GIS Based Environmental Cost−Benefit Analysis of Built Environment at Dar es Salaam Coastline Metropolitan

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Abstract

The hypothesis of global human population growth underpins fast urbanization of global landscape in various regions. Such trends promote built environment expansion, as such the desire for more and comfortable infrastructural place and space value for work, recreation and residence. Putting in place transport and social services connectivity between places and spaces altogether account for the loss of ecological resources. Inspite of this, little information is available on net ecological value benefits of built environment, in particular, on the rapidly urbanizing metropolitan of Dar es Salaam coastline. The study applied geographical information system techniques on Landsat satellite imageries for landuse landcover changes extraction; and globally recognized ecological indexes for valuation of ecosystem services. Furthermore, the use of annual population growth rate and real estate expansion rate underlined annual modulation on input variables hence input data for the subsequent years through the study period. Nonetheless, despite rising human population, expanding built environment and declining vegetation cover experienced along the coastline of Dar es Salaam metropolitan, the study findings displayed general declining trend of net ecological value benefits of built environment with an overall positive net ecological value benefits $(NPV = 617{,}216.66)$. This suggests that the metropolitan of Dar es Salaam coastline is still resilient to built–up environment development initiatives.

Keywords: Environmental cost−benefit analysis, environmental economics, project feasibility analysis, net ecological value, Dar es Salaam coastline

JEL Classification Codes: D61, Q51

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1. Introduction

In project economic analysis, estimating and comparing benefits and costs (C&B) defines the economic life of a project (Sartori *et al.*, 2014). In most cases, C&B that is internal to project weighs more than external C&B (Clark *et al.* 2018, Sartori *et al.* 2014). According to Atkinson *et al.* (2018) and Sartori *et al.* (2014), less weight to external C&B like environmental issues is associated with scarcity of relevant data, avoidance of additional expenses as well as escaping findings likely to support claims for retroactive compensation. However, Lu (2017) show that in recent years awareness on environmental matters present profound challenges on project investment analysis. On the other hand, the desire for better management of climate funding, sustainability initiatives and holistic socio−ecological projects in anthropogenic environment call for paradigm change in investment analysis (Tara *eta l.* 2015, Bell, 2013). Largely, inclusion of ecological values into investment analysis details associated environmental risks at all stages of the project hence effective risk management preparedness. Practically, project financial dealings display greater oversight on environmental benefits than costs; according to Tara *et al.* (2015) and Grzebieluckas *et al.* (2012) environmental investment costs are core components of project economic analysis. Thus, giving it little weight during investment analysis is likely to mislead the balance sheet due to incomplete economic analysis. Furthermore, absence of required environmental C&B in project investment analysis, down position the role of environment and natural resources in project sustainability.

Research by Atkinson *et al.* (2018), Lu (2017), Murdoch *et al.* (2007) and Syafinaz *et al.* (2017) show that the net economic benefits and costs results from well captured and analysed data on social, environmental and economic component of the proposed project. While in the past, a great challenge existed in the capturing and analysis of environmental resources values necessary for project integration; today, technological advancement in geographical information system (GIS) but also open access data sources have resolved the scarcity of relevant data for financial analysis (Sain *et al.* 2017, Arribas-Bel 2014). The GIS platform is an enabler to significant and reliable techniques for data accessing, preparing and analysing past and future spatio−temporal data dynamics (Dennig *et al.* 2017, Bateman *et al.* 2005). Nonetheless, simplicity on monetizing past and future natural and environmental resources is connected to such technological development (Walelign *et al.* 2019, Croitoru and Sarraf 2018, Solís-Guzmán *et al.* 2018, Grzebieluckas *et al.* 2012). Studies reveal that presence of such data is pivotal in modelling C & B of social, economic and environmental life of the project developed on a specific piece of land (Shen *et al.* 2019, Atkinson *et al.* 2018, Kuosmanen and Kortelainen 2007). Although cost−benefit analysis (CBA) has a long history as a tool for investment analysis (Prest and Turvey 1966), particularly, in the naval department of United States of America (Cummins and Wilborn 2009); it is just in the recent past that we have witnessed CBA being used widely in various disciplines and sectors (Dennig 2018, Ward 1994). According to Shen et al. (2019), Liddle *et al.* ((2015), and Drèze and Stern (1987) CBA inclusion of welfare economics, public finance and resource economics contributed significantly to its wide application in appraising desirability of projects hence decision making on investment analysis.

