

Current research has commenced mapping the spatial delivery of ecosystem services across landscapes and several methods have taken the ecosystem services concept further to improve conservation and restoration efforts and support other environmental decision-making, assess possible synergies and trade-offs between services, or evaluate payment options for ecosystem services. Multi-criteria modeling frameworks have also been developed to further provide decision support on sustainable ecosystem service deliveries (**Stosch, Quilliam, Bunnefeld, & Oliver, 2017**).

Ecosystems provide services that contribute to the well-being of people living within a city's borders and on the urban-rural peripheral. While benefits from ecosystem services in urban settings are well investigated, peri-urban areas are significantly less addressed than cities. The city people can influence these places to relax, exercise, and enjoy the fresh air. Such places are usually within easy traveling the cities that they serve, and they are within walking distance(**Grant, 2012**).

The current modeling approaches that aim to assist land-use decision-making generally do not include land-use changes' effects on ecosystem services and mainstream only a limited range of ecosystem services. There are still deficiencies and knowledge gaps about how to identify and quantify ecosystem services, how ecosystem services interact, and how land-use dynamics affect the continuum provision of ecosystem services. Alternative approaches to better understand the problem is useful. Practical applications in ecosystem services are still limited. Limiting factors include inconsistent approaches to ecosystem service modelling, assessment, and valuation; lack of appropriate institutional frameworks; and misunderstanding of the science. The scientific community needs to continue to develop better methods to measure, monitor, map, model, value, and manage ecosystem services. It also needs to more effectively communicate the concepts and results to the public(**Robert Costanza & Steve Farber f, 2017**).

Research objectives

The following research objectives was answered in this study.

1. To identify the potential supply of ecosystem services
2. To analyze ecosystem services supply and demand relationship and draw policy implication

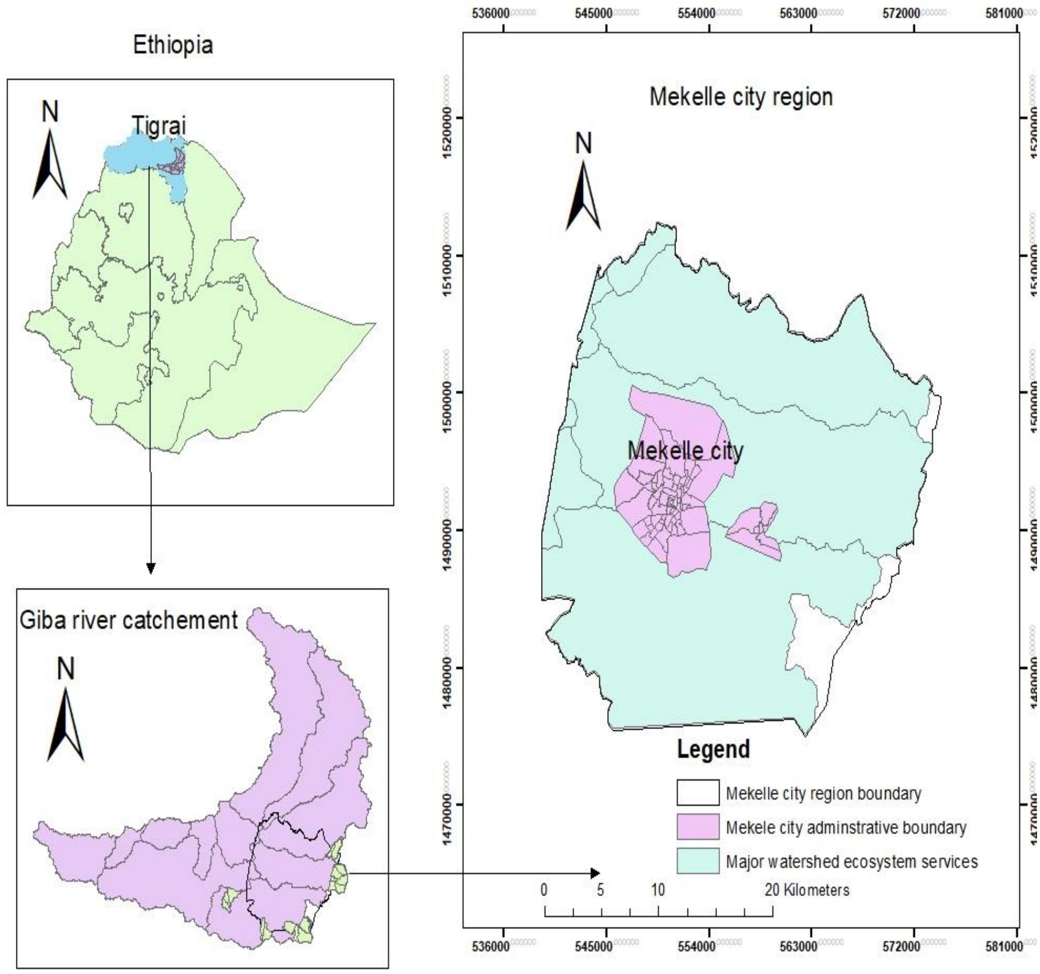
3. Materials and Methods

3.1 Study area

This study area is found in the northern part of Ethiopia. Mekelle city and its environs which are significant in terms of catchment ecosystem services for Mekelle city are named as 'city region for this study and are selected for scientific investigation. The rate of urbanization is estimated to increase rapidly in the coming few decades and this scale of urbanization strains both urban and rural ecosystems, which are required to provide nutrition, clean water, fresh air, recreational opportunities, wellbeing, and other life-supporting and life-enhancing opportunities to city dwellers. Preserving ecosystem services in the city region is crucial. On the one hand, there is a particularly strong consumption of ecosystem goods and services because much of the human population is concentrated in the city. The most important quality of the functional region is its ability it exceeds the administrative region(**Antikainen, 2005**). The city Agule, Dandera, and Maimekden,Gereb Segen ,Gereb Giba are outside the administrative boundary of Mekelle city. But it has intense interaction with the major city Mekelle in terms of ecosystem services.

Fourteen nested sub-catchments of the Geba river basin which areas within and near the city and significant in terms of ecosystem services for Mekelle city were selected in this study namely: Ilala, May-Gebat, Agula, middle Geba, old bride, Suluh, and Genfel. The various types of ecosystems in the city region bring benefits to people both within the Mekelle city borders and the surrounding areas.

Figure 1: Map of the Study area



Source: Author, 2022

3.2 Data sources

To investigate the mismatch between demand and supply both quantitative and qualitative sources of data were employed. Landsat data remote, document review, and qualitative data including focus group discussion and key informant interview was made. Economic value indicators are used to quantify ES demand. And LULC changes are used to quantify ES supply. The supply-side was measured by LULC changes and their effects on the ecosystems. The combination of these different approaches provided an integrative methodological framework for assessing ecosystem services demand and supply.

