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Analysis of Socio-Ecological Impacts of Built Environment at Dar es Salaam Metropolitan Coastline, Tanzania

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Abstract

This paper analyzed and mapped the impact of built environment (BE) on socio-ecological services along Dar es Salaam metropolitan coastline. In the period of 1995-2016, burgeoning population exacerbated high rate of construction processes and activities. Such anthropic initiatives affect the benefits and values delivered by landscape wetlands, estuaries, beach areas, open space and greenery patches in Dar es Salaam coastline. Motivated to understanding socio-ecological impacts (SEIs) of BE along the coastline; the study applied focus group discussions (FGDs) method to identify SEIs, and their category as either positive or negative. Using analytical hierarchy process (AHP) generated weight to each SEIs; thereafter combined that weight with landuse landcover (LULC) change statistics of each of the 67 wards involved in the study. Mapping results of geographically weighted regression and inverse distance weighting (IDW) interpolation (ArcMap v10.3) displayed the variables relationship magnitudes and distribution in positive and negative SEIs for year 1995, 2005 and 2016.

1. Introduction

The wholeness understanding of coupled human-environment interactions [1] [2] involves seamless biophysical, social and economic factors [3]. The flow and use of these factors at spatial, temporal and organizational scale are under control of complex combination of feedback mechanisms from environmental, eco-

logical and social systems [4]. Such intertwining feedbacks results in complex systemic relationship, termed as socio-ecological system (SES) [5] [6] [7].

Existence of human desire for improved economic and social services in SES are external stimuli to coastline resources utilization hence degradation of ecological system [5]. Studies [8] explain that coastline, also referred to as coastal zone, ranges from 60 to 200 kilometre inland and 50 m depth of ocean water system. In between exists highly fertile areas like continental shelf, estuaries and wetlands at both low and high tide periods [9]; these fertile characters are a reason for dominant human perturbation in such areas [10] [11]. While [12] justified the relationship of anthropogenic activities and coastal zone, little has done to disclose the existing link of BE and its impact on SES.

BE as a product of construction activities [13], in the search for suitable and comfortable places for recreation, residence and work; impacts the landscape by aggravating vegetation cover clearance, waste generation and permanent consumption of a piece of land [14] [15]. The habitat loss and fragmentation caused by such impacts account significantly for biodiversity loss. According to [16], the functioning of biodiversity species are greatly the determinant of the quality and quantity of services derived from SES. Thus, state of landscape loss or gain of such biological component is a socio-ecological impact (SEI) that alters SES functioning capacity [17]. Scholars such as [18] and [19] typify that some of the positive SEIs include cooling, shadow, air filtration, climate variability and flood prevention by trees; pollinations by avian and arthropods species as well as medicines and food from both fauna and flora.

However, irreversible anthropic construction activities provoke landscape environmental challenges as result of megacities development processes and activities [20] [21]. In the search for quality product of BE, demolition is part-and-parcel in construction sector, thus construction and demolition (C & D) terminology [22]. From global-to-regional-to-local settings, C & D depicts serious challenges affecting SES [23]. Global statistics show that C & D activities worth one million US$, generates 28 to 121 tons of wastes with variations observed among countries [24]. Waste generation stream in C & D activities extends to involving excavation and extraction of resources such as rock and soil, waste asphalt, concrete, bricks, timber and vegetation, plasterboard, asbestos and contaminated soil. Studies [25] epitomize that in developing countries such wastes constitute between 25 to 55 percent of municipal waste reaching the landfill; consequently contributing hugely to environmental degradation. According to [26] C & D wastes generation indicates the rate of urbanization, economic and social activities, which altogether exacerbate environmental degradation in the coastal zone cities such as Dar es Salaam. Indirect and direct downsizing of marshes, water, fen or peatland in a wetland by BE shapes the SEIs as well as SES capacity to deliver such impacts, thus negative SEIs [27] [28].

Further studies [29] [30] [31] exemplify that the ancillary impact of BE is on its ability to create novel habitats. These non-natural habitats like constructed wetland, home planted trees, pavements, and backyard and flower gardens are

instrumental on SEIs to urbanites. [32] and [33] epitomize that some BE characteristics like household debris and roadside tree strips influence existence of urban species that can co-exist with human being, hence, increase biodiversity species in a human-dominated landscape. Furthermore, changes in biogeochemical cycles linked to urban BE emission, atmospheric flow and sea breezes interaction present more impact to SES [34]. The response of different biodiversity species, in particular, human being to changes happening in the SES differ significantly [35]; similarly the perceptions of negative and positive SEIs.

Nonetheless, practically, positive and negative impacts of BE do co-exist in the same SES, in a way that feedback of either side triggers differently the SES [36]. This being the case, the positive or negative perception of coastal urbanites on SEIs is likely not to be permanent [37]. Therefore, this paper driven by the objective to understanding the interactions between human being, construction activities, built environment and natural resources; analyzed the perceived SEIs of BE in the coastline of Dar es Salaam Metropolitan. Furthermore, the research sought the correlation between vegetation, BE and agricultural landscape in the study area for the past 21 years, from 2016.

