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An Assessment of Risks and Opportunities Related to Ecosystem Services, in the Case of Mekelle City

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Abstract

Information on current status of ecosystem services has vital importance in preparing local, regional and national economic plans. Results from assessment report of the condition of ecosystem services help decision makers to focus on the services that are more likely to be sources of risks and opportunities for specific decisions. The main objective of this study is to assess the risks and opportunities that are related with ecosystem services within Mekelle city. Data for the study has been utilized from secondary sources. Findings of the study show that, there are different ecosystem services that provide a variety of goods and services in Mekelle city. Food and fresh water supply, genetic resources, air quality, climate and water regulation, water purification and waste treatment, recreation and eco-tourism, nutrient cycling and water cycling are screened to be relevant ecosystem services in the city. To assess the condition and trends of the relevant ecosystem services in the city, a detailed analysis of the condition of relevant ecosystem services is done. For this purpose, indicators are selected and used to evaluate the condition and trends of the relevant ecosystem services and the drivers.

Keywords: Energy; Ecosystem; Service; Valuation

Introduction

Mekelle is one of the ancient cities of Ethiopia in which its historical development is based on oral tradition. According to the oral tradition, the formation of the city goes far back as to the medieval periods [1]. It was founded by emperor Yohannes IV in 1860's.

According to Kibrom [2], Mekelle is located between 13°32' north of latitude and 39°33' east of longitude with an elevation 2000 to 2200 meter above sea level. It is located in the northern highlands of Ethiopia covering an area of 130 square kilometer. The major land forms of the city is classified in to four categories; namely flat go gently sloping, gently sloping to rolling, sloping to moderately steep and steeply to very steeply sloping type. The fuel wood consumption of Mekelle inhabitants has a great pressure in the environmental degradation of the outskirts such as Hintalo-Wajirat and Saharti-Samre woredas causing high deforestation. The rivers that makes Mekelle look like Oasis includes May Degene, Mai Zagra, May Anshti, May Atsgeba, May Fakar, May Bakel, May Ayini, May Gafuf, May Liham, May Kikuto, Gerebubu, and May Ataro.

Mekelle enjoys a mild climate that can be described as Woina Dega. During the dry season, the days are pleasantly warm and the nights are cool; in the rainy season, both days and nights are cool. There are two rainy seasons, namely 'Kiremit and Belg'. It is estimated that the average rainfall ranges from 579 to 650 mm. The rainfall in the Belg rain season is too low for growth of plants as a whole. The main rainy season is Kiremit where by sufficient rain and moisture is available for plant growth [2].

Mekelle as part of the globe is suffering much from global warming aggravated by the neighboring area deforestation and desertification. So, in the absence of cooling agent that is forest in the city and neighboring areas, the temperature variation is high even from hour to hour. The average maximum temperature per year is 24.1°C and the minimum is 11.11°C. As a result of the neighboring area deforestation and very little tree plantation coverage in the city, there is no any wind barrier that breaks the wind speed and force. The average wind speed of Mekelle per year is 3 m/s. Then the high wind speed and force blown over the bare areas blew up the dust and fine soil very easily [1].

Mekelle city has preserved natural and manmade green areas in various parts of the city. Land escape especially on street green belt urban parks, in public and private garden, in natural and semi-natural green zone. In spite of the urban population growth and associated growing demand for greenery in the past years, only few green structures have been made, i.e., about 772 hectare. The forestry sector has a management problem; few plantations have been made in road side. Only 11 public parks were developed for public greenery and recreation on access [3].

According to Mekelle city plan preparation project office [4], the total population of Mekelle city is 334,816 having an annual growth rate of 5.4%. It is projected to increase to 844,043 in 2030. Residential houses, socio-economic and physical infrastructural development is also increasing with population growth. Moreover, Mekelle is the regional center of politics, administration, trade and industry and destination to different areas [1].

There is high rate of unemployment in the Mekelle city. According to the survey conducted by the central statistical authority [3], the rate of unemployment in the city is 21.6%. Despite continuous efforts of the municipality to alleviate the housing crisis, still there is shortage of housing supply. The total length of asphalt road currently within the city is about 40 kilometer. This represents only 31.5% of the total 128 km required. The water supply of the city is totally dependent on underground water sources. But, 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

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water supply office is forced to ration water on a shift basis. The current water coverage of the city is estimated to be 67% [3].