3.3 Data Analysis

The spatial data were analyzed ERDAS Imagine remote sensing software package 2015 was used to process, classify, and analyze digital satellite images. Arc GIS 10.5.1 was used to compute the area and changes in the land use categories. On the pixels of the different LULC classes in the image, supervised classification was done. This was accomplished by using past knowledge of the area to train the areas (assigning pixels to land use classifications). The image was pre-processed in ERDAS software before classification. To study ecosystem services demand and supply changes this study implemented indicator-based assessments. Ecosystem services under the provisioning category are quantifiable. Nevertheless, the measurement of regulating, supporting, and cultural services are more difficult and this study employed indicators or proxy data. Indicators are variables that provide aggregated information on a phenomenon. Robust biophysical indicators are essential not only to estimate ecosystem services but also to assess the change in ecosystem services provision over time(**Wiggering et al., 2006**).DPSIR framework was applied to quantify ecosystem services and the choice of indicators, the temporal and spatial scales also were considered in the choice of indicators. The demand for Es's overtime or temporal was measured using proxies such as the density of population.

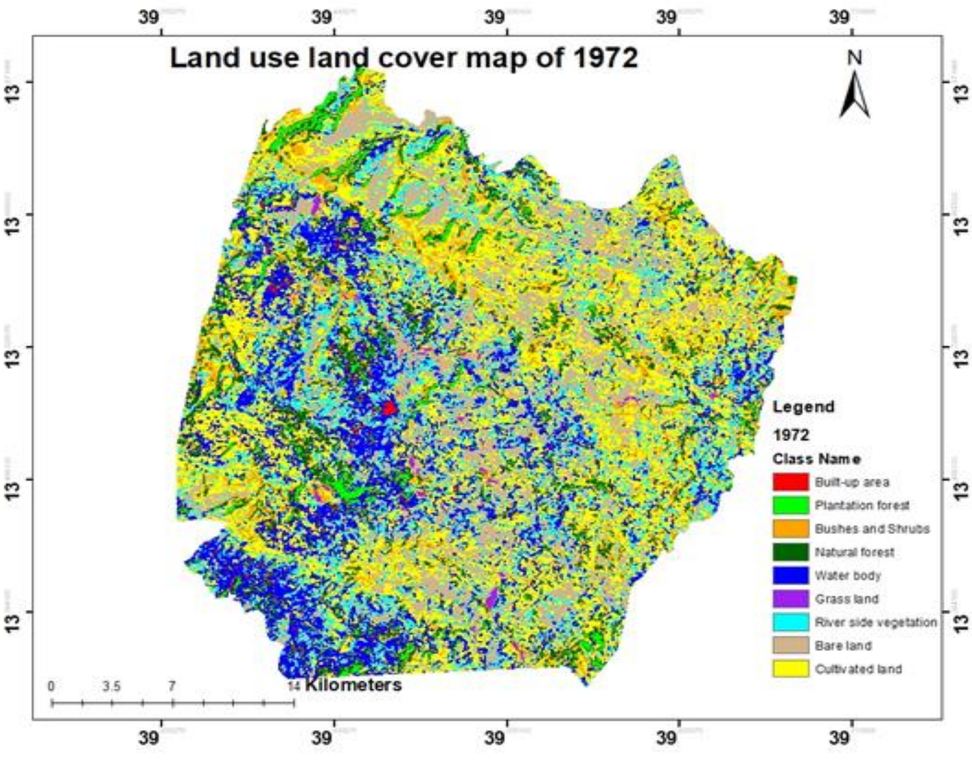
This study employed both Biophysical methods, Economic methods, and expert-based quantification of ecosystem services. The biophysical method is used to map and assess both the supply and the actual use and demand of ecosystem services. A biophysical quantification is the measurement of ES in biophysical units or quantities of a hectare per year and the biophysical methods depend on indicators. Both direct and indirect measurement of ecosystem services was used. The direct measurement was through direct observation and ground data collected using GPS. Indirect measurements of ecosystem services were made through remote sensing data. Expert-based quantification of ecosystem services was employed. ES sources are lacking and to solve this expert knowledge was utilized to provide the information needed for an ES stock, flow, and demand assessment. Moreover, when experts from multiple disciplines were engaged in the assessment and this gave a deeper understanding of the complex interrelations of the DPSIR framework in the ES stock, flow and demand system. Experts were asked to value the provision of a certain ES on a relative scoring scale ranging from 0 to 5. The multivariate regression analysis was applied for relational analysis between land use dynamics and population growth.

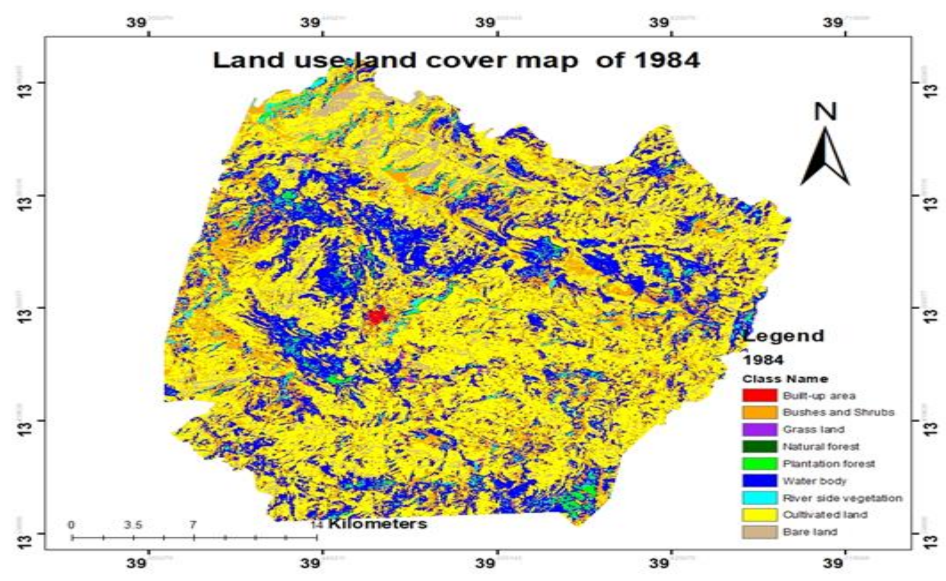
4. Results

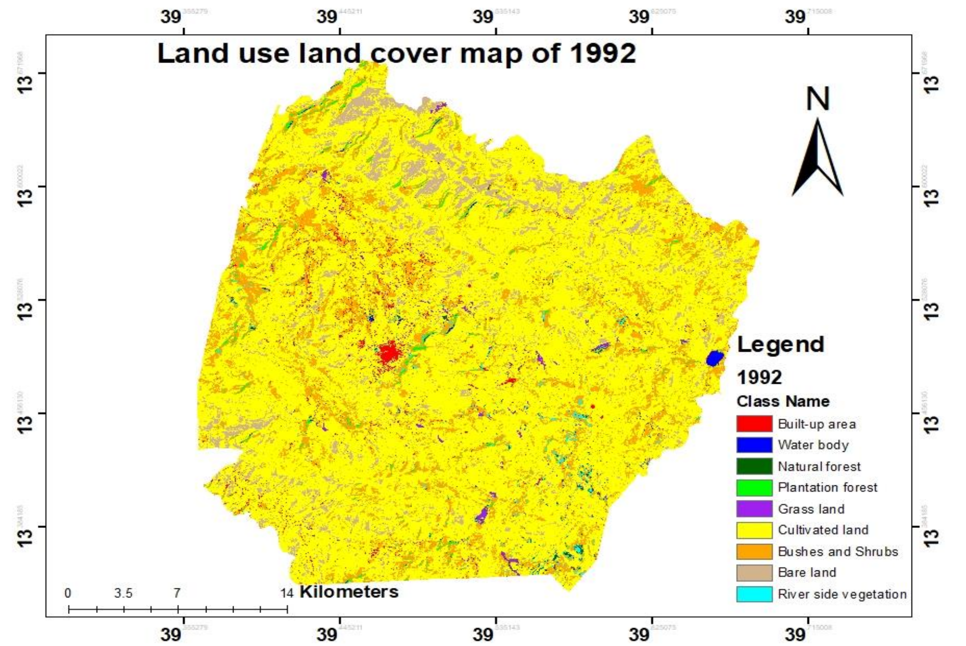
4.1 Ecosystem services in the Mekelle city region