Scholars Dennig (2018), Atkinson *et al.* (2018), Atkinson and Mourato (2008), and McIntosh *et al.* (1999) epitomize that, several methodologies toward CBA techniques include project definition, identification, enumeration of costs and benefits, evaluation of costs and benefits and discounting and presentation of results. This study adopted the discounting of projects costs and benefits on ecological values change statistics. This inclusion of physical environmental changes formed a new dawn known as environmental CBA (Bateman *et al.* 2005). Studies by Atkinson *et al.* (2018), Lu (2017), Hwang (2016), Kuosmanen & Kortelainen (2007) and Duma *et al.* (2013) show that environmental Cost−benefit analysis (ECBA) (an improved version of CBA), is an approach that estimate, quantify and compare total benefits and costs concerning a number of environmental issues in a proposed project development.

While researchers Dennig *et al.* (2017), Xie *et al.* (2017) and Costanza *et al.* (1997) assigned values to natural and environmental resources, Bateman *et al.* (2005) applied ECBA knowledge to appraise LULC conversion enabled the understanding of economic values associated with LULC conversion. According to Duma *et al.* (2013), environmental costs are categorized as prevention costs, operating costs and affect costs; nonetheless, regardless of the categorization, studies by Gerber and Mirzabaev (2017), Nkonya *et al.* (2016) and Almihoub et al (2013) show that the sources of such costs is production activities, environmental pollution, environmental protection and sustainability. On the other hand, environmental benefits (Gerber and Mirzabaev 2017, Nkonya *et al.* 2016, Almihoub *et al*. 2013) are the totality of environmental and life quality, with its sources being similar to that of environmental costs.

This research treated Dar es Salaam coastline metropolitan area as a real estate project site, in which vegetation cover and BE LULC change and conversion; and monetary values of such conversion, provided valuable inputs in computing ECBA. Dar es Salaam, the port and the largest commercial city in Tanzania, in the period of 1995−2016 underwent tremendous population growth hence infrastructural development. According to Chuai *et al.* (2016), Zari (2014) and Pacheco-Torgal and Labrincha (2013) converting natural environment into shopping malls and residential apartments compromises ecosystem services functioning and ESV delivery to urbanites. Therefore, for generating data and knowledge useful for green cities and sustainability initiatives, valuation of LULC conversion and comparison of benefits and costs associated with such urbanizing landscape is inevitable.

2. Materials and methods

2.1. Location and description of the study area

Dar es Salaam metropolitan is located between latitude 6° 3' 43.09'' & 7° 10' 47.35'' S and longitude 39° 6' 36.37'' & 39° 33' 5.66'' E at 24 meters above sea level, on the southwestern coast of the Indian Ocean in Tanzania (Figure 3). It covers a total area of 1800 square kilometers, of which 1350 square kilometers is landmass including its eight offshore islands; the rest is water-covered area. The geographically lowland Dar es Salaam experiences typically hot-humid climate greatly influenced by northeast and southeast monsoon. The metropolitan receives an average annual rainfall of 172 mm, average annual temperature of 29–degrees Celsius and humidity record of 96 percent in the morning and 67 percent in the afternoon. The coastal shrubs, Miombo woodland, coastal swamps and mangrove trees represent the main natural vegetation cover type in the 100 kilometer coastline of Dar es Salaam.

LULC has been changing from natural vegetation to farmlands, human settlements and urban centres leading to increased BE, land degradation, deforestation and biodiversity loss (Mkalawa 2016, Padgham *et al.* 2015, Congedo and Munafò 2014). Governed under five districts of Kigamboni, Temeke, Ilala, Kinondoni and Ubungo; population in the metropolitan grew from 843, 090 in 1978 to 5, 465, 420 in 2016; of which 94 percent are urbanites (urbanization rate is 34 percent) (Worrall *et al.* 2017). Development statistics place Dar es Salaam metropolitan as the most industrialized and urbanized city in Tanzania, as well as a member of the global top ten fastest growing cities (Ndetto and Matzarakis 2015).