2. Literature Review

Socio-ecological system (SES) as a scientific discipline emerged from social ecological theory, which is rooted in the general system theory (the interdisciplinary study of systems) [38]. Studies [39] [40] reveal the existing high demand of interdisciplinary and transdisciplinary approaches toward investigating the interplay and interrelationships of human and natural systems. Despite the fact that interdisciplinary approaches have used in research for decades [38], the past two decades has seen huge application of SES in explaining the interactions in and between factors in the field of environmental sciences, economics, social sciences as well as medicines and psychology [41] [42]. Scholars on interdisciplinary study of systems provide five levels of interactions that govern the SES [43], interaction levels such as intra-individual, interindividual, organization, community and macropolicy profoundly influence interdependent changes [41]. Changes inside an individual in one level influences changes to neighbouring individual and level, hence the mutual influence and effect at one level impacts diversely and variously at another level [44] [45]. According to [13] [46] environmental changes due BE while ensure places for work, residence and recreation, its influences largely result into loss of natural biome habitats. The pace of population growth has promoted urbanization, which in turn disrupts and degrades nature and environmental resources, in particular, ecological system [13] [47].

Scholars depict that the impacts of construction activities as irreversible [15]. The socio-economic impacts of BE is associated with its characteristics of taking and seating permanently on a piece of land [5] [48] [49], thus restricting the biomes connectedness [11] [18] [44] [50] [51]. According to [10] [11] BE notably

human settlements account for significant changes of global landscapes, hence pose serious challenges socially, economically and environmentally. While construction and demolition industry that result into BE account for huge employment and income generation [22] [25] [26], nevertheless its impacts to ecological systems threatens the global community [22] [25] [26] [47] [52] [53]. Public health research [1] [41] [46] reveal the association of physical exercise and urban planning, the absence of space and green infrastructure is reported to influencing public health problems [54].

Despite varying challenges associated with BE; on the other hand studies [8] [29] [30] epitomize the significant roles of BE on creating novel habits for urban biodiversity. Furthermore, presence of debris, home and roadside trees as novel habitats in urban settings influence presence of biodiversity at varying degrees [30]. All biodiversity species that can co-exist in human dominated environment are likely to flourish [29], while weak species in human dominated landscape are likely to escape into different habitats. In either case the degree of biodiversity heterogeneity in a particular landscape is pivotal to an efficient and effective functioning of SES [6] [16] [43] [55] [56], in the context of assuring supply and access to ecosystem services.

3. Material and Methods

3.1. Study Area

Dar es Salaam metropolitan is located between Latitude 6°3'43.09"S & 7°10'47.35"S and Longitude 39°6'36.37"E & 39°33'5.66"E at 24 meters above sea level, on the southwestern coast of the Indian Ocean in Tanzania (Figure 1). It covers a total area of 1800 square kilometre, of which 1350 square kilometre is landmass including its eight offshore islands; the rest is water-covered area. The Geographically lowland Dar es Salaam experience 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-degree 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 [57] [58] [59]. Governed in 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 [48]. 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 [60].

3.2. SEIs in Dar es Salaam Metropolitan Coastline

Dar es Salaam metropolitan, home to about 10 percent of the country population
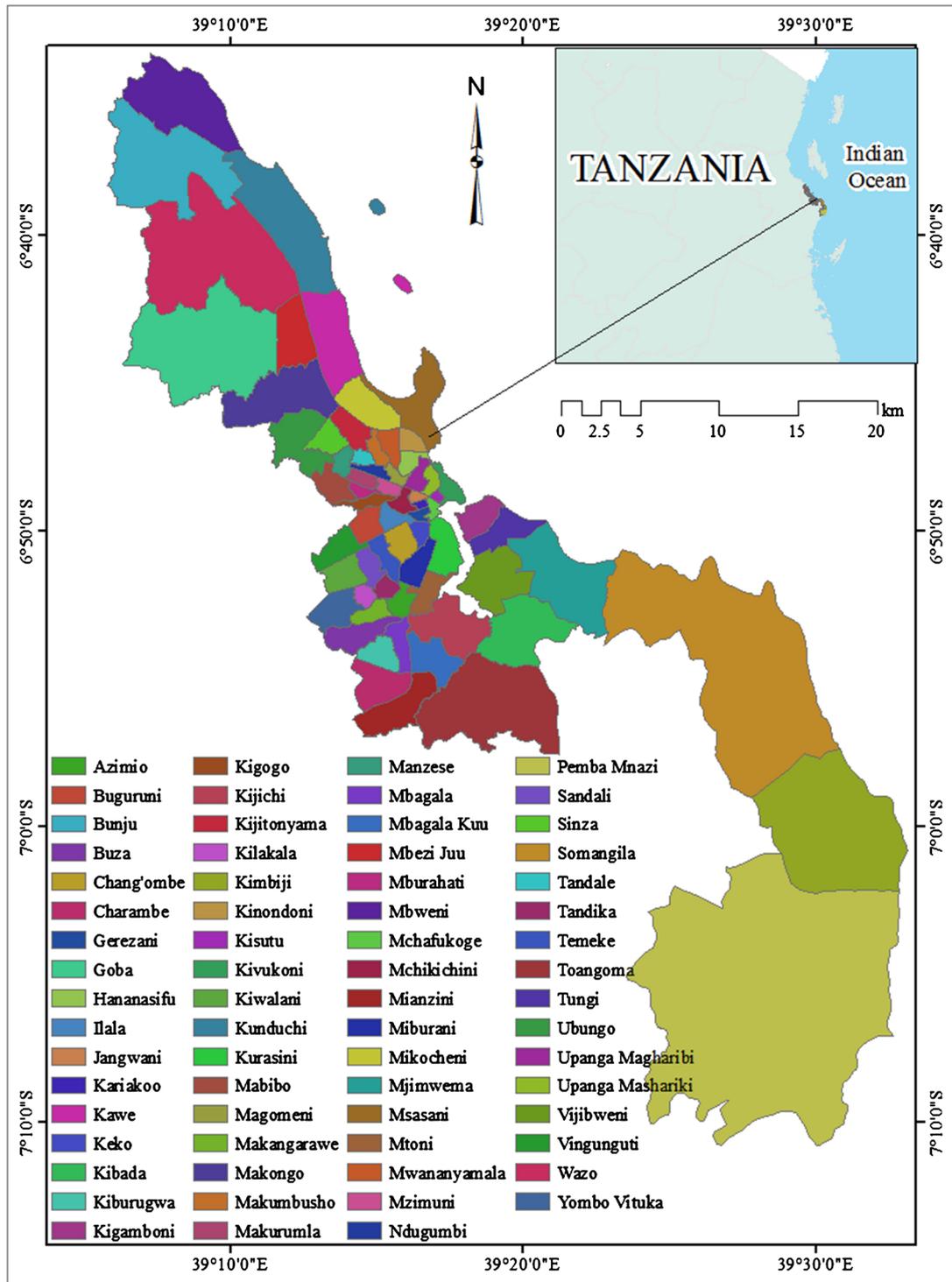
Figure 1. Map of Dar es Salaam metropolitan coastline displaying study area.