Mekelle city had prepared a ten year development plan ranging from 2006-2015. In order to prepare this development plan, the spatial growth and population growth trend are identified in the previous years (1984-2005). The general land use (height, density and use zoning), infrastructure and circulation (road networks, utilities, and terminals), open spaces and environmental aspects and housing provision are plans that are taken as a mandatory provision in the development plan of the city. The spatial development framework of the city has 8 elements such as mixed use, residential areas (cooperatives, real estates, low cost housing, rentable), centers (administrative, commercial, cultural), green areas and open spaces (sports fields, parks, forests, urban agriculture), social services (education, health, livestock market, worship places and ceremonies, slaughter houses, waste disposal facilities), manufacturing and storage (cottage and handicraft, warehouses, garages and workshops, medium and large scale industries), road transport and utility road network (road junctions, mobility and accessibility, street spacing standards) and transport.

Out of 13,000 hectares of the city's land in the plan, land use is allocated to permitted uses in mixed use area for residential (50-60%), administration and commercial (5-10%), social service (5-10%), permitted manufacturing and storages (5-10%), recreation and green area (5-10%) and road (15-25%).

This development plan has negative as well as positive impact on the urban ecosystem of the city. The main objective of this assignment is to assess the risks and opportunities of ecosystem services in Mekelle city. A detailed analysis on each step has been made and is presented below. The analysis is based on the city's development plan decision impacts on the ecosystem service of the city.

Identification of the Ecosystem Services in Play

In Mekelle city, there are different ecosystem services that provide a variety of goods and services. The following ecosystem services are identified according to whether or not a decision depends on or has an impact on the ecosystem service.

Provisioning: Under the provisioning ecosystem service type the following ecosystem services are identified.

Food supply: Includes crops, vegetables and livestock production. The decision made to increase crop, vegetables and livestock production using fertilizers and pesticides, improved off springs, and converting wetlands and open spaces to agriculture. This has to a negative impact on the ecosystem: such as, eutrophication, water pollution and loss of genetic biodiversity.

Fresh water supply: Includes fresh water for domestic use such as for drinking, cleaning, industrial use and watering. The decision to increase the supply of fresh water is extracting underground water using machineries. This has a negative impact on availability of water as it depletes underground water.

Biomass fuel: Includes fuel wood that is collected from the nearby forests. The decision in respect to biomass fuel is to expand provision of alternative energy sources including hydroelectric power and wind energy (Ashegoda wind farm) and expanding use of improved stoves. This development plan protects the forest ecosystem which is otherwise used for biomass fuel.

Genetic resources: Includes the indigenous varieties of crops, livestock and forest species. The decision with regard to genetic resources in the city is producing genetically modified crop and livestock species. This negatively affects the ecosystem through loss of stock of indigenous genetic crops and livestock.

Natural medicines: Includes forests and crops that serve as local traditional medicine. The decision associated with natural medicine services is preserving some ecologically important forests in the upper catchment of the city. This improves the potential of forest ecosystem for providing natural medicine.

Regulating: This constitutes the following ecosystem services.

Air quality regulating service: includes forests and street trees that remove pollutants and particulate matter from the atmosphere. A decision concerned with air quality regulating service is expansion of industries which affect the air quality negatively; whereas a decision to increase forest coverage of the city through reforestation and afforestation programs enhances air quality regulating service by removing pollutants and filtering particulate matter.

Climate regulation: Includes forests, parks and green areas that capture carbon dioxide. The decision with regard to climate regulation is expansion of cattle production, which affects the climate by realizing methane, whereas afforestation and reforestation decision improves the climate through enhancing capacity of forests and parks to capture carbon.

Water regulation: Includes reducing natural flood hazard through retaining water by wetlands and river floodplains. The decision associated with water regulation of Mekelle city is converting wetlands to agriculture for use by small and micro enterprises which affect water regulation service of wetlands and river floodplains.

Erosion regulation: Includes reduction of siltation of water bodies and risk of landslide by vegetative and forests. The decision concerned with erosion regulation service is reforestation and afforestation which enhances the bare land coverage by forests to reduce siltation and landslides.

Water purification and waste treatment: Includes removal of harmful pollutants from water by trapping metals and organic materials by wetlands. The decision with regard to the ecosystem service under discussion is establishing substituting service by wetlands using water treatment plant and use of wetlands for agriculture which negatively affects the water purification and treatment capacity of wetlands.

Pest regulation: Includes control of crop pests by predators in forest such as bats and snakes. The decision with regard to pest regulation in the city is using pesticides to increase crop production which affects water quality due to pesticide runoff to water bodies.

Pollution: Includes pollinating crops and forests by insects like bees. The decision in this respect in the city is bee keeping which provides pollination services to crops and forests.

Cultural services: This ecosystem services is limited to recreation and ecotourism service. The decisions associated with this ecosystem services are expansion of social and physical infrastructures (especially roads and housing projects) which affects recreation and ecotourism services by reducing the amount of forests and parks. Whereas, reforestation and afforestation decisions enhance recreation and ecotourism services by expanding forest and green area coverage.

