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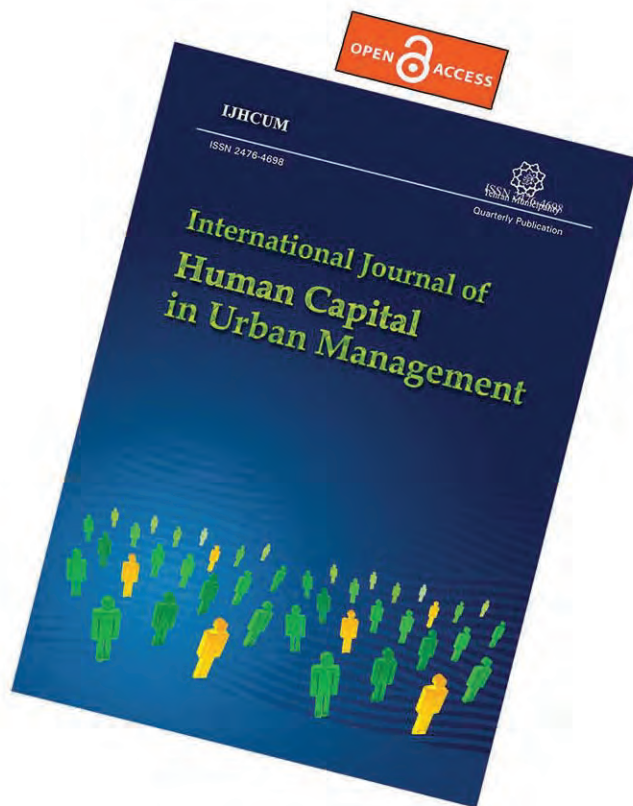
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ORIGINAL RESEARCH PAPER

Spatiotemporal analysis of remotely sensed Landsat time series data for monitoring 32 years of urbanization

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ABSTRACT

The world is witnessing a dramatic shift of settlement pattern from rural to urban population, particularly in developing countries. The rapid Addis Ababa urbanization reflects this global phenomenon and the subsequent socio-economic and environmental impacts, are causing massive public uproar and political instability. The objective of this study was to use remotely sensed Landsat data to identify and quantify the land use and land cover types, as well as changes over time. Maximum likelihood algorithm of the supervised image classification was used to map land use land cover types, which consisted of Vegetation areas, built-up areas, agricultural lands, Bare lands, and Scrublands, for 1985, 2003, and 2017 images. Built-up areas (69 %) are the dominant land cover type in the study area, followed by Agricultural lands (22%) and Vegetation areas (7%), though the compositions have changed since 1985. Rapid urban growth is evidenced by the expansion of built-up areas by 370% the growth is at the expense of agricultural and vegetation areas, exposing farmers to loss of massive farmland and woodlands. Additionally, urbanization eroding percent green and open spaces, while also degrading the diversity of the city's land use land cover types. With one of the world's highest fertility rates and massive rural-to-urban migration, unsustainable Addis Ababa urbanization is likely to continue for the foreseeable future. It is, therefore, critical to adapt sustainable urban planning, which involves consideration of Compact City, Secondary Cities, and Edge city designs to mitigate the adverse impacts of the rapid Addis Ababa urbanization.

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INTRODUCTION

According to World's population prospects of the United Nations ([World Population Prospects, 2019](#)), the shift of human population from rural to urban living is growing rapidly. The urban population jumped from 750 million in 1950, to 4.2 billion people in 2018 (i.e., constituting 55 % of the world's population).