Although Dar es Salaam metropolitan that is only 0.16 percent of Tanzania total coverage area, is home to about 10 percent of the country's total population, estimated to be 55M. The city has 114 wards but the study concentrated on 67 administrative wards covering 714.3 Sqkm, which is 59.8 percent of the total area of Dar es Salaam metropolitan. The geographical coverage defines north–south coastline, estimated to be 100 km long with 3,252, 317 inhabitants; which is about 62.4 percent of the Metro's population. Growing population, mostly due to rural–urban migration drives the metropolitan places to experience rapid urbanization and degradation of local environment; consequently, loss of habitat and species, increased noise, air pollution and soil erosion. Studies by Stow *et al.* (2013) reveal that rising population speed-up construction, reconstruction, rehabilitation, resurfacing, restoration, and operational improvements in search for comfortable places for work, residence, recreation and entertainment; hence the expansion of BE. Moreover, BE expansion indirectly implies encroachment of virgin natural areas for provisioning of construction materials, areas for agricultural activities and places for installing socio-economic infrastructures.

According to Gombe *et al.* (2017) Dar es Salaam metropolitan BE development pattern is characterized along the two main rivers, Msimbazi and Mzinga; and four main roads namely Nyerere heading to the Airport and Kisarawe district, Ali Hassan Mwinyi leading to Bagamoyo, Morogoro that heads to Morogoro region, and Kilwa that stretches southwards to Lindi and Mtwara regions. Kilwa and Ali Hassan Mwinyi roads are along shoreline while Nyerere and Morogoro roads are almost perpendicular to the shoreline and lead towards the hinterland.