estimated to be 55 M; at an urbanization rate of 34 percent, is the most industrialized and urbanized city in Tanzania [57]. Growing population, mostly due to rural-urban migration drives city places to experience rapid urbanization and degradation of local environment; consequently, loss of habitat and species, increased noise, air pollution and soil erosion. Studies [61] reveal that rising pop-

ulation speed-up C & D activities hence 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 [49] Dar es Salaam metropolitan BE development pattern is characterized along the two main rivers, Msimbazi and Mzinga; and four main road namely Nyerere heading to Airport and Kisarawe, Ali Hassan Mwinyi to Bagamoyo, Morogoro that heads to Morogoro region, and Kilwa road that stretches to Lindi region. Kilwa and Ali Hassan Mwinyi roads that are along shoreline are likely to have great influence on SEIs to coastal resources as compared to Nyerere and Morogoro roads that are afar shoreline. Nevertheless, SEIs, as it is to all other environmental impacts, know no borders [62]. The SEIs considered in this research sited in a minimum of 3 kilometre to a maximum of 16.8 kilometer horizontal distance from the seashore along the north-south coast of Dar es Salaam metropolitan.

3.3. Methods

3.3.1. Data and Sources
The study intended on analyzing BE impacts on socio-ecological system using focus group discussions and Landsat satellite imageries extracted data. Landuse landcover (LULC) statistics (**Appendix 1**) extracted from Landsat satellite imageries for 1995, 2005 and 2016, freely downloadable from Earth Explorer USGS website. The FGDs involved field survey, to observe, identify and understand socio-ecological issues that community members perceive to affecting their daily livelihoods. Using FGDs, perceived SEIs of BE collected from 67 wards of the study area bordered with Indian Ocean water. Fourteen (14) SEIs (**Table 1**) that emerged dominant, subjected to further analysis.

3.3.2. Multi-Criteria Decision Analysis and Weight Generation
Decision-making is a day-to-day activities we all do, [63] hypothesize that either consciously or unconsciously, good decision depends on the information gathered. According to [64] decision making requires knowledge of the problem and its socio-ecological context, the objective for the decision, criteria for decision-making, stakeholders affected, prioritization of alternative actions and assessment of trade-off. The combination of all these factors results into complexity, such that combination made by integrating all aforementioned factors need a powerful tool of analysis. Achieving good judgment from combined criteria as mentioned above, involves the use of tools such Multi-Attribute Utility Theory, Analytic Hierarchy Process, Fuzzy Set Theory, Case-based Reasoning, Data Envelopment Analysis, Simple Multi-Attribute Rating Technique, Goal Programming, ELECTRE, PROMETHEE, Simple Additive Weighting, and Technique for Order of Preference by Similarity to Ideal Solution. These tools are representative of multicriteria decision analysis (MCDA) [65].

This socio-ecological study used analytical hierarchy process (AHP) to under-

stand the interactions of socio-ecological impacts (SEIs) along Dar es Salaam metropolitan LULC. The advantage of AHP over other MCDA tools is its capacity to integrating tangible and intangible effects of input variables [66] [67] [68]. In AHP, pairwise comparison square matrix involves assigning values to an element, such that the element in consideration will be a reciprocal of the value of the element in comparison. In AHP method, scale of values to be assigned to an element ranges from 1 (equally important) to 9 (extremely important). In this case, similar criteria being equally important are assigned 1; thus, the value of 1 in the diagonal element of comparison matrix. Dividing each criterion assigned value by the column total in pairwise comparison matrix, form an input on respective criterion in normalization matrix. Each column sum in normalized matrix should be equal to 1.The weight of each criterion is obtained by dividing each row sum in the normalization matrix by the matrix order; the weight obtained is also referred as eigenvectors.