Supportive services: Under supportive ecosystem service type, the following ecosystem services are identified.

Nutrient cycling: Includes cycling of nutrients like carbon and nitrogen by forests to maintain the natural balance. The decision with regard to nutrient cycling is reforestation and afforestation which enhance nutrient cycling and use of fertilizer to substitute the lost nutrients also enhance nutrient cycling.

Primary production: Includes formation of materials through assimilation or accumulation of energy and nutrient by organism. The decision associated with primary production is using urea fertilizer which affects the water quality by leaching.

Water cycling: Includes facilitating water cycle by forests through retaining water and evapo-transpiration. The decision with regard to water cycling is expansion of social and physical infrastructure at the expense of forests that reduce water cycling service, whereas reforestation and afforestation decisions increase forest coverage that enhance water cycling service.

Drivers of ecosystem service change in Mekelle city can be categorized as direct and indirect. Direct drivers include land use change (conversion of wetlands, open spaces and forest to agriculture and infrastructure), loss of indigenous genetic species, discharge of pollutants, use of fertilizer, climate variability (unpredicted rainfall) and animal rearing. Whereas, indirect drivers include demographic (population growth), economic activities (industrial expansion), practicing intensive agriculture, legal framework (environment governance), expansion of social and physical infrastructure (roads, water supply), education and health centers, housing, and civil society (environmental clubs and association).

Screening the Ecosystem Services for Relevance

The ecosystem services that are identified above are analyzed in terms of their relevance to the decision in order to set priorities for detail assessment. This enables the decision makers to include geographic (spatial) and time scales into their decision making process, as well as it informs them to identify other users of the services that may affect or be affected by the decision.

Screening the ecosystem services for relevance task is performed for Mekelle city based on ecosystem service dependencies of a decision on an ecosystem service whether or not cost-effective substitute exists for the service, and ecosystem service impacts whether or not a decision has an impact on an ecosystem service in either of limiting or enhancing the ability of others to use or benefit from that service including spatial (local to global) and time (present to future) scales. Our judgment on the decision's impact considers the total share of the impact on the overall service, the supply and demand nexus for the service and the power to pushing the ecosystem service across a biological threshold (this is the case in genetic resource) that leads to scarcity of the service within the lens of sustainability. Note that, screening team used expert judgment of its own familiarity to the city, referring development plan and case studies that are done in the city. Having this in mind, the following ecosystem services are screened for their relevance in Mekelle city.

Provisioning

Food supply: It is screened out because a decision to apply fertilizer to increase crop production affects a large share of residents and it is in a short supply as well.

Fresh water supply: This ecosystem service is relevant for the decision for that it is hard and cost ineffective to substitute fresh water through water treatment plant establishment for water recycling. In addition, the city's decision to extract large amount of water from underground water affects large share of the local community as it has depleting impact on the water availability in the streams.

Genetic resources: It is relevant as the genetic resources are not substitutable using man-made resources. On the other hand, a decision to produce genetically modified variety of corps and livestock push genetic resource ecosystem service across a biological threshold that leads to scarcity of the service in the long run.

Regulating

Air quality: This ecosystem service is relevant because it is more cost-effective to maintain the natural ecosystem than planting trees that needs an intensive management through its growth. In the contrary, a decision to expand industries and infrastructures in the city affect a large share of the total local and regional, even global communities.

Climate regulation: Its relevance is related to the fact that it is less likely to adequately substitute the role of natural ecosystems in regulating climate artificially. But, a decision to reforestation and afforestation in the city enhances the ability of the city's ecosystem to climate regulation and water supply services. However, a decision to expand industries has a potential effect on a large share of the local to global and present to future communities.

Water regulation: This ecosystem service is relevant for which it is not cost-effective to substitute the water regulation ecosystem service of wetlands by construction of artificial flood ways. A decision of using some part of wetlands for agriculture by small and micro scale enterprises limits the water regulation service of wetlands. It also affects large portion of downstream communities.

Water purification and waste treatment: This is relevant from the experiences where substituting the water purification service of wetland by water treatment plants for the services is costly. On the other hand, a decision made by Mekelle city government to convert wetlands to agriculture, push the ecosystem service across a biological threshold that leads to scarcity of the service.

Cultural services

Recreation and eco-tourism: This ecosystem service is relevant as the decision to expand recreation sites in the city benefits large share of the local community. Besides, the service of recreation and eco-tourism in Mekelle is in short supply as compared to population size of the city and the corresponding demand for the services.

