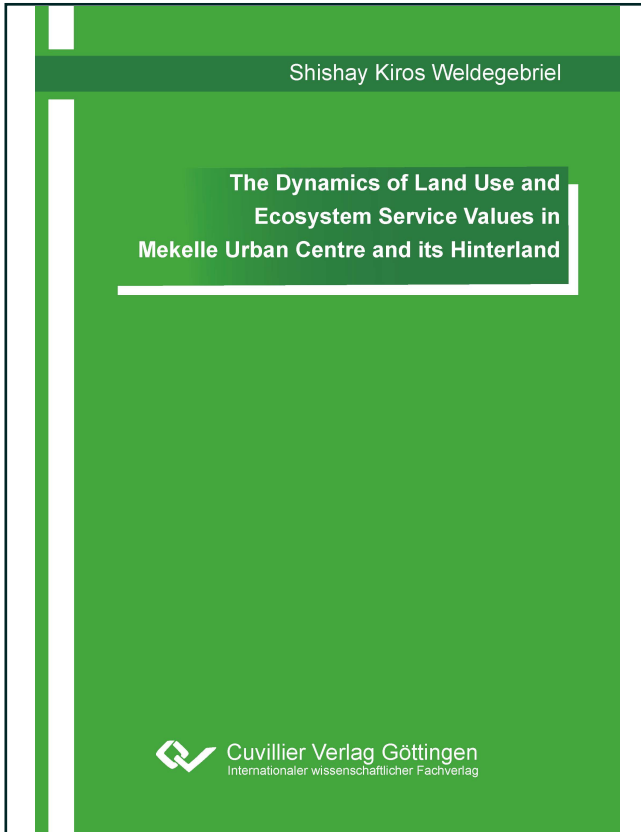Shishay Kiros Weldegebriel (Autor)

The Dynamics of Land Use and Ecosystem Service Values in Mekelle Urban Centre and its Hinterland

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Cuvillier Verlag Göttingen
Internationaler wissenschaftlicher Fachverlag

https://cuvillier.de/de/shop/publications/8497

Chapter 1: Introduction

1.1 Introduction

Ecosystem services are closely related to land use/land cover changes(Fu & Forsius, 2015). The number of researches that have been done on ecosystem services has increased in recent years(Logsdon & Chaubey, 2013). However, adequate methods to quantify ecosystem services and plan for their continued provisioning remain scarce(Andrew, Wulder, Nelson, & Coops, 2015). This situation demands additional more rigorous research method of measuring, modelling and mapping ecosystem services. Identifying the specific problems and providing solutions calls for exhaustive understanding through undertaken empirical study.

This study applied dynamic and connected approaches; undertake modelling at urban centre and hinterland by employing an interdisciplinary research approach which is a combination of Ecology, Economics, and Urban Planning. The combination of the approaches provided a consolidative methodological framework for studying the problem identified. Though there is literature on ecosystem service valuation, researches that investigate the land-use dynamics from orthodox and heterodox Economics perspectives on urban centre and hinterland based on empirical analyses is very limited. This study quantified the dynamics of land use and ecosystem service values in Mekelle urban centre and its hinterland from 1972 up to 2030 through empirical evidence that provides valuable facts explaining the presence of the problem.

This study demonstrates the historical contribution of scientists from different fields towards a social-ecological system approach. Social-ecological systems allow measuring the ecosystem services. This study seeks to enhance the current knowledge base for policymakers and urban planners on ecosystem services. In this study, the historical land use pattern and its driving forces, ecosystem service valuations, and scenario have been investigated. The chapter covered the background of the study, problem statement, the objective of the study, limitations and scope, the concept of Mekelle urban centre and its hinterland, overview of the study area. It also presented the implications of the study and contribution to knowledge.