According to [69], the decision rule is based on consistency ratio (CR), that CR < 0.1; this is the validity threshold in AHP method. CR is a ratio of consistency index (CI) and random index (RI) (Equation (2)). In order to get CI (Equation (1)), maximum eigenvalue involves the total sum of product between each column total in pairwise comparison and eigenvector (row average weight) in normalization matrix. The value of RI depends on the matrix order/number of problems (Table 2). The final AHP output (Table 3 and Table 4) provided useful inputs in further analysis in this study.

Table 1. Dar es Salaam coastline socio-ecological impacts (SEIs) of BE.

Negative criteria of SEIs of BE	Positive criteria of SEIs of BE
A. Loss of traditional norms and culture	J. Enhances social services infrastructural development
B. Pollution of terrestrial and hydrological system	K. Create various employment opportunities
C. Confrontations/land conflicts	L. Provide income for landlords
D. Destruction of landscape and aesthetic	M. Enhances housing services
E. Loss of biodiversity and economically important trees	N. Improves landscaping and aesthetics
F. Soil degradation, erosion and loss of fertility	O. Creates novel habitats for biological species
G. Source of breeding for flies and diseases vectors	
H. Loss/reduction of farm and grazing lands	

Note: in the rest of the article, numbering letter will represent its SEIs respectively.

Table 2. Lambda maximum/Saaty random consistency index (RI) value.

Number of problems (n)	2	3	4	5	6	7	8	9	10
Random index (RI)	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

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Table 3. Pairwise comparison matrix on relative weight of negative socio-ecological impacts of built environment.

	A	B	C	D	E	F	G	H	Weight
A	1	1/2	1/2	1/2	1/3	1/2	1/2	1/9	0.043
B	2	1	1/3	1/2	1/3	1/2	1/2	1/2	0.066
C	2	3	1	1/2	1/2	1/3	1/2	1/3	0.081
D	2	2	2	1	1/2	1/2	1/3	1/2	0.094
E	3	3	2	2	1	1/2	1/2	1/3	0.121
F	2	2	3	2	2	1	1/2	1/3	0.137
G	2	2	2	3	2	2	1	1/4	0.159
H	9	2	3	2	3	3	4	1	0.299

Maximum eigenvalue (γ_{max}) = 8.782; Number of criteria/problems (n) = 8; Consistency index (CI) = ($\gamma_{max} - n$)/($n - 1$) = 0.112; Random index (RI) = 1.41; Consistency ratio (CR) = 0.079.

Table 4. Pairwise comparison matrix on relative weight of positive socio-ecological impacts of built environment.

	J	K	L	M	N	O	Weight
J	1	1/3	1/3	1/2	1/3	1/2	0.074
K	2	1	1/3	1/2	1/3	1/2	0.096
L	3	3	1	1/2	1/2	1/3	0.149
M	2	2	2	1	1/2	1/2	0.162
N	3	3	2	2	1	1/2	0.233
O	2	2	3	2	2	1	0.285

Maximum eigenvalue (γ_{max}) = 6.438; Number of criteria/problem$s$ (n) = 6; Consistency index (CI) = ($\gamma_{max} - n$)/($n - 1$) = 0.088; Random index (RI) = 1.24; Consistency ratio (CR) = 0.071.

$$CI = \frac{(\gamma_{max} - n)}{(n - 1)} \quad (1)$$

$$CR = \frac{CI}{RI} \quad (2)$$

where CI is the consistency ratio;

γ_{max} is the maximum eigenvalue;

n is the number of criteria/matrix order;

CR is consistency ratio;

RI is random index.

3.3.3. Geographically Weighted Regression Analysis

The knowledge of spatially distributed variables and observations though significant, had not been part of statistical analysis methods applied to environmental and social sciences data. Spatial dependence science explains the effect of proximity on value similarities when mapping socioeconomic variables [55] [70]. The science behind various models that make-up GWR appreciates how variables

vary from one geographical location to another [71]. Statistical analysis of such variability required a special technique, henceforth the use of GWR. Advancement in GIS & RS science integrated with GWR has enabled statistical analysis on spatially distributed data across a certain geographical area [72]. Furthermore, GWR provides an opportunity to understand the difference of regression parameters and model performance across the study area [73] [74]. This study adopted the Gaussian adaptive kernel type to understand the relationship between vegetation cover as dependent variable and independent variables namely BE and agriculture. The value of finest bandwidth defined by the GWR algorithm method involves technique such as Akaike Information Criteria (AIC) [75]. The AHP SEIs generated weight at ward level for BE, vegetation and agriculture combined with LULC statistics provided necessary inputs for GWR mapping using ArcMap v10.3.