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The rate is expected to grow to 68 % (i.e., 5 billion people) by 2050, and developing countries constitute 90 % of this urban population growth. Ethiopia's accelerated urban population growth is reflective of this phenomenon ([Tegenu, 2010](#)). According to the Central Statistics Agency, Ethiopia's urban population is projected to nearly triple from 15.2 million in 2012 to 42.3 million in 2037, growing at about 5.4 % a year ([Bimerew, 2015](#)). Especially, Addis Ababa, the largest city in Ethiopia, is witnessing massive influx of people

and urbanization thereof. Principal driving forces of the urbanization are natural growth (birth) rate, redistricting rural towns into cities and rural-to-urban migration (Mahiteme, 2007; CSA, 2007; Teller *et al.*, 2011; Bimerew, 2015). Addis Ababa's birth rate (i.e., 36.5 births/1,000), is relatively high even among the cities of developing countries (CSA, 2007; Teller *et al.*, 2011), whereas the merger of many Oromian smaller towns into a city (i.e., gerrymandering) is causing both numerical and spatial expansion of Addis Ababa (Teller *et al.*, 2011). Almost half of Addis Ababa's population growth is attributed to rural-to-urban migration. The migration is triggered by rural "push" factors consistently higher than the opportunities, services and amenities the city can provide (Bimerew, 2015). As a consequence, the phenomenon is exerting immense pressure on the city and resources of the surrounding Oromia regional state (Fleischman and Peck, 2015). For instance, heightened demand of land for residential, commercial, industrial, institutional and other uses is causing various environmental issues (Young, 2014; Kassa, 2014). Common environmental issues include, but are not limited to, deforestation, expansion of impervious surfaces, erosion and shrinkage fertile agricultural lands (Birhanu, *et al.*, 2016; Derara and Tolosa, 2016; Tarekegn and Gulilat, 2018). Additionally, the phenomenon has caused significant areas of the city to become dominated by crowded and slummy settlements, which are suffering from problematic housing; poor portable water, limited electricity supply and sanitation; and rampant environmental pollution, poverty and social unrest (Gumbo, 2010; Tarekegn and Gulilat, 2018). Moreover, the city itself is unsustainably and unbearably being affected by widespread unemployment, food insecurity, severe shortage of public amenities and reduced transportation services for its residents (Etana and Tolossa, 2017). According to Etana and Tolossa, (2017), approximately 55.9 % of Addis Ababa households are unemployed and only 12.4 % are food secure. Therefore, the main objective of this study was to use archived Remote Sensing (RS) data and geospatial technologies to understand the extent and impacts of Addis Ababa's 32 years urbanization (i.e., 1985 – 2017). Several studies have deployed remotely sensed data for mapping urban Land Use and Land Cover (LULC) types and changes in cities of developing countries (Mallupattu and Reddy, 2013; Rawat and Kumar, 2015; Hassan *et al.*,

2015; Cheruto *et al.*, 2016; Kassawmar *et al.*, 2018). In Ethiopia, such studies are conducted mainly on highlands and watersheds important for agricultural production and natural resource conservation (Etefa *et al.*, 2018; Miheretu *et al.*, 2018; Yesuph and Dagne, 2019). Limited studies investigated spatial matrix and morphological analysis Ethiopia's urban expansion (e.g., Terfa *et al.*, 2019), and yet efforts with regards to drivers and its environmental implications have been inconclusive. Generally, LULC assessment is significant in understanding built environment as it provides important information with regards to geographical locations, characteristics, proportions and distributions of the states, and patterns of urbanization. Additionally, the urban land dynamics could reveal processes and trends of environmental impacts, such as but not limited to processes, factors contributing and consequences thereof. These understandings are crucial for guiding developmental needs of land resources, urban land use mapping, sustainable urban development policies, and predictions of future urban growth, particularly for rapidly growing cities in the developing countries (Etefa *et al.*, 2018; Rimal *et al.*, 2018; Yesuph, and Dagne, 2019). The current study carried out in Geographic Information System (GIS) laboratory of the department of Geography, College of Arts and Sciences, Chicago State University in USA. Data acquisition, quality control, analysis and reporting were done between 2018 and 2020.