1.2 Background of the study

The idea that ecosystems play an important role to support social needs traces back to ancient time starting from Plato's philosophical influence, who understood that the deforestation of Attica led to soil erosion and the drying of springs(Mascarenhas, 2017). The concept of ecosystem services has become an important model for linking ecosystems to mankind benefits. Ecosystem services research has become an important area of inquiry over the past decades(B. C. Fisher, Robert; Turner, R. Kerry; Morling Paul, 2007). The concept had been growing in the academic literature for several years and it is as old as human beings. The concept of ecosystem services first appeared in a 1977 study by Walter Westman. Afterwards, it was more systematically studied by Ehrlich and Mooney in 1983 (Robert Costanza & Steve Farber f, 2017).

The interest in the ecosystem services studies have increased since the publication of the Millennium Ecosystem Assessment in 2005 a monumental work involved 1300 scientists, and come with the report of the global decline of 15 of the 25 ecosystem services, which antedates negative impact on future human welfare. Since then, one of the demands from the MEA was to increase research on measuring, modelling, and mapping ecosystem services, resulting in a positive response to increasing the energies to identify, quantify, and ESVs (Millennium Ecosystem Assessment synthesis report, 2005).

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 fibre 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 the growing human needs ecosystems have been changed into different land-use types. However, the changes that have taken place in the last 50 years have been powerful as society is becoming increasingly urbanized, while ecosystems become worsened(Martínez, 2009).

Land-use change has a significant impact on the planet's ecosystems. Changes in ecosystems have huge impacts on ecosystem services supply(Stephen Polasky & Johnson, 2011). Land use alteration is a major driver of ecosystem degradation, biodiversity loss, and ecosystem service depletion. Land use/cover change and unsustainable land management impact biodiversity, ecosystem services and might even influence local climate if it happens at larger scales (Gebremicael, 2017).

Land use dynamics negatively affect the supply of ecosystem services that threaten human well-being(Quintas-Soriano, Castro, Castro, & García-Llorente, 2016).LULC dynamics change ecosystem services values (Kindu, Schneider, Teketay, & Knoke, 2016). Ecosystem service valuation is now widely recognized for its contribution to economic, environmental, social well-being and ultimately supporting in achieving sustainable development(Pandeya et al., 2016). Evaluating the influence of LULC changes on ESV is a vibrant tool to support decision-making (Sharma et al., 2019). The monetary assessment of ESVs provides an integrated, universal measure for evaluating and communicating land-use dynamics effects to prioritize investment in conservation (Gómez-Baggethun & Barton, 2013).

"No city can attain sustainability on its own"(Mukherjee, 2017, p. 10).

Cities do not function separately but within a domain of dependence on neighbouring areas and their ecosystems. Degradation of these ecosystems results in the ecosystem services loss that supports both urban and peri-urban populations. This indicates Conserving ecosystem services is a pivotal task in urban centre and their hinterlands. The urbanization pattern of large cities has important implications for environmental sustainability. This led to urban sprawl, or suburban sprawl, as such urban development will lead to land-use changes. Urban growth also impacts the environment in terms of altering the landscape, intercepting existing structure of hydrology, and reducing biodiversity (Mukherjee, 2017). The ecological principles of land use promote examining the impacts of local decisions in a regional context (Dale et al., 2000). Mekelle city is dependent on ecosystem services beyond the city boundaries.

Urbanization is a multifaceted spatiotemporal process taking place across lands even in areas far beyond urban cores; therefore, directly and indirectly affecting the functions, processes, and services of ecosystems. Urbanization is a difficult process to monitor, quantify and plan. Land located outside of urban cores is heavily affected by urbanization, yet they provide essential ecosystem services. Many cities depend on continuous flows of ecosystem services coming from adjacent non-urban ecosystems to sustain the urban functions(Barrera, 2019).