3.3.4. Spatial Interpolation and Mapping Impacts of BE

Spatial interpolation is a useful GIS technique of estimating unmeasured data based on measured samples of the same variables [76] [77]. The advent of remote sensing (RS) and geographical information system (GIS) have proved to solving some challenges emanating from time and financial resources with respect to data access and utilization. Furthermore, physical-legal complexities on data capturing, management and consumption contributed significantly to the wide application of spatial interpolations in environmental sciences, geoscience and continuous spatial surface data [78] [79]. According to [80], interpolation science provide efficient techniques to map and understand continuous spatial phenomenon, in particular the spatio-temporal physical changes on the globe landscape. Studies [80] [81] epitomize that knowing GIS procedures, the quality of the work to be performed and geographical boundaries of the study sites; interpolation offers an opportunity to understand and predict the occurrence, distribution and magnitude of an environmental phenomenon with respect to social and economic factors [82]. Studies [76] [78] [79] [83] exemplify spline, kriging, natural neighbor and inverse distance weighting (IDW) as the commonly used geospatial interpolation methods. In this study, IDW, a geospatial analysis tool that treat values of unsampled point as weighted average of values at points within certain cut-off distance [84] is applied to understanding the distribution pattern of SEIs of BE along Dar es Salaam Metropolitan coastline.

3.3.5. Panel Regression Analysis

Working with spatio-temporal data is simply means dealing with space and time-based data. While spatial (space) pertains to observations at a locality, temporal (time) component considers observations over a certain period. The panel data characteristics of carrying cross-sectional and time-series dimensions is key in understanding overall, within and between variations amongst variables [85]. Such knowledge is crucial in change-detection studies like socio-ecological impact analysis. Knowing how variables influence each other, within and between

gauges the overall interactions henceforth-thoughtful characterization of variables and their relative effects. Furthermore, advantage of panel regression on geographically weighted spatio-temporal data lies in its capacity to amplify sample size, thus more degree of freedom, variability and efficiency for estimation with less collinearity among variables [86].

In this study, panel data involved both geographically weighted vegetation cover as a dependent variable (DV), and agriculture and BE as independent variables (IV). This econometric model in STATA v14.1 did take the form presented in Equation (3).

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \cdots + \beta_k X_{k,it} + (\alpha + \varepsilon_{it}) \tag{3}$$

where Y_{it} represents vegetation cover, entity, i at time, t;

β_0 is a model constant;

β_k is the coefficient for independent variables;

$X_{k,it}$ represents BE and agriculture;

α is the specific time invariant effects;

ε_{it} is the error term.

4. Results

4.1. Modelling Spatial Relationships of SEIs

The LULC changes AHP weighted data on BE, agriculture and vegetation as variables with respect to positive and negative SEIs, separately analyzed using GWR in ArcMap v10.3. The analysis results displayed a poor relationship between variables in the southern part of the study areas, particularly in year 1995. Contrary to year 1995, in 2005 and 2016, the same section of the study area experienced very strong relationship between variables of on both positive and negative SEIs (Figure 2). Generally, positive and negative SEIs occurred simultaneously.

4.2. Impact of Built Environment

Treating vegetation cover as a dependent variable, and BE and agriculture as independent variables into robust fixed panel regression analysis, revealed significant negative effect of BE on vegetation cover while agricultural activities displayed insignificant effect on vegetation cover. Table 5 provides detailed analysis results. Furthermore, spatial interpolation using IDW on impact distribution and pattern, displayed the northern section of the study area to experiencing strong impact of BE than the rest (Figure 3).

4.3. Results Summary

Spatial relationship modelling (GWR) displayed simultaneously occurrence of both positive and negative SEIs, nonetheless an obvious changes was observed in the southern part of Dar es Salaam Metropolitan. In 1995 the section displayed a very weak relationship in both positive and negative SEIs as compared to 2005 and 2016 that showed a very strong relationship. Results from spatial distribu-