MATERIALS AND METHODS

Study area

Addis Ababa, was founded in 1887 and became the capital city of Ethiopia between 1889 and 1891. The city was founded on a land originally occupied by an indigenous Oromo nation of Ethiopia and currently, it has triplet city statuses. It is the capital city of both the country as well as Oromia regional state (Fig. 1). It is also the diplomatic capital of Africa as it hosts the headquarters of the African Union, the United Nations Economic Commission for Africa (ECA) and many other continental and international organizations. Addis Ababa is currently home to over 4.8 million people (WMI, 2020). Geographically, the city is centrally located at Latitude 9° 01' 29.89" N and Longitude 38° 44' 48.80" E. Topographically, situated in the foothills of the Entoto Mountains, which stands out 3,000 m above sea level, the has an average

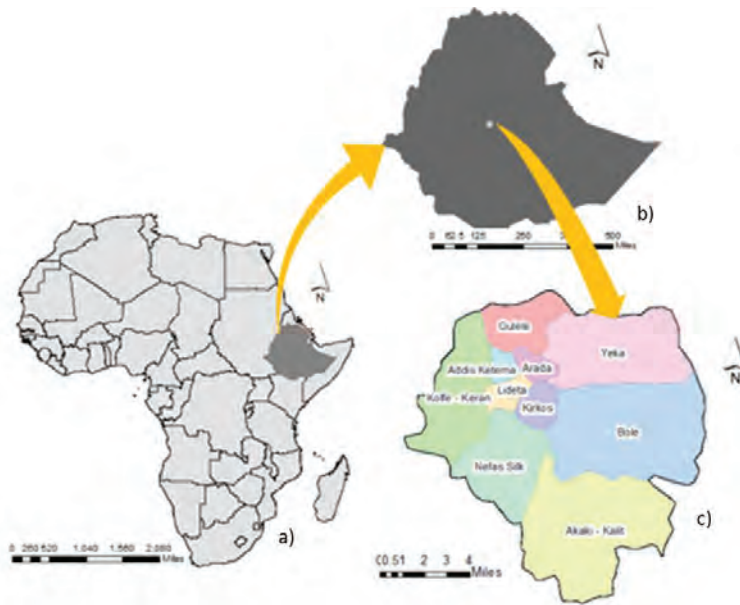


Fig. 1: Map of the study area: a) and b) are maps of Africa and Ethiopia, respectively to show the context; and c) Addis Ababa city and sub-cities

Table 1: Specifications of landsat thematic mapper TM images

Year	Date of Image Acquisition (mm/dd/yyyy)	Sensor	Cloud cover (%)	Image Quality	Swath Width	Spatial Resolution
1985	01/02/1985	Landsat 4-5 Thematic Mapper (TM)	0	9	185 km * 185 km	30 m x 30 m
2003	01/12/2003	Landsat 7 Enhanced Thematic Mapper Plus (ETM+)	0	9	185 km * 185 km	30 m x 30 m
2017	01/08/2017	Landsat 8 Operational Land Imager (OLI)	0	9	185 km * 185 km	30 m x 30 m

elevation of 2356 m and occupies 536 km² (333-mile square) land area. The annual mean temperature of Addis Ababa ranges between 7 °c – 24 °c, May being the hottest month while December is the coldest. On average, it receives 1,165 mm of rainfall annually, although the precipitation varies considerably from month to month.

Data acquisition and description

This study used remotely sensed imageries of 1985, 2003 and 2017 to monitor 32 years of Addis Ababa urbanization. The imageries taken by a sensor mounted on Landsat thematic mapper (Archive level 1) have 30 m * 30 m spatial resolution and 185 km *

185 km swath width. The images are of high quality, and were taken in the period of January to February as this is a clear sky season in the region. They were acquired from the United States Geological Survey (USGS) after being pre-processed for their systematic and terrain distortions, and geo-rectified and spatially referenced into UTM's coordinate system. Detail specifications of the data are tabulated in [Tables 1 and 2](#).