To analyze changes in the supply of ES this study used expert consultation and landscape changes were analyzed through land use/land cover information obtained from remote sensing or spatial data sets. A group of experts scored the potential of specific land use/land covers to provide certain ecosystem services. This results to identify the potential of the landscape to supply ES. This study used land cover serves as a proxy indicator of the provision of ecosystem services, thereby enabling the analysis of trade-offs between land cover changes and the supply of ecosystem services. To study trends of supply of ecosystem this study undertaken LULC changes assessments. The historical LULC changes trend analysis was applied to understand the ecosystem services supply. Applying the trend analysis to different components of ecosystems and related services contributed to the understanding of the past and current developments as well as the possible future of ecosystems.

Figure 2: Land Use/Land cover changes (1972-2019)




Land use land cover map of 1984
N
Legend
1984
Class Name
Built-up area
Bushes and Shrubs
Grass land
Natural forest
Plantation forest
Water body
River side vegetation
Cultivated land
Bare land
0 3.5 7 14 Kilometers


Land use land cover map of 1992
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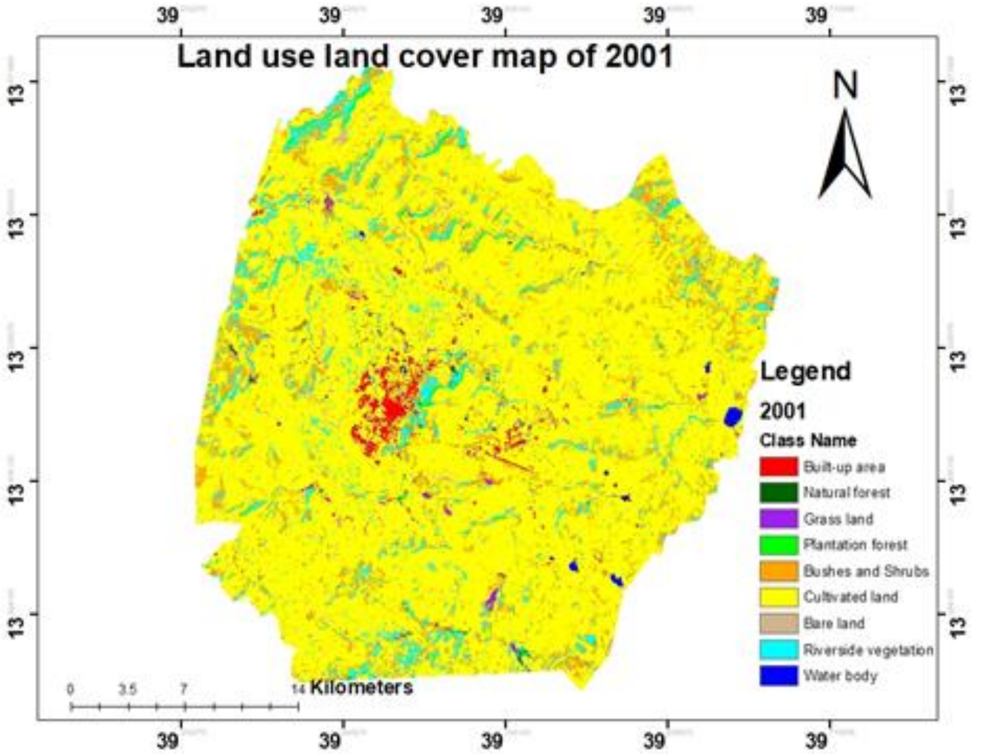
Legend
1992
Class Name
Built-up area
Water body
Natural forest
Plantation forest
Grass land
Cultivated land
Bushes and Shrubs
Bare land
River side vegetation
0 3.5 7 14 Kilometers


Land use land cover map of 2001
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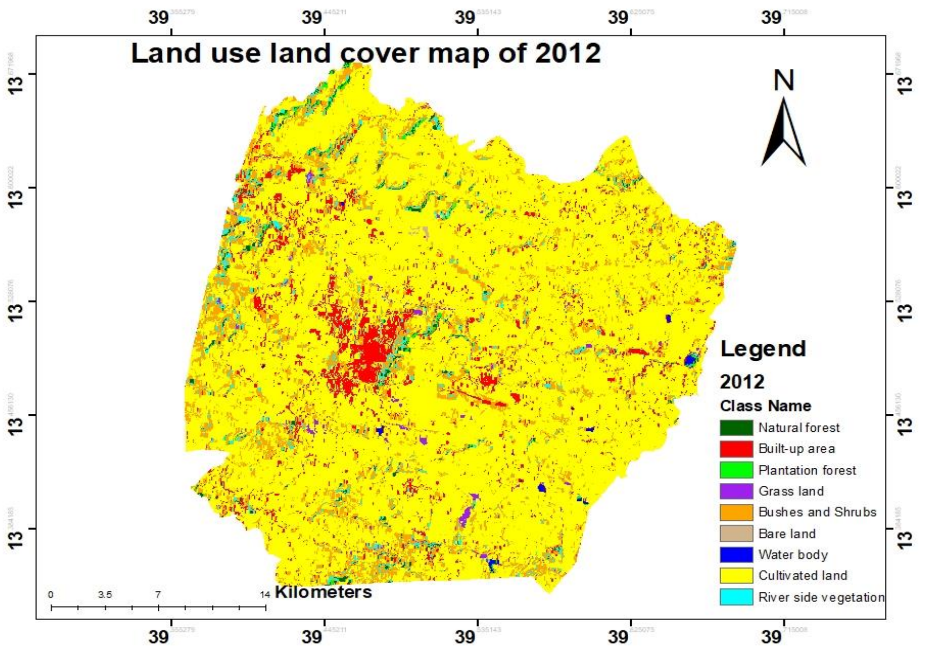
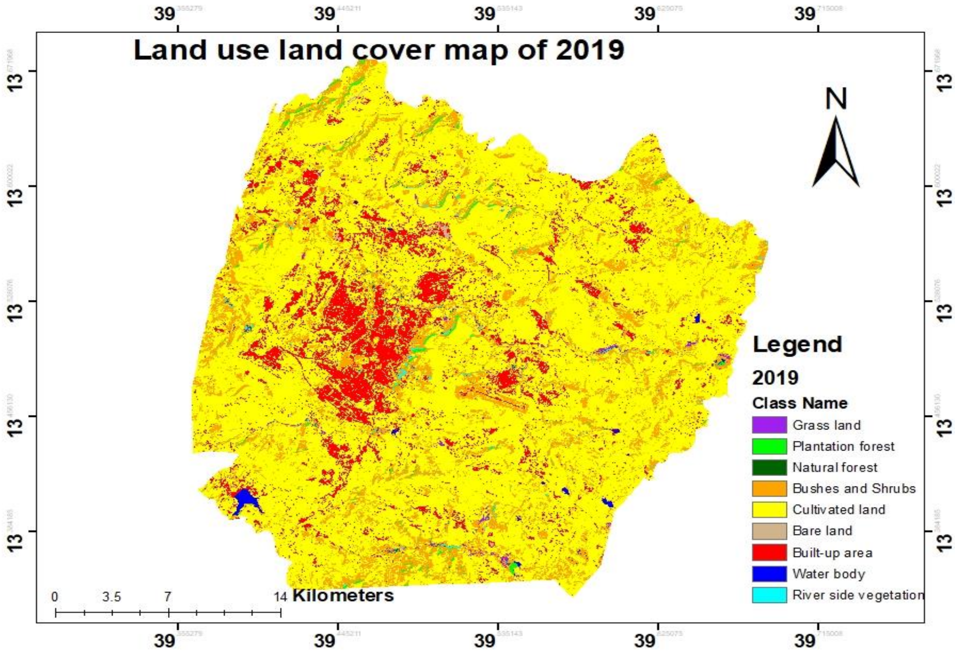
Legend
2001
Class Name
Built-up area
Natural forest
Grass land
Plantation forest
Bushes and Shrubs
Cultivated land
Bare land
Riverside vegetation
Water body
0 3.5 7 14 Kilometers