Human population growth together with competitive land use causes land scarceness. The anthropogenic aspect has a significant impact on LULC changes(Kanianska, 2016). Land use/land-cover changes on the planet reflect the interaction of anthropogonic activities and the natural environment. Each person in a population makes some demand on the environment for various ecosystem services. On a global scale, population growth has been positively associated with the expansion of agricultural and urban land, land intensification, and deforestation. The rapid increase in population over the past century has created the conversion of the earth's surface(Addae & Oppelt, 2019). The rapid increase of population and economic development of Ethiopia worsens the pressure on natural resources(Commission, 2008). Biophysical driving forces are moderately stable and have aggregate effects. Anthropogonic driving forces are comparatively active and are the main driving forces of LULC changes in the short term(Shao, Wei, & Xie, 2006).

Catchments have been extensively transformed through large-scale LULC change, including industrialization, urbanization, and intensive agriculture. This has benefitted economic growth but has also led to unintended consequences, such as reduced water quality and ecosystem functioning and reduced resilience against other pressures such as climate change. The ecosystem services might be endangered when the upstream catchment areas, within the water body, is located, is poorly and improperly managed (Stosch, Quilliam, Bunnefeld, & Oliver, 2017). The increasing population in both rural and urban areas generates pressure on natural resources by over-utilizing the endowment and change the ecology to different developmental activities(A. A. Getahun, 2017).

Watersheds provide numerous ecosystem services to downstream beneficiaries often with no cost to them. Non-optimal use of the ecosystem leads to watershed degradation. One method that could address this problem is payments for ecosystem services (Margaret Mejorada Calderon, 2012). PES can be established around specific ecosystem services in a specific watershed or for more general environmental conservation (Max Nielsen-Pincus, 2017). Wunder definition of PES has become commonly accepted, who defined PES as a voluntary transaction where a well-defined ecosystem service or a land-use is likely to secure that ecosystem service is being bought by a minimum one ES buyer from a minimum one ES provider if and only if the ES provider secures ES provision(Danyang Feng, 2018). This study was aimed at PES for general environmental conservation in watershed ecosystem service using WTP.

Catchments provide a variety of ecosystem goods and services. City people can reach catchment areas to relax, exercise and enjoy the fresh air. Such places are usually within easy travelling distance of the conurbations that they serve, and in some places, they are within walking distance(Grant, 2012). Increasing tree coverage in upstream areas helps to maintain water quality and quantity for urban areas located downstream. Watershed

ecosystems provide a wide range of ecosystem services to downstream city residents(UNDP, 2011).

The spatial extent of urban areas has grown almost four times stronger than their population(Tobias, 2013) and this influenced the demand for ES. Findings by (Ayele Almaw Fenta, Sewale Belay, & Mekonnen, 2017) indicate there is high consumption of ecosystem goods and services in Mekelle city. Henceforth, what is needed is careful planning of the complex urban centre and its hinterland systems. Urban policymakers and planners need to incorporate sustainable watershed management as part of urban development and land-use planning, to build resilience against ecosystem services-related hazards and the effects of climate change(UNDP, 2011).

Ethiopia's urbanization will happen, and this probable brings challenges. Without effective management, Ethiopia's urbanization will be reactive. Urbanization of this type, if unchecked, can result in an urban structure that is damaged in design with the result being inefficient, unsustainable, and unequal(GGGI, 2015). The environmental degradation related to LULC change costs Ethiopia about $ 4.3 billion per year(Ango, 2016). Measuring the changes in ecosystem service values is an important tool to increase awareness of different stakeholders (Liu et al., 2010), contribute to developing knowledge on the management of natural capital (Costanza et al., 1997; Frélichová et al., 2014), improve decision making in the allocation of scarce resources among contending demands (Guo et al., 2001; Barral and Oscar, 2012), formulate policies (Schägner et al., 2013) and provide an incentive to conserve the ecosystems that offer the most valuable services (Konarska et al., 2002; Bateman et al., 2013) as cited by (Kindu et al., 2016).