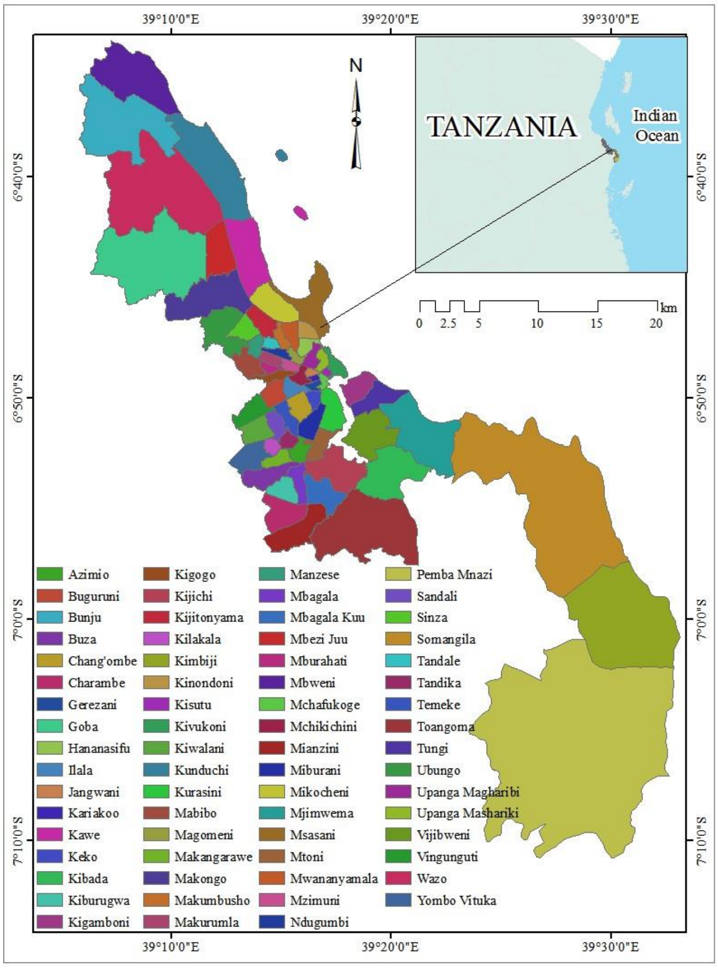

Figure 1: Dar es Salaam metropolitan coastline displaying the study area

2.2. Data sources and preparation

The free registration, access and download of Landsat satellite imageries at USGS Earth Explorer website provided the raw data for Dar es Salaam coastline metropolitan. Using Landsat 5 and Landsat 8 for the years 1995 & 2016 in ArcGIS v10.3 platform, the study analysed LULC changes in the period of 21 years (1995 − 2016) to get statistics on most vegetated and built−up areas. Data statistics in Figure 2 and Table 1 on most vegetated areas in 1995 provided input on ecosystem services values (ESV), carbon footprint estimation and cost benefit analysis (CBA) computation.

Table 1: LULC changes and population in most vegetated wards

Theme	Year 1995	Year 2016
Agriculture (ha)	9926	46187
Forest (ha)	11084	6394
Bushland (ha)	31348	7050
Grassland (ha)	13264	337
Bare soil (ha)	6526	540
Water (ha)	1638	717
Built Environment (ha)	1912	7731
Population (Inhabitants)	337233	1020432

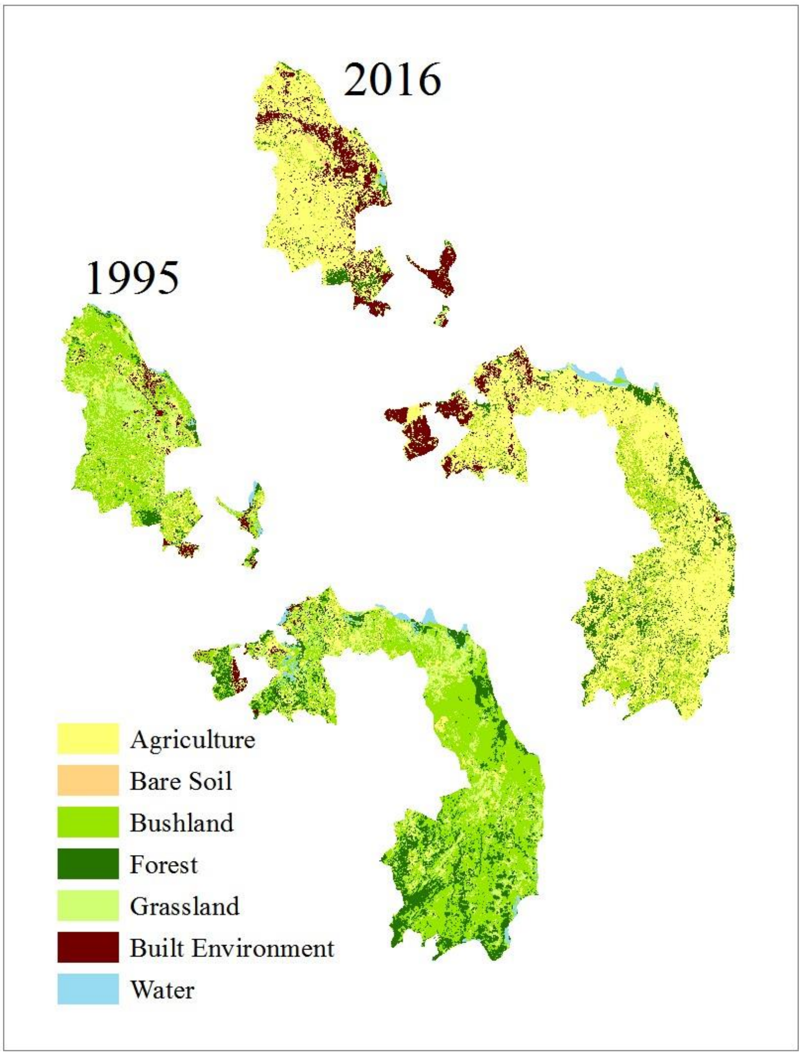

Figure 2: Dar es Salaam coastline most vegetated area transitions (1995 & 2016)