Land use land cover map of 2012
N
Legend
2012
Class Name
Natural forest
Built-up area
Plantation forest
Grass land
Bushes and Shrubs
Bare land
Water body
Cultivated land
River side vegetation
0 3.5 7 14 Kilometers



Source: (**Weldegebriel & Yeshitela, 2021**)

In the Mekelle city region, the urban areas have demand, while rural areas show supplying ecosystem services. For Mekelle city, the supply and demand of ecosystem services occur at different locations. The beneficiaries of ecosystem services are located outside of the actual ecosystem services provision spots. Accordingly, the demand for ecosystem services was quantified and mapped, and flows from supply to demand were estimated. The ecosystem services are produced in all directions of the surrounding hinterlands.

4.2 Expert FGD assessment of the supply of ecosystem services

A list of 17 ecosystem services existing in the study area was compiled by adapting (**Costanza et al., 1997**) and the MA 2005 classification of ecosystem services. From this, a matrix was developed to identify the potential of ES supply for each of the nine LULC classes. The expert consultation assessment was based on a matrix consisting of ES in columns and land use/land covers in rows. Six experts were contacted and asked to score the potential of each ecosystem to provide specific ecosystem services using a qualitative scale from 0 to 5, where 0 means no potential and 5 means have potential to provide ecosystem services. The score ranges considered for study was adapted from (**Montoya-Tangarife, De La Barrera, Salazar, & Inostroza, 2017**).

Table 1: Academic Background of FGD participants

S. N	Field of specialization	Educational level	Responsibility
1	LARMEP	MSc	Watershed Expert
2	Forestry	BA	Forest expert
3	SWEM	BA	Soil and watershed conservation
4	LARMEP	BA	Land resource expert
5	Ecology	BA	Ecosystem expert
6	Soil and water conservation/SWC/	BA	Integrated watershed management expert

Source: Field survey, 2011

Table 2: Potentials of Ecosystem services supply in the study area

Ecosystem services		LULC types ecosystem service								
		Built-up area	Natural forest	Plantation Forest	Water Body	Cultivated land	Grass land	Bushes and shrubs	Riverside vegetation	Bare land
Provisioning Services	Water supply	0	2	3	5	0	0	2.7	4.2	0
	Food production	0	2	2.9	2	5	4.5	5	3.2	0
	Raw material	0	4	2.4	0	0	0	4.2	4.1	0
	Genetic resources	0	3.5	2.4	0	0	0	4.1	4.1	0
Regulating Services	Water regulation	0	2.1	2.1	5	0	3	2	3.6	0
	Water treatment	0	2.9	3.9	5	0	2.8	1.6	3.6	0
	Erosion control	0	3.3	4.3	0	0	2.9	4.5	2.4	0
	Climatic regulation	0	1.7	3.9	0	0	0	4.3	4.8	0
	Biological control	0	0	0	0	4.4	2.3	0	0	0
	Gas regulation	0	2.3	4	0	0	2.7	3.68	3.68	0
	Disturbance regulation	0	1.7	3.6	0	0	0	5	5	0
Supporting services	Nutrient cycling	0	2	4	0	0	0	4.4	4.4	0
	Pollination	0	2.	4.	0	4	2.5	2.7	2.27	0
	Soil formation	0	2.4	4.4	0	0	1	2	1.0	0
	Habitat	0	1.9	4.9	0	0	0	1.3	1.7.	0
Cultural services	Recreation	0	3	4.8	5	0	0.8	4.8	4.8	0
	Cultural	0	5	5	0	0	0	3.4	3	0
	Average sum of potentials for provision of ecosystem services	0	2.61	3.72	4	4.46	2.5	3.48	3.4	0

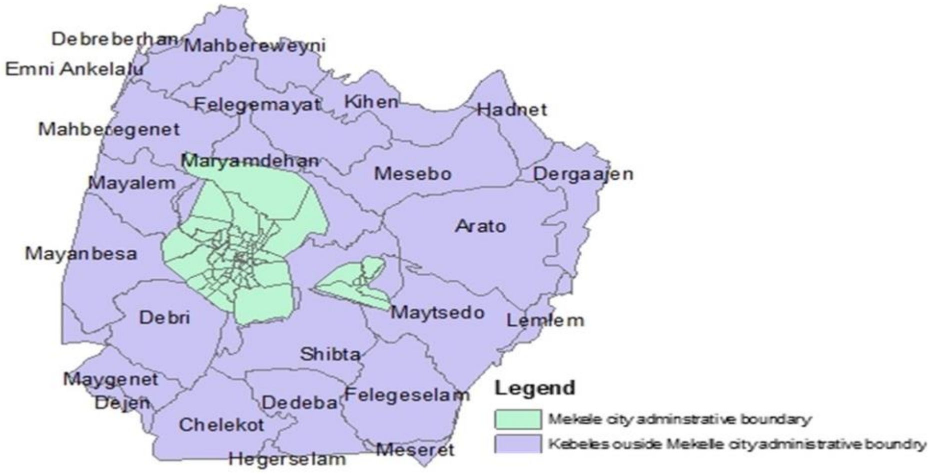
Source: Field survey, 2019.

Experts from different disciplines with experience in landscape management were contacted. The average for all responses was calculated to identify the potential supply of watersheds to provide ES. The standard deviation of the answers was calculated to determine variability among various responses of experts and the smaller the standard deviation, the more the experts agree.

The above Matrix assessment of the ecosystem services indicates the potential of the ecosystem for the provision of ecosystem services.