Land use land cover mapping

LULC mapping comprises image classifications, which include a process of sorting and assigning pixels to categories of LULC classes. The image

Table 2: Specifications of the major LULC types identified in the study area

Role No.	LULC categories	Descriptions
1	Vegetation areas	Lands dominated by density populated trees and shrubs.
2	Built-up areas	Lands modified by human settlement including cities, towns and other infrastructural facilities such as road network.
3	Agricultural lands	Lands modified crop cultivation such as teff, corn, maize, beans and other crops. Lands covered by low vegetation (grasses) or no grasses
4	Barren Lands	Lands covered by gravel pits, pavement, soils or other earthen material etc. It is land areas that are degraded and/or not fertile enough for vegetation growth.
5	Waterbodies	Lands covered with rivers or inundated open water areas mainly lagoons, ponds, lakes and reservoirs (dams) or Lands in transition zones between inundated ponds and surrounding uplands where a hydrologic characteristic produced unique ecosystems.
6	Scrublands	Lands covered by low vegetations, extremely dispersed trees, bushes or shrubs. It is a portion of land (infertile) where plant growth may be sparse, stunted and/or contain limited biodiversity

classification was conducted based on the LULC categories developed by Anderson (1976). Accordingly, six major LULC types were visually identified on current Addis Ababa jurisdiction. The identification was accomplished using high resolution historical and current images via Google Earth Pro. The specifications of the identified LULC types are given in Table 2.

Supervised classification with Maximum Likelihood Classifier (MLC) algorithm was applied for producing the LULC maps of the study area. This classification involves image analysts control over the process through training samples selected for each LULC class. On the other hand, the MLC algorithm develops probability density functions of Brightness Values (X) of each training sample selected. The algorithm evaluated the BV of every pixel on the image and assigns pixels to LULC classes based on their highest likelihood of membership to categories. The probability density functions (p) for a training site Wi is given by Eq. 1 (Richards, 2013):

$$\hat{P}(X|Wi) = \frac{1}{(2\pi)^{1/2} \hat{\sigma}_i} e^{-\frac{1}{2} \frac{(x - \hat{\mu})^2}{\hat{\sigma}_i^2}} \quad (1)$$

Where e = the natural logarithms, x is the brightness values, μ = the estimated mean of the values of the class and σ = the estimated standard deviation of the values in the class.

For a multispectral image, the n-dimensional density function is given by Eq. 2.

$$P(X|Wi) = \frac{1}{(2\pi)^{\frac{n}{2}} |V_i|^{\frac{1}{2}}} e^{-\frac{1}{2} (x - M_i)^T V_i^{-1} (x - M_i)} \quad (2)$$

Where V_i = the determinant of the covariance matrix, V_i^{-1} = inverse of the covariance matrix, $(x - M_i)^T$ = the transpose of the vector $(x - M_i)$ the mean of the vectors (M_i) and variance matrix (V_i) for training sites of each class. Therefore, the maximum likelihood decision of X is a member of W_i is given by Eq. 3.

$$P(x|w_i) \cdot P(w_i) \geq P(x|w_j) \cdot P(w_j) \quad (3)$$

Where i and j are possible training sites of LULC classes under consideration.

The mapping accuracies of the image classification was performed using stratified random sampling method for 150 randomly selected points in Earth Resources Data Analysis System (ERDAS) Imagine software. It was stratified such that each LULC types has at least 20 randomly selected points for evaluation. The 150 random points were ground truth data referenced from high resolution Google Earth pro for comparison with produced map. Four statistical indices were used to evaluate the accuracies of the map produced: Overall, Producer and User accuracies, and Kappa statistics.