Mekelle city is rapidly expanding spatially; the surrounding peri-urban areas are overwhelmed to become part of the built area that has the potential to affect the value of ecosystem services. The peri-urban ecosystems are at risk of degradation and natural resources are losing. The ecosystem services are becoming progressively scarce. Currently, Mekelle urban centre and its hinterland is experiencing rapid population growth, urban sprawling, and rapid expansion of industries. Most of the water consumed by the Mekelle city comes from the hinterlands which are outside the city administrative boundary. The current land use dynamics manifesting in the urban centre and its hinterland are detrimental to the environmental quality at a time when the city is already facing an environmental crisis occasioned by the loss of several ecosystems.

The internal urban watersheds like Endarufael, Mayduba, and Illalla are highly degraded due to urbanization and human settlement(MU, 2015). The rapid conversion of land-use/cover types is having a significant negative impact on ecosystem services they can provide various services. Specifically, the conversion from one land use/cover to another is largely contributing to the loss o f water ecosystem services. Urban expansion has a particularly strong impact on provisioning services of food production in Mekelle city in the last 25. Expansion of the town, resulting from rapid urban population growth, is also likely to put growing pressure on the peri-urban ecosystem(Ashebir, Pasquini, & Bihon, 2007). The ESVs is a promising method to tackle the decline of ecosystems(Shuang Liu, 2010).

The ecosystem service approach (ESA) is advocated for use in both environmental management and academic issues. However, despite the extensive conceptual

development, there are still few exemplary attempts for effective use of the ESA in ecosystem management(Beaumont, Mongruel, & Hooper, 2017). This study adopted a transdisciplinary perspective to address ecosystem services degradation. Analysing, modelling, quantifying, and ecosystem services management requires a transdisciplinary approach(Robert Costanza & Steve Farber f, 2017).

Several studies demonstrate the need of applying a social-ecological system approach in ecosystem services study. However, there is still a lack of empirical evidences that applies the concept of social-ecological system in ecosystem services valuation. The empirical results about the scientific basis for integrating ecosystem services into land-use decisions are still lacking. Some key variables regarding the problem have been overlooked. Several efforts have been made to improve the measurement of ecosystem services and to understand ecosystems' contribution to human well-being. From the reviewed works of literature, there are still deficiencies and methodological inconsistencies. Alternative approaches to better understand the problem is useful. Economic incentives for conservation, including the PES scheme in developing ecosystem services market can encourage conservation to apply a new management approach to protect and improve ecosystem service provision. Therefore, studying the dynamics of land use and ecosystem service values through a social-ecological systems outlook under different spatial and temporal scales can support decision-making to understand the past, current, and future changes in land use and ESVs.

1.3 Problem Statement

The need to deliver ecosystem services coupled with poor land management has meaningfully contributed to ecosystem degradation in Ethiopia (Gebremicael, 2017). The ecosystem services consumed in Mekelle city are provided from the adjacent hinterlands. The current market does not capture the ecosystem service values. Besides, the relationships between land-use dynamics and ecosystem services value remain unknown. Spatially clear values of ecosystem service values across landscapes inform land-use decisions (Tammi, Mustajärvi, & Rasinmäki, 2017) and these are lacking and the ecosystem services are poorly understood and scarcely monitored in the study area. Failure to know the complication of interactions across ecosystem service provision can endanger sustainable ecosystem services provision(Nassl & Löffler, 2015). The study area has a semi-arid climate and it is environmentally vulnerable.

Degradation of ecosystems results in the loss of ecosystem services that support both the urban and peri-urban populations. Accelerated urban expansion not only influences socioeconomic change, but also influences the ecosystem, and threatens sustainable urban development(Rimal, 2018). Integrated watershed management is practiced in the upper catchment of Mekelle urban centre and its hinterland that benefits Mekelle city residents. The local farmers have played a leading role in watershed improvement, but the Mekelle city residents who are beneficiaries, have also to play their role in conservation, are often discounted.