The experts scored over the four categories of the ecosystem along with their 17 types of ES. The result shows natural forests have 2.61 potentials to generate ecosystem services considering the existing coverage of the ecosystem, plantation forest 3.72, water body 4 with the hope of IWSM could result from more water ecosystem services, cultivated land 4.46, grassland 2.5, bushes and shrubs 3.48 and riverside vegetation 3.4. The highest scores were for cultivated land and associated services. The lowest scores were 2.5 for the grassland ecosystem. The results were compared to the scores given by experts with scores extracted from similar studies such as (**Montoya-Tangarife et al., 2017**). The exceptions this study employed is all for categories of ES which have differences in the potential provision of different ecosystem services. The results are difficult to compare with previous studies.

Figure 3: Map of Ecosystem services supply and demand area



Source: Author,2020

The above map shows the Mekelle city region (Mekelle city and neighboring kebeles). The maps reveal a clear pattern of supply areas for each ESs from the rural kebeles. Maps of ES demand showed more clear spatial patterns. The areas with the highest demand for ES are in Mekelle city and nearby peri-urban areas. The above maps show the complex relationship between ecosystem services supply sources and demand. Many goods and services are imported from remote places. Groundwater source has been the sole water supply source for the city of Mekelle water supply system. Among the available well field in and around Mekelle City, are namely Aynalem, Chinferes, and Ashegoda. The ecosystem services of the river basin and watersheds have been decreasing throughout the years. It is apparent that due to the over-exploitation, increasing demand, and the limitation of the groundwater source there is a need to look for additional water supply sources, including surface sources. The existing groundwater supply source could not meet the demand of Mekelle City. Further, there is a study and design to develop the surface water resource at Giba River. Moreover, the demand for clean water in the study area is increasing rapidly, and the population of the city region is expected to nearly double by 2060. The flows of ecosystem service in Mekelle urban center and its hinterland is illustrated in the figure below using a 3D landscape

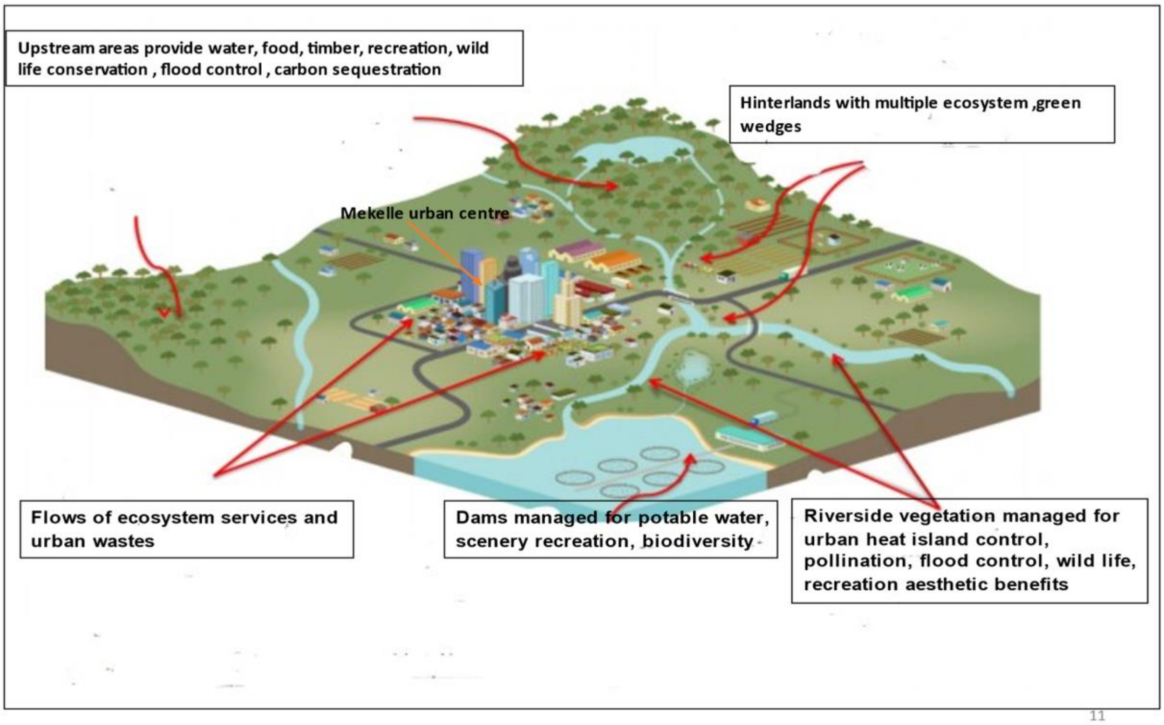


Figure 4: Flows of Ecosystem services between Mekelle city and its hinterland

Source: Author based on (**Forster, Santini, Edwards, Flanagan, & Taguchi, 2015**)

Table 3: Lists the major watersheds in the city region (In hectares)

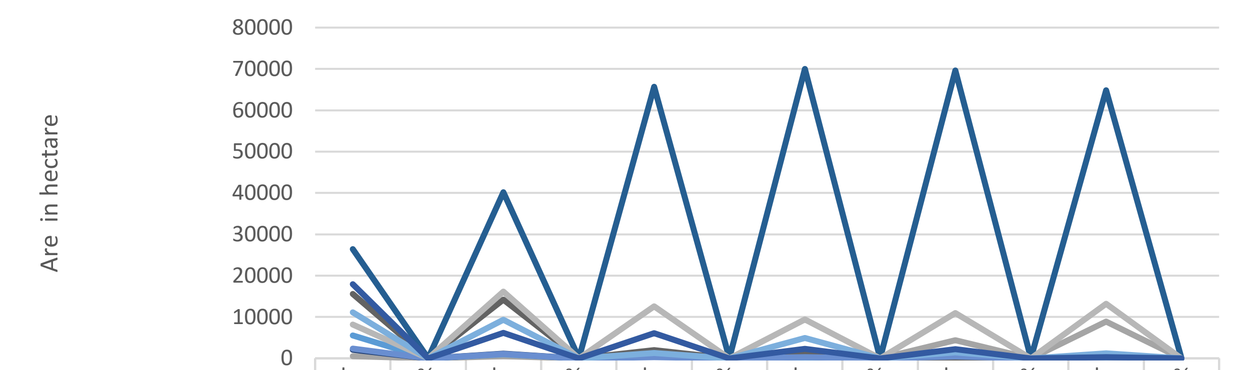
S. N	Name of water shade	Area(hectare)
1	Suluh	213.81
2	Genfel	1493.20
3	Agula	19878.14
4	Old bridge	933.41
5	Middle Geba	2088.85
6	Illala	31728.85
7	May gabat	33375.8
	Total	89,712

Source: Remote sensing data,2019

The data collected about watersheds were classified into distinct categories, according to the identification of patterns of land use/land cover changes. The major watersheds were divided into seven distinct categories. The above figure shows lists of major watersheds in the city region (In hectares). Currently, out of the 89,712 hectares of watershed areas in the study area, only about 15,383 hectares are covered with green vegetation namely natural forest (106 ha), plantation forest (497 ha), Bushes and Shrubs (13215 ha) grassland (330 ha) and riverside vegetation (1235 ha). The rest are cultivated land, built-up area, and water bodies. This has resulted in significant impacts in downstream areas for the continuum provision of ecosystem services. There are an estimated 423,174 downstream dwellers and 132,953 upstream residents who are the de facto managers of these watersheds.