2.3. Environmental benefits variables

In generating the environmental benefit variables for the ECBA framework, the study monetized ecological system services (ESV). Utilizing LULC statistics (Table 1) and ecosystem services value coefficients (Table 2) (Costanza *et al*. 1997) as inputs in Equation 1 to get the ESV variables. Furthermore the benefit stream was computed from property rental fees in Equation 2, with US$ per m^{-2} as a unit in both cases. Thus;

$$ESV_n = \sum(A_k * VC_k) \quad (1)$$

$$RF = BE * RC. \quad (2)$$

Where;

ESV_n: total estimated ecosystem services value at year, n; treated as initial environmental benefits

A_k: Landuse size (ha) for category k (m^2)

VC_k: ESV coefficient (US$ ha^{-1}yr^{-1}) for LULC category k

RF: Is rental fee ($US\$\, m^{-2}$)

BE: Built environment (m^2)

RC: Rental cost ($US\$\, m^{-2}$)

Table 2: Habitat equivalents and corresponding ESV

LULC Classes	Equivalence biome	Ecosystem services coefficient (US $ ha-1yr-1)
Agriculture	Cropland	92
Bare soil	Bare soil	0
Bushland	Grassland/Rangelands	232
Forest	Forest	969
Grassland	Grassland/Rangelands	232
Built Environment	Urban	0
Water	Lake/River	8498

Source: (Costanza *et al.*, 1997)

Based on the general philosophy that environmental benefits decrease as population based BE expands; therefore, variables for consecutive years further involved bringing in the concept of lost benefit due to vegetation clearance, population growth rate and real estates growth rates as crucial factors in quantifying a portion of pollution associated with it on loss of vegetation based ESV. Integrating the idea changed Equation 2 into Equation 3. Therefore;

$$EB_{n-1} = ESV_n - LB - PPG + BBE \tag{3}$$

Where:

ESV_n: Total estimated ecosystem services value at year, n; treated as initial environmental benefits

EB_{n-1}: Environmental benefit at subsequent year, $(n-1)$

LB: Environmental benefit (ESV) cost factor due to vegetation clearance

PPG: Environmental cost factor due to population growth

BBE: Environmental benefit factor due to real estates growth

On the other hand the environmental benefit stream generation form BE rental fees was modulated by the rate of property occupancy, this means the environmental benefit variables from real estates rental fees on each year was obtained as;

$$BBE_n = RF_n + (RF_n * RO_n) \tag{4}$$

Where;

BBE_n: BE benefit at year n (US$m^{-2})

RF_n: Rental fee at year n (US$m^{-2})

RO_n: Rate of property occupancy at year n (%)

2.4. Environmental cost variables

On computation of environmental cost variables for ECBA framework, the study assumed that ecosystem services functions (ESV_f) in built environment is costly due to ecosystem services production and supply hence valuation of LULC change data (Table 2) using (ESV_f) coefficient (Table 3) provided initial environmental cost $Equation$ 5 for ECBA framework for year one. On the other hand, cost modulation for the subsequent years ($Equation$ 6) involved bringing–in the value of lost benefit (LB_n), environmental cost factor due to population growth rate ($Equation$ 7), BE cost associated with rate of property unrented spaces ($Equation$ 8) and environmental cost factor due to property carbon emission ($Equation$ 9).

Table 3: Coefficients of ESV functions (U S$ha−1yr−1) in construction land

ESV functions category	Construction land
Food production	0.09
Hydrological regulation	0.04
Waste treatment	0.09
Soil formation and conservation	0.01
Biodiversity maintenance	0.05
Providing aesthetic value	0.11

(Yuan *et al.* 2019)

Hence;

$$ESV_{fn} = \sum(A_k * VC_{fk}) \tag{5}$$

$$EC_{n-1} = ESV_{fn} + LB_n + PPG_n + CRoE_n + BCE_n \tag{6}$$

In which;

$$PPG_n = ESV_n * RoPG_n \tag{7}$$

$$CRoE_n = RoE_n * BE_n \tag{8}$$

$$BCE_n = CF_t * RO_n \tag{9}$$

Where:

ESV_{fn}: Ecosystem services values functions treated as initial environmental cost at year, n

A_k: Landuse size (m^{-2}) for category, k

VC_{fk}: Ecosystem services values function coefficient of LULC category, k

EC_{n-1}: Environmental cost at subsequent year,$(n-1)$

LB_n: Average annual lost benefit i.e. ESV, at year n

PPG_n: Environmental cost factor due to population growth

$CRoE_n$: Cost due to property unrented space at year, n

ESV_n: Total estimated ecosystem services value at year, n.