tion modelling (IDW) exposed the northern section of Dar es Salaam Metropolitan to be experiencing more impact of BE than other areas. The highest magnitude of positive SEIs relationship was changed from 0.89 in 1995 to 0.99 in 2016, in similar times interval, negative SEIs similarly changed from 0.91 to 0.99. Additionally, in 1995 IDW indicated 0.000037 as the lowest negative impacts of BE as compared to 0.000052 in 2016, in the same time periods, IDW showed 0.000048 as the lowest positive impacts of BE as compared to 0.000069 in 2016.
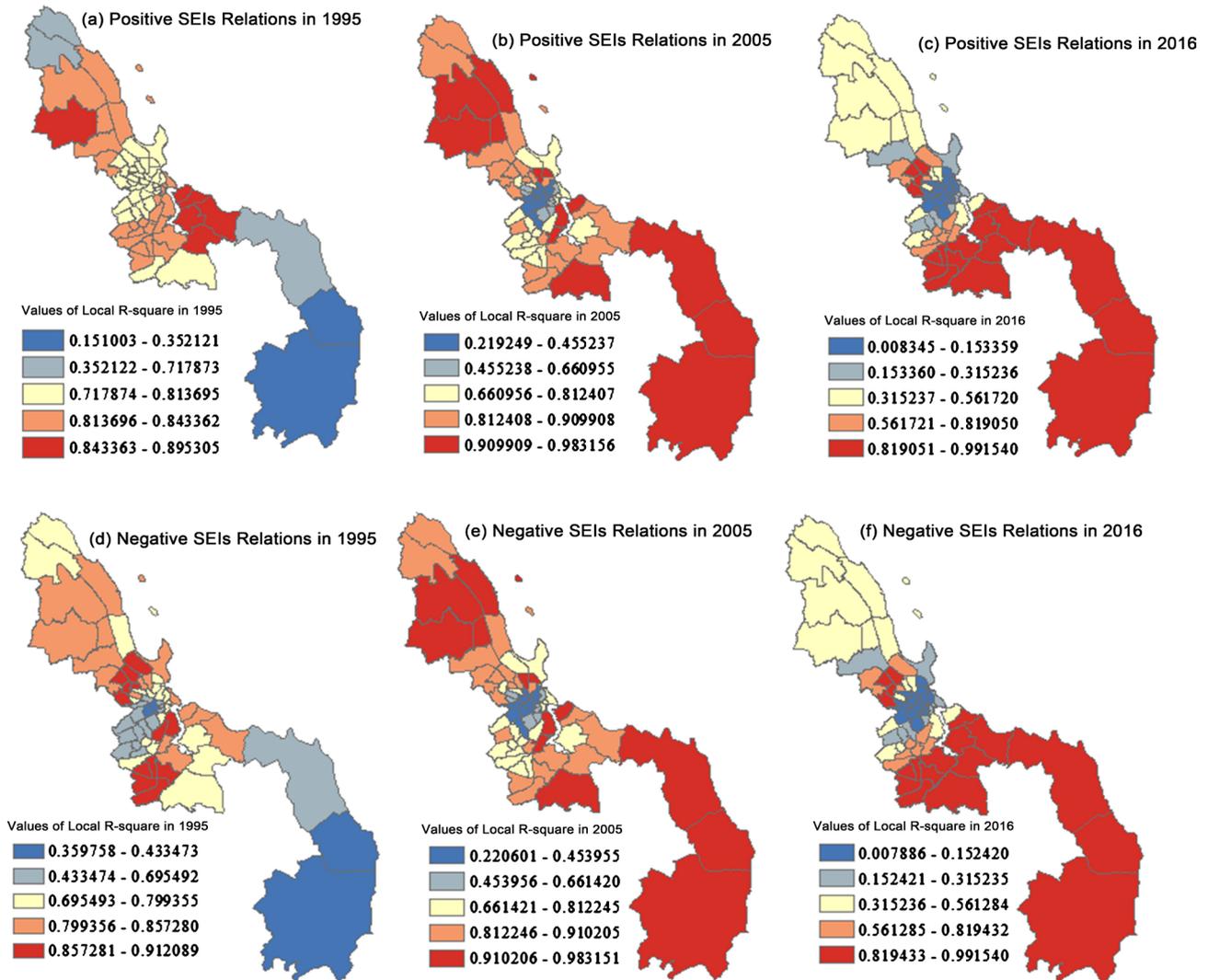
Figure 2. GWR analysis of positive and negative relationships in the study area.

Table 5. Fixed effect panel regression analysis of LULC statistics of the study area.

Vegetation	Coefficient	Standard Error	t	P > |t|
Built environment	−0.3405852	0.1358987	−2.51	0.015
Agriculture	0.0599997	0.144274	0.42	0.679
Constant	0.000272	$5.07e^{-06}$	5.37	0.000