Overall accuracy (OA) is the ratio of correctly classified pixels to the total number of pixels given by Eq. 4.

$$OA = \frac{\text{Total number of text pixels correctly classified}}{\text{Total number of pixels in test set}} \quad (4)$$

Producers accuracy (PA) is the proportion that a land cover of an area is as correctly classified as the ones produced on the map and is given by Eq. 5.

$$PA_i = \frac{\text{Number of test pixels correctly classified for class } i}{\text{Number of pixels in test class } i} \quad (5)$$

User accuracy (UA) is the probability that a land cover mapped corresponds to it on the ground, and it is given by Eq. 6.

$$UA_i = \frac{\text{Number of pixels correctly classified in class } i}{\text{Number of pixels classified as class } i} \quad (6)$$

Overall, Producer and User accuracies are expressed as a percent ranging from 0 – 100 %; and 0 % mean poor mapping accuracy while 100 % indicate an excellent mapping. On the other hand, The Kappa analysis is used to measure the proportion of agreement between classified image and reference data after a possible agreement by chance is removed (Congalton, 1991). KAPPA index ranging from 0 to 1; and while 0 means poor agreement, 1 means great agreement. KAPPA (\hat{K}) index is computed as in Eq. 7.

$$\hat{K} = \frac{P_o - P_c}{1 - P_c} \quad (7)$$

Where P_o = proportion of correctly classified pixels, and P_c = proportion of pixels correctly classified by chance.

Only the result of image classification, which produced an overall accuracies and kappa statistics of the maps ranged between 84 % - 95.7 % and 0.87 – 0.94, respectively; are considered for LULC map production. However, before the LULC map production, the classified maps were cleaned from random noises known as speckles. Majority filter is a neighborhood operation deployed with a moving 7 X 7 window to ‘clean up’ the image and making it visually attractive. Majority filter is the most common smoothing neighborhood operation (Mather and Koch, 2011). Finally, cleaned and visually presentable maps were clipped into appropriated sizes of the study area for publication and further change analysis.

Monitoring Addis Ababa urbanization

Addis Ababa urbanization was monitored using anniversary images of 1985, 2003 and 2017. The monitoring is conducted by quantifying pixel-based changes using Land Change Modeler (LCM) of TerrSet software of Clark lab (clarklabs.org). For this the model requires two LULC maps at a time (e.g., 1985 vs 2003; 2003 vs 2017, and 1985 vs. 2017 LULC maps) to quantify the patterns and processes of urbanization. LCM performs the analysis in three panels: Change analysis, Change maps and Spatial Trend analysis of change. The Change maps produced gains/ losses and persistent maps, which illustrated and quantified areas of Addis Ababa that gained, lost or maintained built-up areas and percent change from the urbanization during the study period. Percent Change (PC) is given by Eq. 8.

$$PC = \left(\frac{\text{Number of pixels Changed for a class}}{\text{Area of a class in the later LULC map}} \right) * 100 \quad (8)$$

Change analysis provided map of changed area, graphs and tables of importance for quantifying areas of LULC contributing to the observed change in urbanization. Percent Area (PAr) is estimated by Eq. 9.

$$PAr = \left(\frac{\text{Number of pixels changed for a LULC class}}{\text{Total areas of the LULC map}} \right) * 100 \quad (9)$$

Finally, Spatial Trend of Change panel used for indicating areas enduring activities of hotspots urbanization (Eastman, 2012).

RESULTS AND DISCUSSION

LULC map of Addis Ababa

The map of the 1985 image identified and mapped five LULC types. These are: Vegetation areas, Built-up areas, Agricultural lands, Bare-lands and Scrublands (Fig. 2a). Accordingly, the dominant LULC type of Addis Ababa land was Agricultural lands, which stretched over approximately 315 km² (i.e., 59 %), followed by Vegetation areas, which occupied 109 km² (i.e., 20 %) and the cloth third Built-up areas, which held 101 km² (i.e., 19 %). The remaining less than 2 % (11.4 km²) of the city was Bare-lands (8.8 km²) (i.e., degraded lands covered