RF_n: Rental fee at year n (USm^{-2})

RO_n: Rate of property occupancy at year n (%)

$RoPG_n$: Rate of population growth at year, n. (%)

BCE_n: Property carbon emission at year, n. (tCO_2e/m^2)

BE_n: Size of built environment at year, n. (m^2)

CF_t: Carbon footprint in BE (tCO_2e/m^2)

The other stream of environmental cost variable involved quantification of carbon footprint because of carbon emission from BE. According to Biswas (2014) and Ngo *et al.* (2009) carbon footprint for construction materials production and transport is given as 9.1 tCO_2e/m^2. Study by Wahlgren (2010) show that, this account for only 10 percent of the total carbon footprint in BE. Thus;

$$CF_t = 1.1CF_{pt} \tag{10}$$

Where;

CF_t: Carbon footprint in BE $\left(\frac{tCO_2e}{m^2}\right)$

CF_t: Carbon emission from construction materials and its transportation (tCO_2e/m^2)

2.5. Discounted values

In determining the present value of the future cash flows in DCF modelling, the discount rate is applied. Research by Dennig *et al.* (2017) shows that, discount rate in construction sector can be computed by capital assets pricing model (CAPM) and weighted average cost of capital (WACC). However, the widely applicable model is WACC ($Equation\ 11$). WACC takes into account average values to all sources of funds with respect to external market, contrary to CAPM that assumes risk free investment. In the context of this study, computation of discounting factor, ($Equation\ 12$); used Bank of Tanzania (BoT) discount rate, which is 8 percent. The application of discounting factor on environmental benefits and costs is crucial in supplying compounded environmental benefits and costs, which are pivotal input variables in ECBA framework. Thus;

$$WACC = \frac{D}{D+E}(1+T_m)K_d + K_e * \frac{E}{D+E} \tag{11}$$

$$DF = \frac{1}{(1+r)^n} \tag{12}$$

Where

D is the cost of debt, E is the cost of equity,

K_d is the weighted average cost of debt,

K_e is the weighted average cost of equity

T_m Tm is the marginal tax rate.

DF: discounting factor

r is interest/discount rate

n is number of compounding years.

2.6. Net present values

Presence of benefits and costs data accrued in different periods and discounted to their present value provide an opportunity to compute net present value (NPV). The project NPV equals the difference between present value benefits and present value costs, summed over the project lifetime($Equation$ 13). According to Banerjee (2015), NPV greater than zero portrays net economic benefits, meaning that overall gains generated from the project in environmental perspective outweigh the losses likely to occur. Conversely, research by Maravas and Pantouvakis (2018) depicts that a project with an NPV less than zero display a great possibility of loss occurrence. In the context of this study, the greater the NPV, the more efficient is ESV hence more benefit generated from the costs of the resources invested in BE. That is;

$$NPV = \sum_{t=0}^{t} PV\ (Benefits - Costs) \quad (13)$$

Where:

NPV: Net present values from time t, to n^{th} time

PV: Present values of ecosystem services at time t

$Benefits$: The sum of all ecological and non−ecological benefits (all financial inflows)

$Costs$: The sum of all ecological and non−ecological costs (all financial outflows)

2.7. Sensitivity analysis

Sensitivity analysis is the measure of how output variation of model is attributed to variations of input variables (Pianosi *et al.* 2016). Some of the reasons for increased application of sensitivity analysis in environmental studies include uncertainty assessment, robustness assessment of results, model calibration and diagnostic evaluation (Pianosi *et al.* 2016, Hadley 2011). In this environmental cost–benefit analysis study, considered interest rate to be an input of influence, thus chosen to run sensitivity analysis test.

3. Results

In this study, the analysis quantified the net ecological value benefits of BE along the coastline of Dar es Salaam metropolitan. The main input data involved valuation of LULC change data from Landsat satellite imageries (Table 14), together with population growth rate, carbon emission valuation and property development data that provided crucial inputs to $Equation\ 1\ to\ Equation\ 9$. The result (Table 17) provided crucial input variables for ECBA framework (Table 18).