Supportive services

Nutrient cycling: This ecosystem service is relevant because a decision of the city to reforestation and afforestation enhances nutrient cycling service whereas fertilizer application to increase crop production may push nutrient cycling service across a biological threshold that leads to deterioration of the services.

Primary production: It is relevant ecosystem services for which decision to use urea fertilizer to improve crop growth vigorously enhances primary production service. On the contrary, use of urea fertilizer in crop production results in eutrophication that affects the aquatic ecosystem, as well as shortage of water for agriculture in the downstream communities.

Water cycling: This ecosystem service is relevant to the decisions in the city in which afforestation and reforestation decision enhances the water cycling services where its impact covers a large share of the community which may range from local to global scale.

Assessing the Condition and Trends of the Relevant Ecosystem Services

To assess the condition and trends of the relevant ecosystem services of Mekelle city, a detailed analysis of the condition of relevant ecosystem services is done. For this purpose, indicators are selected and used to evaluate the condition and trends of the relevant ecosystem services and the drivers, as summarized in the Table 1.

Assessing the Need for an Economic Valuation of Ecosystem Services

The relevant ecosystem services of Mekelle city are assigned with quantitative economic values by using market values for the relevant ecosystem services that are captured in the market and indirect values for those that are not currently valued in the market place. The need for economic valuation of ecosystem services are; indicating the value of

Ecosystem services	**Indicators**	**Conditions and trends of relevant ecosystem services**			**Drivers**				**Impact**	**Predictions**
		Increasing	**Constant**	**Decreasing**	**Types**	**Trend**				
						Increasing	**Constant**	**Decreasing**		
Food supply	Amount of crops and vegetables and livestock	√			Use of fertilizer and pesticide	√			High: because increased run off pesticides and fertilizers affect fresh water quality and quantity and reduce aquatic life	Irreversible change may occur on aquatic life
					Landuse change	√			Medium: because this impact is associated with periphery areas and illegal encroachment	
Fresh water	Water withdrawal from ground water wells	√			Water drilling technology	√			High: because water drilling technology easily extracts water from under ground	Availability of fresh water supply will decrease in the longrun
					Technical know how	√			High: because the increase in technical knowhow speeds up the extraction of fresh water supply	
Genetic resource	Flora and fauna species			√	Bio genetic technology	√			High: because increasing genetic resources fully depends on bio genetic technology	The indigenous genetic resources will reach irreversible change
Ecosystem services	Indicators	Conditions and trends of relevant ecosystem services			Drivers				Impact	Predictions
		Increa-sing	Const-ant	Decre-asing	Types	Trend				
						Increas-ing	Constant	Decrea-sing		
Air quality	Peoples affected by respiratory disease	√			Industrial expansion	√			High: because the emissions from industries affect air quality	
	Area under forest cover			√	Land use changes	√			Medium: because land use conversion from green to urban use moderately affect air quality	
Climate regulation	Area under forest cover			√	Land use change (forests to agricultural land and infrastructure)	√			Medium: because the amount of forest cover has an impact on climate regulation	
Water regulation	Drainage facilities		√		Land use change (wetlands to agriculture and housing)		√		Low: because the amount of wetland in the city is small and its effect or retaining flood water is relatively low	
Ecosystem services	Indicators	Conditions and trends of relevant ecosystem services			Drivers				Impact	Predictions
		Increa-sing	Const-ant	Decre-asing	Types	Trend				
						Increas-ing	Constant	Decrea-sing		

Water purification and waste treatment	Level of impurities	√			Types of chemicals used	√			High: because chemical effluents can highly harm the ecosystem service	Wetlands may disappear
					Waste disposal	√			High: because wastes from different sources can affect the ecosystem	
Recreation and eco-tourism	Total area of parks and green spaces			√	Land use change (green areas to built environment)	√			High: because land use change highly reduce recreation and ecotourism services	The amount of green spaces will decrease
Nutrient cycling	Area under forest cover Area under built environment	√		√	Land use change (forest to built environment)	√ √			High: because nutrient cycling depends on forest to facilitate cycling	
Ecosystem services	Indicators	Conditions and trends of relevant ecosystem services			Drivers				Impact	Predictions
		Increa-sing	Const-ant	Decre-asing	Types	Trend				
						Increas-ing	Constant	Decrea-sing		
Primary production	Total amount of green spaces			√	Land use change (green areas to built environment)	√			High: because primary production has been affected by built environment expansion	
Water cycling	Forest cover			√	Land use change (forests to agriculture and infrastructure)	√			High: because land use change highly reduce amount of forests that facilitate water cycling through retaining water and evapo-transpiration	

Table 1: The ecosystem services, their conditions and trends, and drivers and indicators for change.

ecosystem services by ecosystem service type so that policy makers of the city could use it for prioritizing actions for ecosystem conservation and their contributions to sustainable development; comparing the cost-effectiveness of the substitutes of various ecosystem services, for example, the cost-effectiveness of maintaining wetlands for water purification services could be compared with constructing and operating water treatment plant; the city government can also evaluate the impacts of development policies that include evaluating the ecosystem service costs associated with habitat conversion, runoff, or pollutant discharge which could also include looking at the benefits of conserving ecosystem services by enforcing environmental regulation and in strengthening resource management; and building markets for ecosystem services through, for example, payment for ecosystem services.