Upstream watersheds can affect the household's demand for ecosystem services if sustainable funding is not raised(Abebe, Dagnew, Zeleke, Eshetu, & Cirella, 2019). The upstream local communities' participation in watershed improvements is not adequate to

sustain the provision of ecosystem services to city residents. Sustainable watershed management planning in the study area can be hampered due to financial capacities limited to undertake watershed conservation. Hence alternative sources of conservation funds are vital. It is also important to realize the major factors that affect households' willingness to participate and to identify effective policy instruments.

The current situation indicates there is a lack of information, understanding, and planning about LULC changes and their driving forces which affect essential and beneficial ecosystem services provision and societal wellbeing. Studies about LULC at a small scale in Mekelle city only exist(Fenta et al., 2017; Tahir, Imam, & Hussain, 2013). Some studies were done in other parts of Ethiopia (Tolessa, Senbeta, & Kidane, 2017) studied the impact of LULC change on ecosystem services in Ethiopia's central highlands. Different international works of literature show there is a methodological gap in ecosystem services and from the reviewed literature there are still deficiencies and knowledge gaps. To sustain the ecosystem services provision with other technological options, a detailed understanding of the status of LULC changes in the urban centre and its hinterland is crucial.

The last few decades have observed changes in policies related to land use in Ethiopia(Teka, Van Rompaey, & Poesen, 2013). Nevertheless, a detailed study on the effects of these changes on ecosystem services value from the urban centre and its hinterlands remains scanty. Mekelle city has been not studied as a complete network with consideration of all ecosystem services, in consideration of nearby watersheds by previous investigators. The LULC dynamics and ecosystem service values in the urban centre and its hinterland are not well understood. No study has been undertaken in a city and with its hinterland level. In the study area, quantitative and empirical information about land use dynamics and ecosystem service values is absent. Furthermore, beyond analysing LULC dynamics only, a thorough understanding of the consequences of these changes on ecosystem service values through quantitative knowledge is limited.

In theory application of ecosystem service valuation is advocated in developing countries. But in practice; there is a lack of empirical research on ESV in Ethiopian cities and the absence of legislative standards for ESV. To fill the gap, this study was intended to examine the problem through analysis of land use dynamics and its drivers, ecosystem services valuation and modelling under a set of scenarios to improve decision-makers understanding of the sustainable provision of ecosystem services. Therefore, this research is novel and proposed to fill the mentioning gaps.

1.4 Objective of the study

1.4.1 General objective

The objective of this study was to assess and model the temporal and spatial land-use dynamics and ecosystem service values in Mekelle urban centre and its hinterland, Tigrai (Ethiopia).

1.4.2 specific objectives

1.To assess land use/land cover dynamics over a period of 47 years
2.To analyze the driving forces of land use/land cover dynamics.
3.To quantify the spatial and temporal variations of ecosystem service values
4.To estimate the willingness to pay of Mekelle city residents for watershed ecosystem services improvements
5. To model the potential future LULC change and their effects on ecosystem service values

1.5 Research questions

The above objectives were answered from the following research study questions

1. What is the pattern of land use/land cover dynamics in the past 47 years?
2. Why are land use and land cover changing in Mekelle urban centre and its hinterland?
3. Are the values of ecosystem services affected by land-use patterns?
4. How much economic value do the Mekelle city residents willing to pay for watershed ecosystem services improvement in Mekelle urban centre and its hinterland watersheds?
  4.1 What are the determinant factors that affect households' willingness to pay for watersheds ecosystem services?
5. How the future changes of LULC expected to affect ecosystem service value?

1.6 Implications of the study and contribution to knowledge

Researching the dynamics of land use and ecosystem service values is important in Ethiopia. This research studied ecosystem services valuation from the urban centre and its hinterland perspective. This research contributes knowledge towards understanding ecosystem services valuation, practical gaps, and their implications, strategies to sustain ecosystem services provision in Mekelle urban centre and its hinterland in particular and in the cities of rapidly urbanizing cities in general. Furthermore, this study contributed to the building of scientific knowledge on ecosystem service valuation. The findings and recommendations can also contribute to increased academic discourse.