3.1. Extracted input variables

From Landsat satellite imageries, data extraction and processing in ArcMap v10.3 platform and analysis, the study managed to obtain input variables for ECBA framework (Table 4). In the context of this study, rental fee variable was computed from per night cost at Mayfair Plaza Hotel (https://mayfairhotel.co.tz/) in Msasani ward, a swampy area in Dar es Salaam before the installation of Mayfair Plaza Hotel in early 2000s. Nevertheless, the rental fee variable was assumed to apply across the coastline.

Table 4: Input variables for ECBA framework of BE at Dar es Salaam coastline

Variable Description	Value
ESV Benefits for year 1995 (US $/m^2):	1,192.66
ESV Benefits for year 2005 (US $/m^2):	525.09
ESV Benefits for year 2016 (US $/m^2):	150.36
Rate of vegetation clearance from year 1995 - 2016 (%):	0.08
Population growth rate in year 1995 - 2004 (%)	0.04
Population growth rate in year 2005 - 2009 (%)	0.05
Population growth rate in year 2005 - 2016 (%)	0.06
Rate of real estates growth in year 1995 (%)	0.02
Rate of real estates growth in year 2000 (%)	0.04
Rate of real estates growth in year 2006 (%)	0.06
Rate of real estates growth in year 2015 (%)	0.03
ESVf in year 1995 (US $/m^2):	4.85
ESVf in year 2005 (US $/m^2):	5.87
ESVf in year 2016 (US $/m^2):	6.62
BE size in year 1995 (m^2):	124,271.00
BE size in year 2005 (m^2):	150,434.00
BE size in year 2016 (m^2):	169,648.00
Average annual rate of property occupancy (%)	0.03
Average annual rate of property emptiness (%)	0.02
Mortgage discount rate (%)	0.08
Project time frame (years)	21.00
Carbon Emission (tCO2e/m^2):	3.10
Carbon price (US $/tCO2e):	20.00
Rental Fee (US $/m^2):	27.69

3.2. Environmental cost–benefit analysis framework

The ECBA framework in Table 5 resulted from the present value (costs subtracted from benefits) then discounted $Equation\ 12$ to get the net ecological value benefits $Equation\ 13$. The findings show that the net ecological value benefits have been declining from year 1995 to year 2016. The overall net ecological value benefits judged by NPV decision rule displayed a positive value, but the benefits expressed a general declining trend from 1995 to 2016.The profound implication of such positive value is that despite declining vegetation cover and BE expanding trend along the coastline landscape the ecological value benefits exceeded the ecological value costs of BE.

Table 5: The environmental cost – benefit analysis framework

Period (Year)	Time (Years)	Ecological Benefit Variables	Ecological Cost Variables	Discounting Factor	Present Value (PV)	Net Ecological Value Benefits
1995	0	4,990,735.45	551,980.05	1.00	4,438,755.40	4,438,755.40
1996	1	5,123,000.00	1,126,236.71	0.93	3,996,763.29	3,700,706.75
1997	2	5,257,122.87	1,723,010.49	0.86	3,534,112.38	3,029,931.73
1998	3	5,392,875.05	2,343,207.02	0.79	3,049,668.03	2,420,924.81
1999	4	5,530,126.34	2,987,524.29	0.74	2,542,602.04	1,868,888.41
2000	5	5,668,732.88	3,656,676.08	0.68	2,012,056.80	1,369,372.05
2001	6	5,808,530.28	4,351,403.87	0.63	1,457,126.41	918,236.80
2002	7	5,949,341.25	5,072,459.70	0.58	876,881.54	511,651.96
2003	8	6,090,968.35	5,820,618.68	0.54	270,349.66	146,061.51
2004	9	6,233,194.19	6,596,676.40	0.50	-363,482.21	-181,831.60
2005	10	6,375,840.55	7,401,400.47	0.46	-1,025,559.93	-475,032.68
2006	11	6,518,490.10	8,235,803.79	0.43	-1,717,313.69	-736,526.41
2007	12	6,660,984.43	9,100,557.16	0.40	-2,439,572.74	-968,787.90
2008	13	6,802,979.04	9,996,607.95	0.37	-3,193,628.90	-1,174,290.72
2009	14	6,944,133.80	10,924,862.10	0.34	-3,980,728.30	-1,355,282.90
2010	15	7,084,078.57	11,886,249.67	0.32	-4,802,171.09	-1,513,844.60
2011	16	7,222,411.90	12,881,723.96	0.29	-5,659,312.07	-1,651,899.24
2012	17	7,358,697.82	13,912,264.29	0.27	-6,553,566.47	-1,771,225.54
2013	18	7,492,464.34	14,978,875.13	0.25	-7,486,410.79	-1,873,467.03
2014	19	7,623,200.82	16,082,587.11	0.23	-8,459,386.29	-1,960,141.86
2015	20	7,750,354.90	17,224,458.83	0.21	-9,474,103.93	-2,032,652.01
2016	21	7,873,232.51	18,405,675.16	0.20	-10,532,442.65	-2,092,330.27
					Net Present Value (NPV)	**617,216.66**