In light with this, economic valuation of ecosystem services of Mekelle city is done based on the available data from different case studies, researches and literatures, such as, development plan of the city and other sources.

The method of valuation for the relevant ecosystem services with their spatial scale and constituents are summarized in the Table 2.

According to the above methods of economic valuations, the value of the relevant ecosystem services in Mekelle city is calculated as follows:

Food supply: Includes cereals, horticulture and livestock. Economic value of cereals is calculated in the Table 3.

According to Dereje et al. [3], farmers earn 925 birr per 0.004 ha on average of producing horticulture in urban agriculture of Mekelle city. And the total cultivated area for horticulture production is 1220.6 ha. Accordingly, farmers earn 282, 263, 750 birr.

Economic value of livestock production in Mekelle is shown in the Table 4.

Total value of food supply ecosystem service=14,934,890 + 282, 263, 750 + 45, 680, 240=342, 878, 880 birr/USD $ 18, 046, 256.

Fresh water supply: According to Miehiko et al. [5], daily domestic water consumption per capita of Tigray regional state is 7.9 litters. Furthermore, according to Mekelle city.com [6], the price for 20 liter of potable water is 25 cents. Assuming that, 75% of the price of potable water is subsidized, the price of a litter of potable water will be 0.5 cents. As to the population projection made in the local development plan (2006) of the city, the current total population of the city is 334, 816. Accordingly, the total value of fresh water supply is calculated as:

334,816 × 7.9 litter=2645046.4 litter (total fresh water consumption)

2645046.4 × 0.5c=1,322,523.2 birr/day=1322,523.3 × 365= 482, 720, 968 birr/year or in USD is $ 25,406,366.7.

Genetic resources: According to Brush et al. [7], traditional farming systems do not differ markedly from natural ecosystem. Therefore, we omitted valuation of genetic resource as we valued in the food supply ecosystem service. This is because, to avoid double counting.

Air quality: According to Mohammed et al. [8], there were 992 air pollution related patients in Mekelle city. According to Abebe et al. [9], the price for ceftriaxone which is prescribed for air pollution related patients is 75 birr per individual. Accordingly, the value for air quality ecosystem service is:

992 × 75 birr=74,400 birr or in USD $ 3915.79

Climate regulation: According to the local development plan [4] of the city, 18.75 ha of the city is covered by forest. According to Oromia

Ecosystem service	Scale	Valuation methods	Constituents	Remark
Food supply	Region: because, these ecosystem services provide benefits for the whole city.	Market price: because, this service is captured at market place	Households.	-
Fresh water supply	Region: because, this ecosystem service provides benefit for the whole city.	Market price: because, fresh water supply is found at market.	Households and individuals.	-Subsidy by the government is considered.
Genetic resources	Region: because, this ecosystem service provides benefit for the whole community.	Production function: because, the input for genetic resources highly determines its output.	Experts	
Air quality	Region: because, this ecosystem service provides benefits for the whole community.	Damage cost valuation: because, this best represent the cost of air quality by including costs incurred for treatment of air borne disease.	Researchers	
Climate regulation	Region: because, these ecosystem services provide benefits for the whole community.	Replacement cost: because, the cost incurred the substitute to service can best represent the value of the service.	Researchers	
Water regulation	Neighborhood: because, this service is located at specific areas and provides service to the vicinities.	Replacement cost: because, the cost incurred to substitute the service is the value of the ecosystem service	Engineers/experts	
Water purification and waste treatment	Neighborhood: because, this service is available at specific locations and give services to the neighboring community	Replacement cost: because, the cost insured to replace the service is the value of the ecosystem	Engineers experts	
Recreation and eco tourism	Neighborhood: because, this service is available at specific locations and gives services to the neighborhood community.	Market price: because, the price paid for refreshment and visit are the value of the ecosystems	Visitors	
Nutrient cycling	Regional: because nutrients are available in all places of the city and provide service for the while community	Replacement cost: because, the cost incurred to replace nutrients is the value of the ecosystem service	Farmers	
Primary production	-	-	-	No data
Water cycling	-	-	-	Double counting due to valuation on climate regulation

Table 2: Ecosystem services and method for economic valuation of Mekelle city.