The graph below shows the drastic decline in ecosystem services supply in the Mekelle city region in the last five decades. The results clearly show that LULC changes were significant during the period from 1972 to 2019. The study area experienced an enormous spatial change in LULC during the study period. During the period between 1972 and 2019, 60,714.83 ha (67.68%) of the total landscape of the study area was transformed from one LULC type to the other. Ecosystem services were strongly influenced by LULC changes. There is a significant expansion of the built-up area. On the other hand, there is a decrease in the agricultural area, water bodies, and forest areas. The ESs involves both supplies with the potential to benefit people and demand (desired amount of human consumption of that supply, which depends on people's desire for and access to ESs. In the city region, the benefits to the city residents arise from the interaction of supply and demand of watershed ecosystem services. Accounting for demand when measuring benefits, and beneficiary preferences can support sustainable development. The continuing rise in population accompanied by rapid urban expansion and other factors such as climate changes are resulting in LULC changes.

Figure 5: Trends of Supply side of ecosystem in Mekelle city region from 1972 to 2019



	1972 ha	1972 %	1984 ha	1984 %	1992 ha	1992 %	2001 ha	2001 %	2012 ha	2012 %	2019 ha	2019 %
Built-up area	497	0.55	536	0.6	541	0.61	1029	1.15	4420	4.94	8897	9.92
Natural forest	5543	6.18	1011	1.13	647	0.72	181	0.2	147	0.16	106	0.13
Plantation forest	2082	2.32	1118	1.25	529	0.59	398	0.44	292	0.33	497	0.55
Waterbody	15577	17.36	14209	15.83	2024	2.26	1207	1.35	130	0.14	263	0.29
Cultivated land	26403	29.43	40156	44.76	65700	73.23	70003	78	69610	77.59	64843	72.27
Grassland	2359	2.63	1049	1.17	310	0.35	297	0.33	445	0.5	330	0.37
Bushes and Shrubs	8183	9.12	16149	18	12559	13.99	9404	10.48	10982	12.24	13215	14.73
Riverside vegetation	11132	12.42	9359	10.42	1277	1.42	4907	5.47	1430	1.59	1235	1.38
Bare land	17936	19.99	6134	6.84	6125	6.83	2286	2.58	2256	2.51	326	0.36

Source: Remote sensing data, 2019

As a result of the linear relationship between ecosystem service supply and LULC changes, there was a direct relationship. Beyond that moment, only slight changes were detected, which suggests hope for environmental rehabilitation. Nevertheless, there was a marked reduction in the potential supply of water ES. The landscapes continue to be converted and used in unsustainable ways. Human activities and city region land development have caused intense interference to ecosystems. The changes in ecosystem service supply were determined more by land-use dynamics, such as the intensification of agricultural production.ES supply was affected by external drivers such as temperature or precipitation change and human society including management practices. The recent slight increase in the provision of ES is noteworthy, especially in the context of the ongoing, larger landscape transformations.

4.3 The demand for ecosystem service

The demand for ecosystem services is ecosystem services currently consumed in the Mekelle city region. The demand is changing over time and space. Ecosystem service users can also be driven in the future by increasing demand induced by rapid population growth. In the study area, the status of ecosystem services was also influenced not only by their provision but also by human needs and the desired level of provision for this service by the society. As the demand is increasing improved watersheds can provide sustainable ecosystem services. The total population of Mekelle city is 423,174 (TCSA, 2019).

4.4 Governance for sustaining ecosystem Services

The in-depth interviewing was conducted with individuals who are directors of various sectors to explore their perspectives on the political/policy drivers of land use/land cover charge related to legal frameworks. The environmental protection authority has the mandate to monitor sectors to incorporate ecosystem services in their plan. The interviewee from this sector replied that they are excluded from urban planning initiation. The sector has awareness problems about the concept of ecosystem services. Ecosystem services is a new concept to them but based on regulatory frameworks they implement environmental activities. Based on existing regulatory frameworks they tried partially to implement ES but it lacks incorporate all in all. The developmental activities in the city region are not in compliance with the environmental regulatory framework. The wetlands are encroached on by urbanization and residential houses. There is a lack of sectoral integration in watershed management. The existing governance frameworks did not support sustainable watershed management. They lack to implement from an ecosystem services perspective. The national and regional policy and institutional frameworks are helpful in the implementation of an environmental regulatory framework. However, due to comprehensiveness problems they face in implementing environmental regulatory frameworks.

The semi-structured interview with the urban development trade and industry vice head and green space director indicates that during urban planning they incorporate ecosystem services through a 30 % allotment of land of a city for green spaces. However, the plan lacks to adopt all ecosystem services and faced implementation problems related to planning violations. Environmental authority only focused on rural areas and the urban development sector focus only on land allocation for different urban developmental activities. All regulatory frameworks are supportive of urban development. But in urban planning, there is no clear accountability due to a lack of comprehensive regulatory frameworks. The developmental activities in the city region are not in compliance with the spatial Plan or land use planning due to the absence of regional planning and this aggravated conflict with rural jurisdictions. The interview made with two KII from Enderta district watershed coordinator and forest coordinator indicates that due to integration problems between the urban and rural administration the watersheds are encroached by built-up area, industries, grazing, lack of watershed ownership, rivers are polluted affected by urbanization. City development has led to the encroachment and ecological degradation of green spaces. Before 2003 there was deforestation but now due to awareness creation deforestation is decreasing.

Interviews with Enderta district officials on the environment and land use indicate that urbanization is at the expense of the ecosystem. When rural areas are engulfed in urban areas there is an absence of conservation. As a result, there is deforestation, lack of industrial treatment plants, location of industries in watersheds, and environmental degradation due to construction mining activities by crashers. This is the cumulative result of the absence of integration between urban and rural jurisdictions. There are no soil and water conservation practices within the urban area. There is solid waste dumping in watersheds in Mekelle city. Due to the absence of a land use policy, inappropriate allocation of residential housing on fertile lands exists. Regional planning is not in place for both urban and rural policy is needed. Regarding property rights in watersheds government and NGOs like sustainable land management are working to facilitate ownership and assigning property rights. To some extent, there is transferring ownership to residents after the watersheds are improved. Local by-laws are drafted. However, there are implementation problems.

Figure 6: Key informant interview

Source: Field survey, 2019

4.5 Watershed Ecosystem services demand and supply analyses and their applications for regional spatial planning

The various types of ecosystems in the city region bring benefits to people both within the Mekelle city borders and the surrounding areas. A growing urban population increases the demand for ecosystem services in Mekelle and the sprawling areas around the city. The urban-rural–fringe is growing in terms of the number of inhabitants, private and mass housing developments, industrialization such as foreign direct investment and domestic companies, and other economic activities which have transformed the rural landscapes. The Land-use patterns analyses show that the benefits from ecosystem services in the city surroundings are higher than those within Mekelle city's administrative boundary.

The sources of ecosystem services have a higher water supply and other ecosystem services than the core of the study area Mekelle city. The demand is more clustered in the city center because of the higher population numbers and economic activities. The spatial distribution of ecosystem service supply and demand showed a mismatch. Mekelle city government introduced the previous land use plan and the current structural plan was launched in 2016. Those plans worked but lacked a solid scientific basis for the management of watershed ecosystem services. Policymakers need measurements connecting land management to ESs supply and demand to design green spaces for multiple ESs. In this study, the influence of land-use change on supply and demand was demonstrated.