The study findings revealed that appropriate policy for sustaining ecosystem services provide useful bases for balancing ecosystem services supply and demand, which can have a key role in policy-making decisions. Specifically, the findings provide immense information to assist in adopting regional strategic spatial planning. Information on the current status of ecosystem services values has great importance in preparing plans. Understanding the dynamics of land use is a requirement for planning. Spatial planning could benefit from implementing innovative tools being developed by this research to improve the valuation of ecosystem services. Spatial planning has a strong impact on ecosystem services, particularly, because it is the policy domain to direct development (Tobias, 2013). Despite this fact, the current planning in Mekelle urban centre and its hinterland is not geared to conserve ecosystem services. Mekelle city administration can adopt appropriate strategies and procedures for sustainable urban development to put land into its well-planned use and to be utilized in an environmentally responsible manner.

Furthermore, estimating the WTP for improved watershed is very important. It will help produce empirical evidence that could inform decisions about ecosystem services provided by the watersheds that supply to the city. Creating shared ecosystem conservation benefits and externalities with stakeholders outside of a watershed like city residents of Mekelle is very important. Watersheds provide abundant ecosystem services to downstream communities of Mekelle city often with no cost to them. Although the ecosystem services are valuable to the city residents, they do not have monetary values, which results in watershed degradation. One method that could address this problem is PES schemes.

The findings of the study could provide important information to guide the future for enhanced management and conservation of watersheds in urban centre and its hinterland. In addition to this, the findings could be useful for the development of PES schemes as guiding policy at the federal level and elsewhere in Ethiopian cities. PES initiatives, however, are not without debate. Some scholars suggest that the development of a land ethic should be based on moral, rather than financial, responsibility for stewardship. Another debate also recommends ecosystem services beneficiaries, have an ethical responsibility to contribute to the stewardship of the environment. Despite, these debates, this study can bring pragmatic solutions to the academic discourse.

To summarize, this study made in-depth study of an environmental issues. Theoretical, this academic investigation extended the applicability and predictive power of socio-ecological system theory and complex adaptive system theory to ecosystem services valuation. In additions to this, it contributed to the current theoretical understanding of the studied phenomena to comprehend environmental degradation using a multi-lens approach to sustain the environment. These findings come up with improved city region concept to refer the relationships between urban centre and hinterland. Empirically, this study answered the global call to study ecosystem services due to increasing scarcity which would have negative impact on the current and future human welfare. Methodologically, diverse sources of data and modelling significantly increases result comparability and consistency. This helped to methodological advancement to study the research problem through improved research tool and improved environmental degradation halting model through adopting combination of Economics, Urban Planning and Ecology disciplines. Practically, the findings have policy real-world implications for crafting regional strategic spatial planning, design optimum land use planning, Payment for ecosystem services policies. Finally, it has an implication for positive social change in order to improve the well being of society.

Figure 1.1: Proposed halting Environment degradation model
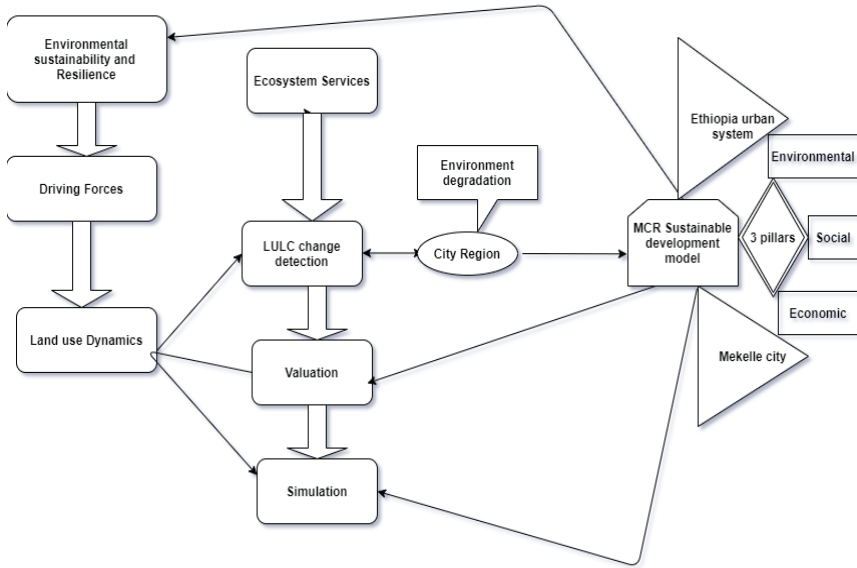
Source: Author,2021