Cereals	Total area cultivated in hectare	Average product per hectare in quintal	Total product in quintal	Unit price per quintal in birr	Total value in birr
Maize	652.64 ha	25	16,316	550	8, 973, 800
Teff	76.18 ha	12	914,16	1300	1, 188, 408
Wheat	294.61 ha	18	5,302.98	900	4, 772, 682
Total					14, 934, 890
Source: urban agriculture of Mekelle (2007)					

Table 3: Economic values of cereals of the city.

Livestock type	Total product	Average unit price	Total value in birr
Cattle	7,013	6220	43, 620, 860
Sheep and goat	1563	900	1, 412, 100
Hen	8,091	80	647, 280
Total			45, 680, 240
Source: urban agriculture in Mekelle			

Table 4: Economic values of livestock in the city.

forest enterprise and market cited in Yitebitu et al. [10], Ethiopian forests capture 44.94 ton of carbon per hectare on average. Hence, the total amount of carbon captured by the forest of the city is; 18.75ha × 44.94=842.525 ton of carbon and they stated that the value for a ton of carbon is 415.26 birr. Therefore, the value for climate regulation service is:

842.625 ton of carbon × 415.26 birr=349, 908.46 birr or USD $ 18,416,235

Water regulation: The value for water regulation ecosystem service is the cost incurred for engineered flood control infrastructures. But, we couldn't find data that indicates the distance and the cost needed for flood control infrastructure construction.

Water purification: the value of wetlands for their natural purification of water is the price of water treatment plants. According to Alibaba.com [11], the price of containerized brackish water treatment plant in USD is $ 35,000. Therefore, the value of water purification ecosystem service is USD $ 35,000.

N.B. we couldn't indicate the amount of water treatment plant needed in the city as we lack data about the amount of water that wetlands purify and the capacity of the water treatment plant.

Recreation and eco-tourism: To measure the value of recreation and eco-tourism in Mekelle city, we consider the total number of recreational and eco-tourism centers, total number of visitor per day, and the average cost incurred during their stay. Finally, we take the difference in cost among other common sites and recreational and eco-tourism services as the value of the ecosystem.

Total number of recreation and eco-tourism services in the city=10.

Average number of visitors in each center=60: total=60 × 10=600 visitors.

Average cost during their stay in recreation and eco-tourism center=37 birr.

Average cost incurred in other common centers=29 birr.

Therefore, difference=37- 29=8 birr per individual.

Total=8 birr × 600 visitors=4800 birr/day, in a year it will be; 4800

Decision	Goal	Winners	Losers
Food supply Converting green areas to agriculture. Increasing fertilizers application.	- Increasing productivity and production of crops and livestock.	-Farmers and consumers.	-Local community. -downstream users of fresh water.
Fresh water supply Extracting underground water using machineries.	-Increasing amount of fresh water supply in the city.	-Local community.	-Downstream farmers.
Genetic resources Increasing use of genetically improved seeds.	-Increasing productivity of crops.	-Farmers and consumers.	-Farmers and local community in the long term.
Air quality Expanding transportation and industries. Afforestation and reforestation	Ease transaction of peoples, good and services Raising income of the community and government. Improving the scenery and water shed management.	Local community's firms and some parts of the community, government. Local community.	Some local communities along transport expansion sites. -Downstream local community. -Some farmers who are using grazing land and open spaces.
Climate regulation Livestock rearing. Reforestation and afforestation	Increasing cattle production. Improving the scenery and sinks of carbon.	Farmers and consumers. Local community.	Community near to cattle rearing area. Some farmers who are using grazing and open spaces.
Water regulation Using wetlands for agriculture.	Increasing crop and livestock production.	-Micro and small scale enterprises.	-Downstream farmers.
Water purification and waste treatment Converting wetlands to agriculture.	Increasing the production of crop.	-Farmers.	-Downstream fresh water users and farmers.
Recreation and eco- tourism Expansion of infrastructures (social and physical). Expansion of parks and green areas.	Improving the human well being (connectivity, health, etc). Improving the scenery and refreshment.	-Local community.	Property owners. Farmers that rely on open spaces and green spaces for grazing and agriculture.
Nutrient cycling Use of fertilizers.	-Increasing nutrient content of soils.	-Farmers.	-Downstream users of fresh water.
Primary production -Use of urea fertilizer.	-Increase the vigorous growth of plants leaves.	-Farmers.	-Downstream users of fresh water.
Water cycling Reforestation and afforestation. Expansion of social and physical infrastructures.	Increasing forest-area coverage. Improving the well-being of the local community.	-Local community.	Farmers who rely on open spaces and green areas for grazing. Farmers who are along the social and physical infrastructural expansion.