R square: within = 0.0358; between = 0.4356; overall = 0.3669. F Statistics (2, 66) = 4.76. Model test (Prob > F) = 0.0117.
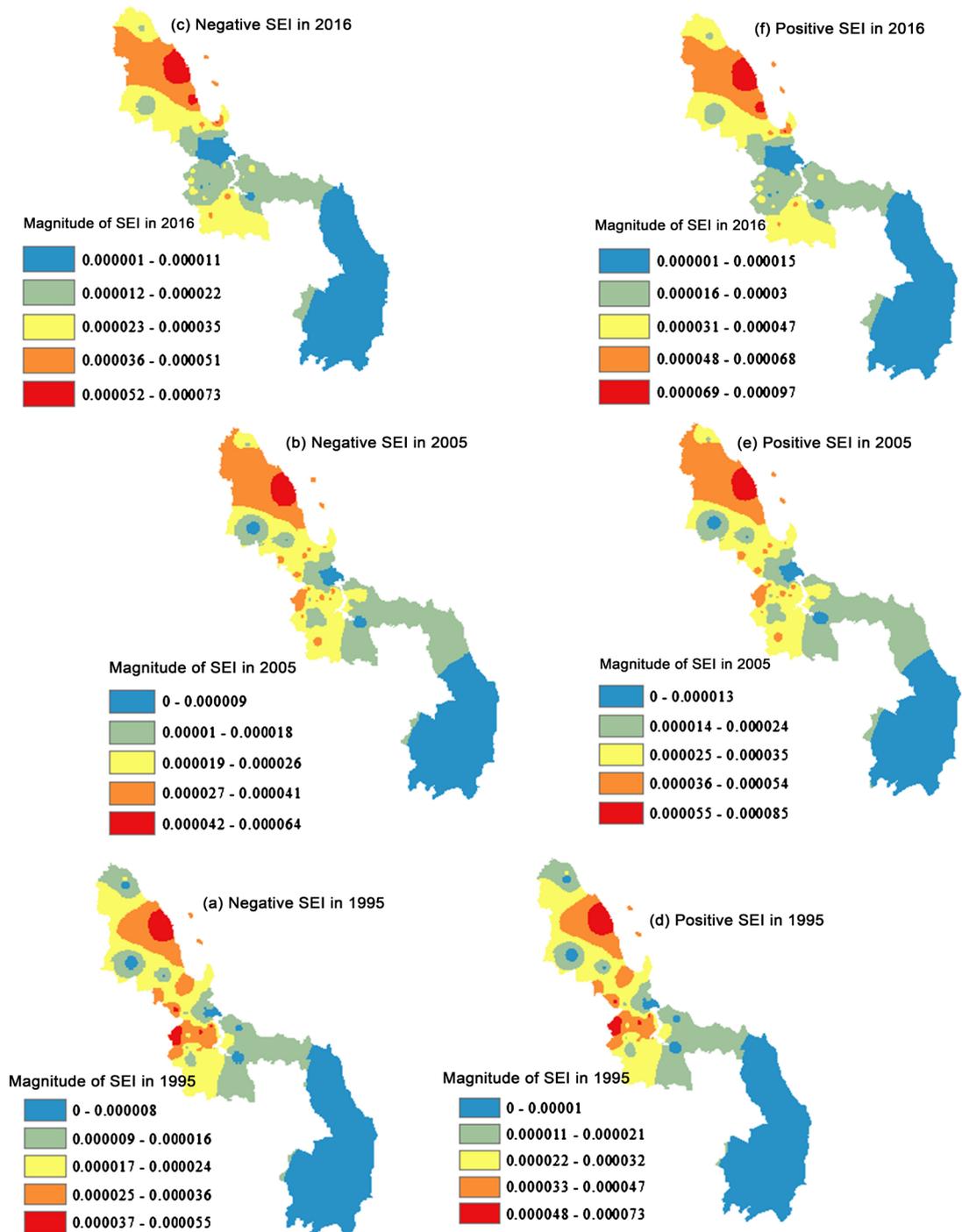
Figure 3. IDW spatial interpolation of BE impacts at Dar es Salaam Coastline.

5. Discussion

Study findings revealed that increasing BE decreases vegetation cover; this anthropogenic force influences LULC on the local environment [23]. The LULC changes due to provision of building materials and demand for food is likely to influence negative SEIs like loss of biodiversity and economically important trees, loss/reduction of farm and grazing land, soil degradation, erosion and loss

of fertility, destruction of landscape and aesthetics and loss of sacred place hence loss of traditional norms and culture. On the other hand, BE, with its construction and demolition waste, wastewater systems, urban runoff channels and stagnant water ponds account for pollution of terrestrial and hydrological system, and breeding sites for flies and diseases vectors.

The positive SEIs of BE as a product of construction and demolition processes and activities is associated with the desire to enhance social services infrastructure, employment creation, income generation and improvement of aesthetics and landscaping. Novel habitats creation for biological species is positive SEIs of BE, resulting from the interconnectedness of construction and demolition activities but also presence of home trees, flower and backyard gardens. Studies [87] exemplify that urban residential yards and residents' perception on biodiversity and ecosystem services are fundamental to urban novel habitats and biodiversity species presence. In this study, geospatial interpolation (Figure 3) displayed not only increasing but also high magnitude values of positive SEIs across the study period as compared to negative SEIs respectively. The strong spatial relationship of SEIs displayed in the southern part of the study area (Figure 2) is associated with high magnitude of BE impacts in the northern part (Figure 3). Loss of vegetation cover in the southern section of Dar es Salaam Metropolitan could be resulting from increasing BE landscape; resources-rich southern part is the base for construction materials extraction and supply as well as agricultural landscape expansion.

As findings revealed, SEIs observed in the study area is due to land development likely for infrastructure development; which in-turn creates income and employment. Developed land though lead to loss of natural aesthetics; nonetheless, beautify the landscape to suite the appetite of the developer. Consequently, the degraded area once subjected into construction and demolition processes and activities improve to a better scenic as well as for other uses, including species habitats. In practice, the overlapping characteristics of positive and negative SEIs are due to complex intertwined relationship between human being and nature [88], though in all study periods, negative SEIs has low magnitude values than positive SEIs accordingly. Practically strengthened synergies on people-nature connection with respect to nature values and values conservation into construction projects; could be a strategically promising initiative likely to make BE deliver more positive SEI in this fast urbanizing global landscape.

6. Conclusion

The study applied analytical hierarchy process (AHP), geographically weighted regression (GWR) analysis, IDW geospatial interpolation and fixed effect panel regression to analyze the SEIs of BE in the coastal line of Dar es Salaam metropolitan. Although positive and negative SEIs occur concurrently, findings and analysis revealed significant changes in southern part of the study area. In the southern part, the magnitude of SEIs changed from very low in 1995 to very high

in 2016. Panel regression revealed the inverse relationship between BE and vegetation cover; the BE expressed significant negative impact on vegetation cover as compared to agriculture. Therefore, strengthened efforts on people-nature connection, through integrating nature values and conservation initiatives in construction projects could provoke more strategic management of SEIs of BE.