Hence, to ensure environmental sustainability and resilience understanding the dynamics of land use and its drivers through LULC detection is crucial. Research investigation methods of valuation of ecosystem services along with simulation of LULC changes in urban centre and its hinterland environmental degradation can be halted by employing the model developed by this author using the MCR sustainable development model to achieve the three pillars of sustainability and would have significant contribution to Ethiopia urban system in general and with particular to Mekelle city. This proposed model can be applicable in rapidly urbanized cities of the world with a similar societal and institutional setting.

1.7 Limitation and scope of the study

1.7.1 Limitations

To conduct the research study different problems were confronted. Uncertainties and inconsistencies from collection devices (sensors), inconsistencies in LULC class definitions, and uneven distribution of reference data are some of the limitations that might affect the result of this study. To minimize these limitations great efforts were made to validate the

results derived from remotely sensed data by searching different data from different sources through undertaking field survey, observation, interviewing residents, comparing the results with different local and national LULU maps and municipal records by searching relevant documents and interviewing major officials and employees. The study applied and used different data collection methods. These methods proved helpful as a source of triangulation of different information. The study acknowledges the limitations in producing spatio-tempo ESV. This study estimated ESVs by multiplying the area for each land use type by the corresponding value coefficients. The estimations using this method could have high variation and uncertainty. To minimize this uncertainty expert knowledge of the estimated ESVs was made.

1.7.2   Scope of the Study

Spatially, Mekelle city and its surrounding hinterlands significant watersheds in terms of ecosystem services for Mekelle city dwellers are selected. Mekelle's surrounding areas including rural and its satellite towns were taken for the study. Thematically, it was limited to studying the dynamics of land use and ecosystem service values of seventeen significant ecosystem services for the study area. Furthermore, the study investigated the demand side of ecosystem service using the contingent valuation method. This research aimed at examining the effects of land-use/cover dynamics on ecosystem services value in a spatially explicit way and cross-sectional data was employed to estimate WTP. Temporally, the study took years between 1972-2030 to establish the trends of land use /land cover changes and scenario generation. Methodologically, the study was delimited to sequential explanatory mixed-method design.

1.8 Selection of Mekelle urban centre and its hinterland

Mekelle city and hinterlands which are significant in terms of watershed ecosystem services for the city are selected for scientific investigation. To determine and delineate the study the concept of urban centre and its hinterland was adopted. The rate of urbanization is predicted to increase rapidly in the coming few decades and this scale of urbanization could strain both urban and rural ecosystems, which are required to provide ESs and other life-supporting to city dwellers. On the one hand, there is high consumption of ecosystem goods and services because much of the population is concentrated in Mekelle city. Mekelle city and the peripheral areas have formed an increasingly interwoven and interactive functional region. The most important quality of a functional region is its ability it exceeds the administrative region(Antikainen, 2005). The city Meremeyti, Dandera, Aragure 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.

The study was conducted within the catchment of Geba river tributary of the Tekeze, draining an area of 5,133 km^2 in northern Ethiopia, Tigrai region. Seven nested sub-catchments of the Geba river basin which are within and near the city and significant in terms of ecosystem services for Mekelle city were selected for investigation namely: Ilala, May-Gebat, Agula, middle Geba, old bride, Suluh, and Genfel. The various types of ecosystems in the urban centre and its hinterland benefits to people both within the Mekelle city borders and