Table 5: Decisions associated with the city's ecosystem services and their goals, winners and losers of the impact of decisions.

birr × 365 days=1,752.000 birr/year or USD $ 92, 210.53 is the value of recreation and eco-tourism in Mekelle city.

Nutrient cycling: The value for nutrient cycling is the cost incurred to replace the nutrients. According to Dereje et al. [3], 1030 hectare of agricultural area is cultivated using two quintal of fertilizer per hectare on average, of which 50% of the fertilizer is DAP and the rest 50% is UREA. According to Ministry of agriculture [12], the prices for a quintal of DAP and UREA is 1482 and 1273 birr respectively. Therefore, the value of nutrient cycling will be:

1273 + 1483=2756 birr (price of fertilizer per hectare)

2756 birr × 1030 ha=2,838,680 birr/USD $ 149,404.21

Based on the above ecosystem valuation, the total economic value of the relevant ecosystem services in Mekelle city in USD is:

18,043,256 + 25,406, 366.7 + 3915.79 + 18,416.235 + 35000 + 92,210.53 + 149, 404.21=$ 43,748,569

Identifying Ecosystem Service Risks and Opportunities

Identification of the risks and opportunities of ecosystem services that are associated with the development plan of the city involves utilization of the information analyzed in the discussions of the above portion. We take in to consideration of the results of different scenarios which indicate the status of a given ecosystem in the future. In identifying the risks and opportunities of ecosystem services, we tried to consider the decision's dependence on ecosystem service that might be poorly recognized jeopardizing of decisions on the unbalanced state of supply and demand of an ecosystem service and the existence of any unforeseen impacts of the decision on ecosystem services that others depend on for their well-being both in spatial and time scales. Basically we critically discuss the ecosystem service changes in terms of trade – offs when identifying risks and opportunities in relation to each relevant ecosystem service.

The tools applied in trade-off analysis are:

Poverty and ecosystem service mapping: This tool is used to identify which areas provide critically important services to the poor; who has access to natural resources; who benefits and loses by using our team's best knowledge of the city ideally.

Action impact matrix: This tool is used to assess the interactions between development (decision) goal and ecosystem by explaining the effects of decision goals on ecosystem as well as the effects of ecosystems on development.

Economic valuation: This tool is used to draw attention to the value of ecosystem services that might otherwise be ignored when making decisions that affect ecosystem.

Accordingly, the decisions, goals, winners and losers of the ecosystem services of Mekelle city are summarized in the Table 5.

The risks of the ecosystem services that are related with the development plan of Mekelle city includes:

- Reduction in land available for crops and livestock production as a result of expansion of physical, social and green infrastructures leading to impacts on the wellbeing of the farmers and local community.
- Degradation of fresh water supply due to over extraction as well as an increased water pollution from effluent of industrial discharges and open waste dumping into streams and rivers affect the downstream farmers in particular and the whole community in general.
- Loss of indigenous genetic resources as a result of use of genetically modified crops and livestock offspring.
- Reduction in air quality as a result of emissions from extended transportation and industrial activities.
- Occurrence of unpredicted extreme weather events as a result of loss of climate regulation services due to expansion of infrastructures and agriculture at the expense of forests and other green areas.
- Reduction in flood hazard regulation and water purification services by wetlands that increases the vulnerability of downstream farmers and other communities due to conversion of wetland to agriculture use.
- Reduction of recreation and eco-tourism services owing to the expansion of physical and social infrastructures at the expense of green and open spaces.
- Reduction in nutrient cycling services as a result of excessive use of fertilizers to substitute the naturally occurring nutrient service in the soil.
- Reduction in water cycling services as a result of conversion of forest and other green lands to social and physical infrastructure constructions.

The opportunities of the ecosystem services related to the development decisions of the city include:

- Enhancement of the availability of food in the city via the use of fertilizers to increase crop production.
- Improvement of fresh water supply by increasing the water filtration, purification and erosion control services through forest and wetland ecosystem preservation.
- Improvement of air quality through reforestation and afforestation programs that remove pollutants from the atmosphere through filtration of particulates and air pollutants by the leaves of the trees.
- Moderate the climate through planting trees that can enhance the capacity of forests to sink carbon and serve as storage of excess carbon.
- Enhancement of natural flood hazard and water purification regulation service through preservation of wetlands.
- Increment of recreation and eco-tourism services through expansion of forests, open spaces and parks.
- Enhancement of nutrient cycling due to the use of organic fertilizers, like compos for crop production
- Improvement of primary productions as a result of use of urea fertilizer to enhance growth of leaves.
- Enhancement of water cycling service through increasing forest coverage in the upper catchment area.