Authors' Contribution

Mkama Manyama designed the study, collected the data, analyzed and wrote the manuscript. Dr. Cuthbert Nahonyo and Dr. Aloyce Hepelwa supervised the study and revised the manuscript.

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Conflicts of Interest

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

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Appendix 1. Landuse Lancover (LULC) Change

FID	Ward	VEG1995	AGRIC1995	BE1995	VEG2005	AGRIC2005	BE2005	VEG2016	AGRIC2016	BE2016
0	Azimio	40	16	178	78	6	158	9	21	212
1	Buguruni	82	25	237	83	13	246	7	82	257
2	Bunju	2512	714	157	2091	917	278	280	2310	748
3	Buza	412	61	55	276	145	115	17	160	359
4	Chang'ombe	65	2	276	43	32	269	10	33	300
5	Charambe	532	65	124	242	203	273	23	131	553
6	Gerezani	14	0	64	10	3	68	3	7	71
7	Goba	3775	780	24	3522	1005	48	290	4055	228
8	Hananasifu	58	0	104	77	3	101	20	13	148
9	Ilala	67	1	144	53	8	152	7	27	179
10	Jangwani	19	0	45	4	1	59	0	6	58
11	Kariakoo	0	0	41	0	0	41	0	0	41
12	Kawe	781	460	188	957	198	251	91	471	854
13	Keko	34	1	110	23	6	117	3	6	136
14	Kibada	1492	291	19	1310	218	31	236	1175	113
15	Kiburugwa	266	23	102	109	96	187	6	88	293
16	Kigamboni	245	52	55	266	73	129	86	160	206
17	Kigogo	47	1	116	36	2	126	0	17	145
18	Kijichi	686	277	127	701	243	200	157	431	568
19	Kijitonyama	135	21	236	121	19	252	3	27	363
20	Kilakala	42	6	104	43	10	100	2	11	139
21	Kimbiji	5239	452	0	3906	1684	16	1454	4155	36
22	Kinondoni	95	2	92	97	4	88	2	7	178
23	Kisutu	12	0	15	2	0	26	0	1	27
24	Kivukoni	139	6	14	101	15	50	16	42	103
25	Kiwalani	99	5	324	92	32	306	13	44	371
26	Kunduchi	1718	357	380	1452	423	555	300	1068	1096
27	Kurasini	151	42	300	129	47	320	21	48	430
28	Mabibo	84	21	276	79	18	284	5	40	335
29	Magomeni	40	1	68	36	1	71	8	10	90
30	Makangalawe	111	35	93	85	28	124	8	18	210
31	Makongo	1264	435	48	1469	194	81	488	895	353
32	Makumbusho	22	0	153	17	3	153	1	8	165
33	Makurumla	11	0	144	17	1	137	1	6	147
34	Manzese	18	4	161	8	2	174	1	5	177

Continued

35	Mbagala	175	45	113	149	43	141	10	60	258
36	Mbagala Kuu	407	92	154	351	143	161	42	188	424
37	Mbezi Juu	599	160	125	609	139	125	23	363	491
38	Mburahati	25	1	85	20	6	85	2	7	103
39	Mbweni	1941	283	10	1414	546	300	253	1776	244
40	Mchafukoge	17	0	51	9	1	58	0	7	60
41	Mchikichini	80	1	88	72	6	90	31	17	121
42	Mianzini	546	77	145	460	142	164	45	231	489
43	Miburani	137	25	226	113	41	234	26	69	293
44	Mikocheni	373	163	218	475	37	241	37	94	615
45	Mjimwema	1411	784	33	1741	276	166	297	1542	362
46	Msasani	544	134	142	686	48	231	51	96	782
47	Mtoni	103	24	184	125	10	190	50	32	247
48	Mwananyamala	81	3	163	58	4	186	3	16	229
49	Mzimuni	33	0	89	27	2	92	4	15	103
50	Ndugumbi	16	0	115	11	2	118	0	2	129
51	Pemba Mnazi	18643	906	0	14965	4719	0	6093	13667	8
52	Sandali	108	26	139	105	28	141	21	82	170
53	Sinza	165	57	112	99	14	222	6	59	269
54	Somangila	6950	2625	39	6956	2555	119	2515	7190	75
55	Tandale	2	4	109	5	0	110	0	3	113
56	Tandika	26	2	143	20	7	143	5	7	159
57	Temeke	62	6	224	41	19	232	9	29	254
58	Toangoma	2582	576	60	2567	575	136	560	2363	380
59	Tungi	359	124	105	302	86	225	49	286	257
60	Ubungo	477	273	192	654	39	247	226	302	413
61	Upanga Magharibi	145	0	48	122	7	66	107	9	79
62	Upanga Mashariki	67	0	77	54	6	83	16	6	122
63	Vijibweni	725	185	127	739	233	147	99	670	330
64	Vingunguti	114	17	312	79	17	343	20	60	362
65	Wazo	4382	705	225	3492	1388	292	329	4104	711
66	Yombo Vituka	271	39	228	219	85	234	21	115	402