Understanding of the effects of planning decisions on both the supply and demand of ecosystem services is still lacking in the study area. To support planners in enhancing ecosystem services, there is a need to understand what actions are at stake and how changes in planning may affect ecosystem services. Urban planning affects ES by defining the spatial arrangement of land uses and functions, hence the distribution of population and physical assets that determine the demand for ES. Generally, a complete picture of the links between ES supply and demand and urban planning decisions is still lacking in the Mekelle city region.

Results show that watersheds may be potentially exposed to overcrowding. Resulting in a mismatch between demand and supply in both the city and rural areas. The assessment can support planners in addressing the sustainable use of ES. Hence, to improve ESs supply there is a need for regional spatial planning. Urban planning also affects ES by defining the spatial arrangement of land uses and functions, hence the distribution of population and physical assets that determine the demand for regulating ES.

Urban sustainability is in urgent need of a new understanding of how ecosystem services are generated in places where human and non-human stakeholders interact within the urban landscape. In the study area, the rate of urbanization is estimated to increase rapidly and this scale of urbanization strains both urban and rural ecosystems, which are required to provide nutrition, clean water, fresh air, recreational opportunities, wellbeing, and other life-supporting and life-enhancing opportunities to Mekelle city dwellers. Among such challenges as rapid urbanization and abrupt climatic changes, ecosystem services are needed to provide the material and non-material benefits required to keep the ever-growing population. However, the current understanding of ecosystem services in the city region is inadequate. Preserving ecosystem services is a crucial task in the city region. On the one hand, there is a particularly strong consumption of ecosystem services because much of the human population is concentrated in Mekelle city and its environs. This study thus provides a detailed methodology for the successful implementation of ecosystem management in a city region based on regional spatial planning for supply and demand.

In summary, this study revealed it is both possible and useful to quantify the supply and demand for ecosystem services in watershed management. This study provides some important lessons for ecosystem services continuum management. The findings show there is a growing disparity between supply and demand in the study area. The ecosystem services are coming from distant watersheds transferred by natural processes to the city residents. There is a mismatch between Supply and demand. The ecosystem services are generated generate outside Mekelle city. The findings also suggest that all four ESs have a major mismatch between supply and demand in spatial, particularly in the city center because of higher demand. Urban expansion from 2005s to 2019 was one of the important factors aggravating the mismatch between ESs supply and demand. The results also demonstrate that optimal land management might reduce ESs mismatches by considering their specific location.

Both the demand and the supply of the three ecosystem services under investigation changed substantially. This study also revealed that the ecosystem services demand is more than the supply. These findings revealed that ES provided by watersheds are widely not acknowledged, they are not considered a relevant aspect when interventions on land use are planned. There is an unsustainable flow of ES supply and unsatisfied demand by city residents. The study found ecosystem service demand plays a leading role in the supply-demand relationship.

These results show that the assessments of both supply-and-demand are important to understand their mismatch, and results can be used by managers to identify areas in which services are declining or priority areas for conservation based on maximizing ecosystem services and will be useful in detecting potential conflicts associated with new management and planning practices.

4.6 Mathematical relationship between Ecosystem services supply and demand

The correlation analysis between LULC and population in each period from 1972-2019 shows that population growth is positively correlated with the land-use dynamics and reduction of ecosystems. The interaction between population and land use shows that, with the population growth, the cultivated land increases to meet food consumption. The migration population needs residential areas and thus it is inevitable to take up the cultivated land, grassland or forest land, and other non-cultivated lands. The multivariate regression analysis is presented below

mvreg built nat plan water cult grass bushe riverside bare = pop

Equation	Obs	Parms	RMSE	"R-sq"	F	P
Built	5	2	659.6637	0.9754	118.7573	0.0017
Nat	5	2	2177.066	0.3550	1.65146	0.2890
Plan	5	2	660.8253	0.4115	2.097829	0.2433
Water	5	2	5947.717	0.5739	4.04065	0.1380

	5	2	17250.51	0.4315	2.27718	0.2284
Grass	5	2	759.4059	0.4321	2.282383	0.2280
Bushe	5	2	3553.948	0.0570	.1812532	0.6990
riverside	5	2	2563.882	0.7585	9.42181	0.0546
Bare	5	2	5833.541	0.4953	2.943723	0.1847

	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval
built pop	0.019272	0.001769	10.9	0.002	0.013644	0.0249
_cons	-2001.53	551.4589	-3.63	0.036	-3756.52	-246.545
nat pop	-0.0075	0.005836	-1.29	0.289	-0.02607	0.011074
_cons	3373.608	1819.962	1.85	0.161	-2418.32	9165.538
plan pop	-0.00257	0.001772	-1.45	0.243	-0.0082	0.003072
_cons	1553.412	552.4299	2.81	0.067	-204.666	3311.491
water pop	-0.03205	0.015945	-2.01	0.138	-0.0828	0.018693
_cons	14721.41	4972.111	2.96	0.06	-1102.07	30544.88
cult pop	0.069787	0.046246	1.51	0.228	-0.07739	0.216963
_cons	35817.16	14420.9	2.48	0.089	-10076.6	81710.91
grass pop	-0.00308	0.002036	-1.51	0.228	-0.00955	0.003403
_cons	1706.31	634.8403	2.69	0.075	-314.035	3726.655
bushe pop	0.004056	0.009528	0.43	0.699	-0.02626	0.034377
_cons	10517.95	2970.993	3.54	0.038	1062.923	19972.97
riverside pop	-0.0211	0.006873	-3.07	0.055	-0.04297	0.000776
_cons	11170.98	2143.328	5.21	0.014	4349.954	17992.01
bare pop	-0.02683	0.015639	-1.72	0.185	-0.0766	0.022938
_cons	12856.69	4876.664	2.64	0.078	-2663.03	28376.41

The mathematical analysis results revealed that demand and supply for ecosystem services changed substantially during the study period. The number of populations is continuously increasing. At the same time, the resource consumption per capita shows an increment. This has led to an increasing dependency on the city regions on ES. The city still depends on its hinterland for the provision of water, several ESs, and the most important and largest material fluxes into urban ecosystems. The demographic change was the most important indirect driver for changing ES in the study area. The correlational analysis between population density and ecosystem services supply in the last 47 years shows population number and population density were increased. This higher population density led to high demand for the ecosystem, leading to

LULC change. The land /land cover changes increased with population density change.

5. Discussion

Studies that assess the supply and demand of ecosystem services in a city region are scarce. The study addressed both supply and demand sides by spatially analyzing the ecosystem and undertaking a household survey. To achieve this goal, the supply side and sources of ecosystem services were mapped, and the demand was investigated. Experts were also involved to assess the potential provision of ES. They were diverse in terms of disciplines, experienced, and knowledge of the landscape. The standard deviation of the expert responses shows no large inconsistencies between the experts' responses. Studying both of these sides reveals that the status of an ecosystem service is influenced not only by an ecosystem's properties but also by human needs and actions. The provision of ecosystem services depended on changes over space and time due to human-induced factors and climate variability in the previous five decades.