3.3. Sensitivity analysis

The sensitivity analysis results based on the upper and lower limits of interest rate. The result (Table 6) shows the net ecological values benefit at 8 percent (primary interest rate) and 10 percent as the upper limit interest rate while the lower limit interest rate (6 percent) displayed a net ecological value costs.

Table 6: Results on sensitivity analysis test

	Interest Rates	NPV Results (US$)
Upper Limit	10%	4, 527, 633. 97
Primary Limit	8%	617, 216. 66
Lower Limit	6%	– 5, 086, 436. 04

4. Discussion

This GIS based study found that the net ecological value benefits of BE varied enormously across the coastline in the study period (1995–2016), generally displaying declining trend. Expanding BE in the face of rising human population proved to be the causal factor for the declining vegetation cover along the coastline, with very little contribution on production and supply of ecological benefits. The presence of continual declining trend of net ecological value benefits in spite of BE expansion through the study period is a strong proof of such observation.

Expanding BE reduces the connection between biospheres' compartments. This impacts ecosystems structure, components and functions, thus negatively affecting the ESV production and supply in the landscape (Zari, 2014; Parris, 2016). Quantifying such impacts of BE is necessary for informed decision making, notably in investment analysis and conservation initiatives. Ecological benefits is substantial as they are other economic and financial factors considered in investment planning, therefore understanding and conducting ecological valuations is crucial in investment financial mechanisms. Capturing and analysis of net ecological value benefits in today's digital and sustainability generation underscores resources allocation with respect to investment risk management (In *et al.* 2019, Dennig *et al.* 2017).

The findings highlight how technological–based approach can facilitate availability of various information, thus availability of input variables for integrated resources value modelling for investment analysis. The influence of input variables is central in computing net ecological value benefits; as observed in these findings. Study findings show that net ecological benefit values kept decreasing throughout the study period, but negative values emerged from 2005 through 2016. Such display might be a result of coupled impact of population and real estates growth rates of 5 percent in 2005 and 6.1 percent in 2006 respectively. While population growth rate is associated with vegetation clearance for livelihoods, real estates growth, promotes vegetation clearance for infrastructural facilities; which in turn accounts to a great deal on carbon emission.

5. Conclusion

Although studies by Bateman *et al.* (2005), Croitoru and Sarraf (2018), Grzebieluckas *et al.* (2012) and Solís-Guzmán *et al.* (2018) admit the complexity of capturing environmental costs resulting from degradation, this study using GIS technology, Landsat imageries, valuation proxies and CBA modelling has managed to display the impacts (costs) of BE from monetization impact perspective. Since such costs fall on the society as a whole, output of research like this is central to informed decision making hence affect environmental sustainability initiative. Innovations on integrating environmental issues into CBA model has revealed that more work has to be done from green construction projects perspectives, in particular, along the coastline of Dar es Salaam metropolitan.

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Declaration of interest statement

The authors declare no conflicts of interest regarding the publication of this paper.

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