Conclusion

Mekelle is one of the ancient cities of Ethiopia in which its formation as a capital goes as far back as the medieval period. Astronomically, the city is located between 13°22' N 3933'E with an elevation between 2000-2200 meters above sea level.

The current population of Mekelle city with an annual population growth rate of 5.4% is 334,816. The residential houses, social, economic and physical infrastructures development of the city is increasing with an increasing population growth.

Mekelle city has prepared a ten years development plan ranging from 2006-2015 G.C. The city administration identified the general land use, infrastructures, open spaces and environmental aspects and housing provisions as a mandatory provision in the development plan of the city.

In Mekelle city, different ecosystem provisioning services (like food supply, fresh water supply, biomass fuel, genetic resources, natural medicines, etc.), regulating services (like, air quality, climate, water erosion, water purification and waste treatment; pest and pollination regulation services, etc.), and supportive services (like, nutrient cycling, primary production, water cycling, etc.) are provided to the dwellers of the city. Furthermore, the cultural services of the city are limited to recreation and eco-tourism services. The decision associated with this ecosystem services are expansion of social and physical infrastructures-which negatively harm the ecosystem practices of services and reforestation and afforestation practices of the decision enhances the ecosystem service of the city.

The direct drivers of ecosystem service changes of the city include land use change, loss of species, discharge of pollutants, use of fertilizers, climate variability, and animal rearing, while, the indirect drivers include, population growth, urban economic activities, legal framework, expansion of social and physical infrastructures.

The identified ecosystem services were screened in terms of their relevance based on the ecosystem service dependencies and impacts whether or not a decision has an impact on an ecosystem service in either limiting or enhancing the ability of others to use or benefit from that service. To assess the conditions and trends of the relevant ecosystem services of Mekelle city, indicators like amount of crops and vegetables per hectare, water withdrawal from ground wells, flora and fauna species, peoples affected by respiratory, area under forest coverage, drainage facilities, level of impurities, total area of parks and green spaces were identified.

The relevant ecosystem services of the city are assigned quantitatively using market values for those that are captured in the market and indirectly for those that are not currently valued in the market. As a result, the total economic value of the relevant ecosystem services in Mekelle city in USD is $ 43,748,569.

In identifying the risks and opportunities of ecosystem services, we critically considered of ecosystem service changes in terms of trade-offs. Besides, tools like poverty and ecosystem service mapping, action impact matrix, and economic valuation were applied. Furthermore, the

decisions, goals, winners, and losers of the ecosystem service of Mekelle city were considered.

Recommendation

Based on the above identified risks and opportunities, the following possible and feasible recommendations are forwarded below.

- The trade, industry, and urban development bureau of Tigray regional state should design an integrated and strategic urban development plan which avoids a frequent land use change that results in ecosystem disturbance.
- The municipality of Mekelle city should integrate well designed and managed green spaces that can provide an effective recreational and eco-tourism service in its decision to expand social and physical infrastructures.
- The city's urban agriculture office should promote use of organic fertilizers like compos rather than using inorganic fertilizers to reduce eutrophication and nutrient cycling.
- The Mekelle city administration should establish genetic bank institutions that preserve indigenous species of forest and crops by giving more attention to the endangered species.
- The Mekelle city land administration and environmental protection department should enforce and monitor the application of environmental laws and regulations, and provide incentives for industries that use environmental management system so as to trim down air pollutants and hazardous industrial effluents.
- The municipality of Mekelle city should formulate wetland regulation (ordinance) that ensures protection and restoration of wetlands so that water could be regulated and purified.
- The municipality of Mekelle city need to enhance the urban forestry both in quality and quantity by mobilizing and raising awareness of the urban dwellers of the city to take part in a forestation and reforestation programs so as to enhance fresh water availability, climate regulation, water cycling, air quality, and nutrient cycling.
- The transport and construction office of Mekelle city should have a strict regulation which enforces the inspection and maintenance of exhausted motor vehicles annually to reduce greenhouse gas emissions, and need to encourage the use of public transport.
- The city's small and micro enterprises office should provide a special incentive that encourages farmers to engage in off-farm activities so as to reduce the expansion of agriculture in to the ecologically important areas of the city.
- The municipality of Mekelle city has to prioritize the actions in such a way that promote and conserve ecosystem based on their economic valuation, such as food supply, fresh water supply, climate regulation, nutrient cycling, recreation and eco-tourism, and genetic resources.

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