The city region's ecosystem services provide services that contribute to the well-being of people living within a Mekelle city's borders and on the urban-rural fringe. The Peri-urban areas in the Mekelle city region stay under the influence of the Mekelle city. The ongoing land-use/land cover changes in peri-urban areas are significant and have major environmental impacts. The results show that both the demand and the supply of ecosystem services changed considerably during the study period. Due to the rapid population growth and huge investment in the city, the consumption of water is increasing. Despite this, the city's water supply at present is dependent on underground water sources. Moreover, due to persistent drought, the underground water is getting decreased from time to time. As a result, the city's water supply is at risk. Especially, during the dry season, the water supply office is forced to ration water on a shift basis. The proposed solution for the long run is to solve the water supply problem of Mekelle city by constructing an artificial lake from the Geba river in the watershed's hinterlands of the city. Implementation of this would excel the sustainable development and growth of Mekelle.

The water supply service could not meet the water demands of Mekelle city with existing capacity and there is low water coverage and frequent interruption which indicates that water shortage is a serious problem in the city. The average per capita consumption was found to be less than 20 L/person/day which is less than the recommended standard. In line with this, according to the survey results, the most frequent complaints by water customers are regular interruption of water supply and unfair water distribution. The findings of the data lead to the conclusion that there is a huge gap between the water supply and demand of the city. This finding is in line with the results by **Wolff et al, 2017** on the mismatch between supply and demand for ecosystem services.

The Mekelle city catchments have been widely altered through LULC change, including industrialization, urbanization, rapid population growth, and farming by small landholders. This has often benefitted local economic productivity but has also frequently led to unintended consequences, such as reduced water quality and ecosystem functioning, and reduced resilience against other pressures such as climate change. Many of the ecosystem services may be threatened because of the upstream catchment system in the study area, within which a given water body is located outside Mekelle city. If it is poorly or inappropriately managed can lead to severe problems for city residents. This finding is consistent with a study made by many studies that have shown that land use and land cover changes (e.g. rapid urbanization) can decrease various ESs(**Chen et al., 2019**),

The water quantity and quality from watersheds are deteriorating at an unprecedented scale for farmers and other land owners hosting watersheds have not received recognition and incentives to play a positive role in the land use management practices that ensure a sustainable flow of water(**Kagombe, Kungu, Mugendi, & Cheboiwo, 2018, p. 1**). Mekelle city one of the fastest-growing urban areas in Ethiopia has been experiencing serious water shortages partly to the reduced water inflows from the upper catchments of the city region that are major suppliers of its water supplies.

Adoption of the watershed as an urban planning unit allows environmental issues to be integrated with an appropriate territorial demarcation, helping to overcome a sectoral vision that continues to persist in the urban management of Mekelle city. To understand the watershed as complex adaptive system drainage and its connections as the network can be adopted. Here, it is necessary to understand it as a space composed of a set of physical, biological, social, and political elements which interact with each other across space and time, modifying the entire system.

Giba watershed is a major future source of drinking water for Mekelle city. The watershed is important both as the source of drinking water for the city and for maintaining greenery. It also provides provisioning services, in particular, food, and freshwater. The watershed provides other ecosystem services like supporting services (nutrient cycling, soil formation, and primary production), regulating services (climate regulation, flood regulation, diseases regulation, and water purification), and cultural services (aesthetic, spiritual, educational, recreational service). The city residents have faced a limited water supply in recent years due to rapid urbanization and population growth. And the people residing within the watershed have also felt a scarcity of environmental services particularly food production, and water.

The watersheds in the study areas can provide several ecosystem services. To improve the majority of the watersheds that provide the municipal water supply and other services for the City of Mekelle. At present there is awareness and to some extent supported by action in the community to rehabilitee degraded steep terrains using soil conservation measures and planting trees(**MWSDP, 2011**). Giba Reservoir is determined to be the water source of the project(**MCA, 2014**).

Effective spatial planning based on scientific analysis of urban development and their rural surroundings is crucial to attain and ensure a sustainable environment. The basic justification for this argument depends on; the rural areas in the study area are sources of numerous ecosystem services such as water, supply of food products, and other raw materials for the urban economy. The vast areas of ecosystem services provision beyond the city boundaries are affected by land-use planning.

Demographic change is thought to be the major driving force of land-use dynamics in developing countries(**Li et al., 2015**). The results are consistent with previous studies that highlight that the growing population and expansion of cities are leading to a growing demand for ES. A specific management strategy applied at a local level could impact distant ecosystems and this should be taken into account when developing integrated landscape planning. The New Urban Agenda that was adopted in Quito in 2016 identified the sustainable development of urban areas as the main goal of spatial planning. This goal requires, among other things, to adopt of ecosystem-based approaches to preserve and enhance the benefits of ecosystems, contributing to citizens' well-being and quality of life. Finding an appropriate balance of city region ecosystem service supply and demand are important steps toward sustainability. The demand and supply approach followed in this study delivers useful information for environmental management and regional spatial planning, aiming at sustainable use of ecosystem services by city residents.

6. Conclusions and recommendations

As a result of the unsustainable way in which natural resources are consumed, the gaps between the supply and demand of ecosystem services are gradually widening. The results show ES supply-demand mismatches, which have a strong impact on human well-being by causing unsatisfied demand, are influenced by natural and anthropogenic factors. Because of the complex and interactive nature of ecological and economic systems.

The LULC changes that occurred during the last 47-year period have a substantial impact on the ecosystem services. However, the results of ES suggest that regional spatial planning may contribute successfully to its conservation goal, being the core area and the buffer zone the ones with the highest values. The methodological approach developed in this study allows exploring the spatial interactions between biophysical and economic assessment of ES, which may be useful for decision-making and the design of appropriate strategies to reduce the mismatch between supply and demand for ecosystem services. This method is especially appropriate for its application in social-ecological systems, it allows quantifying the supply and demand, which are completely necessary to guarantee sustainable management of the ecosystem. Therefore, it is a useful tool for spatial planning and the design of specific conservation policies for the sustainable development of the area. Finally, it is suggested that the finding of the study can serve as a useful tool to design appropriate policies in regional spatial planning for federal, regional government, and city administration in Ethiopia and the rapidly developing world for improving watershed ecosystem services.

Declaration of interest

The author declares that he has no competing interests.

Ethics approval

Not applicable.

Consent to participate

The author needs to accept and confirm the manuscript has read and agreed to its content and is accountable for all aspects of the accuracy and integrity of the manuscript. The article is original, has not already been published in a journal, and is not currently under consideration by another journal.

Consent for publication

The author is a volunteer for the publication of original research findings entitled " Ecosystem Services Demand and Supply in a City region: Implications for Regional Spatial Planning in Mekelle City". The author grants the journal publisher a license to publish the article and identify itself as the original publisher.

Authors' contributions

The Author (Dr. shishay kiros) contributes significantly to the conceptualization and design, data gathering, and data analysis and interpretation.

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The following abbreviations are used in this manuscript:

ESs	Ecosystem services
FGD	Focus group discussion
IWSM	Integrated watershed management
LULC	Land use/land cover
DPSIR	Driver, Pressure, state, impact, and Response

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