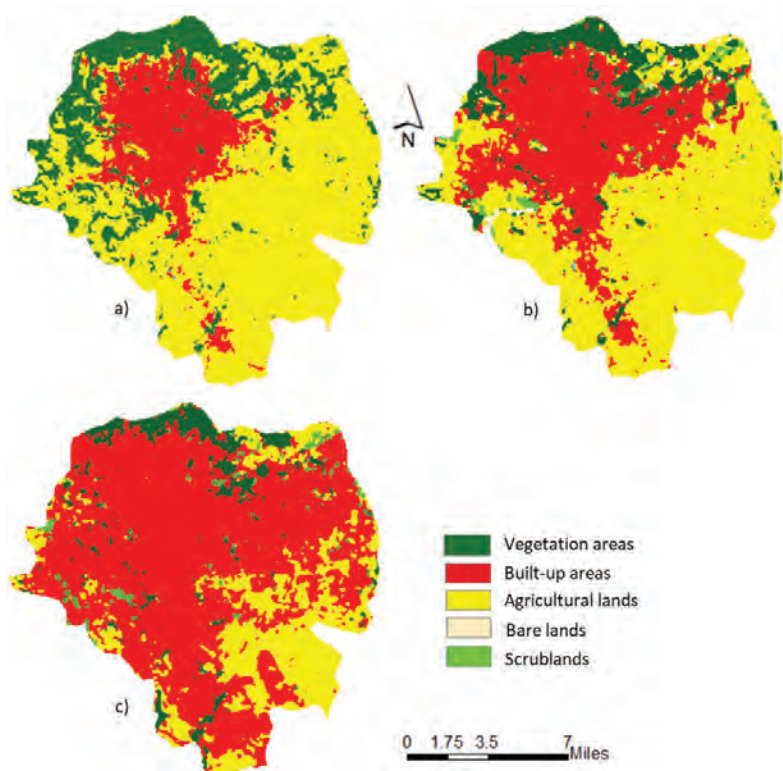


Fig. 2: Classified LULC Map of Addis Ababa: a) 1985; b) 2003 and c) 2017

by gravel pits, pavement, soils or other earthen material etc....) and scrublands (2.6 km²). Similarly, the map of Landsat 2003 image discovered the same 5 LULC types (Fig. 2b). Still the dominant LULC type of the city's jurisdiction was Agricultural lands, and was stretched over 264 km² (i.e., 49 %), which is 51 km² (i.e., 16 %) less than the size in 1985. The second dominant LULC type was Built-up areas, overtaking Agricultural lands and occupied 187 km² (i.e., 35 %), followed by vegetation areas, which expanded over 62 km² (i.e., 12 %) of the landscape. Agricultural lands, Built-up and Vegetation areas combined constituted 96% of the Addis Ababa, and the remaining Bare-lands and Scrublands covered only 7% (i.e., 23.4 km²). Bare lands covered a percent (7.4 km²) of the landscape, while Scrublands covered 3% (i.e., 16 km²). On the other hand, the 2017 mapping detected and recognized rather 4 LULC types, one than the maps of 1985 and 2003. These are Vegetation areas, Built-up areas, Agricultural lands and Scrublands (Fig. 2c). In 2017, the Built-up

areas are again the dominant LULC type stretched over 371 km² (i.e., 69 %). Agricultural/Grass lands were the second dominant expanded over 117 km² (i.e., 22 %) followed by Vegetation areas occupying 37 km² (i.e., 7 %). Lands covered by Scrublands (i.e., low vegetations, extremely dispersed trees, bushes) covers only 11 km² (2 %) of the city. However, the intensity of urbanization is not uniform throughout the city (Fig. 3). It ranges from as low as 50% in southern part of the city (i.e., Akaki-Kaliti sub-city) to 99 % in the center (i.e., Addis Ketema, Arada, and Kirkos sub cities).

With an apparent 31% (i.e., 165 km²) open and green spaces (i.e., consisted of Vegetation areas, Agricultural land and Scrublands), Addis Ababa is seemingly green. However, the spatial pattern of the city's greenness is variable with time, and spatially among the sub-cities and their state of development (Fig. 3; Table 3). While the peripheral less developed parts of the city are endowed with green and open spaces in 2017, well-developed parts of the city are

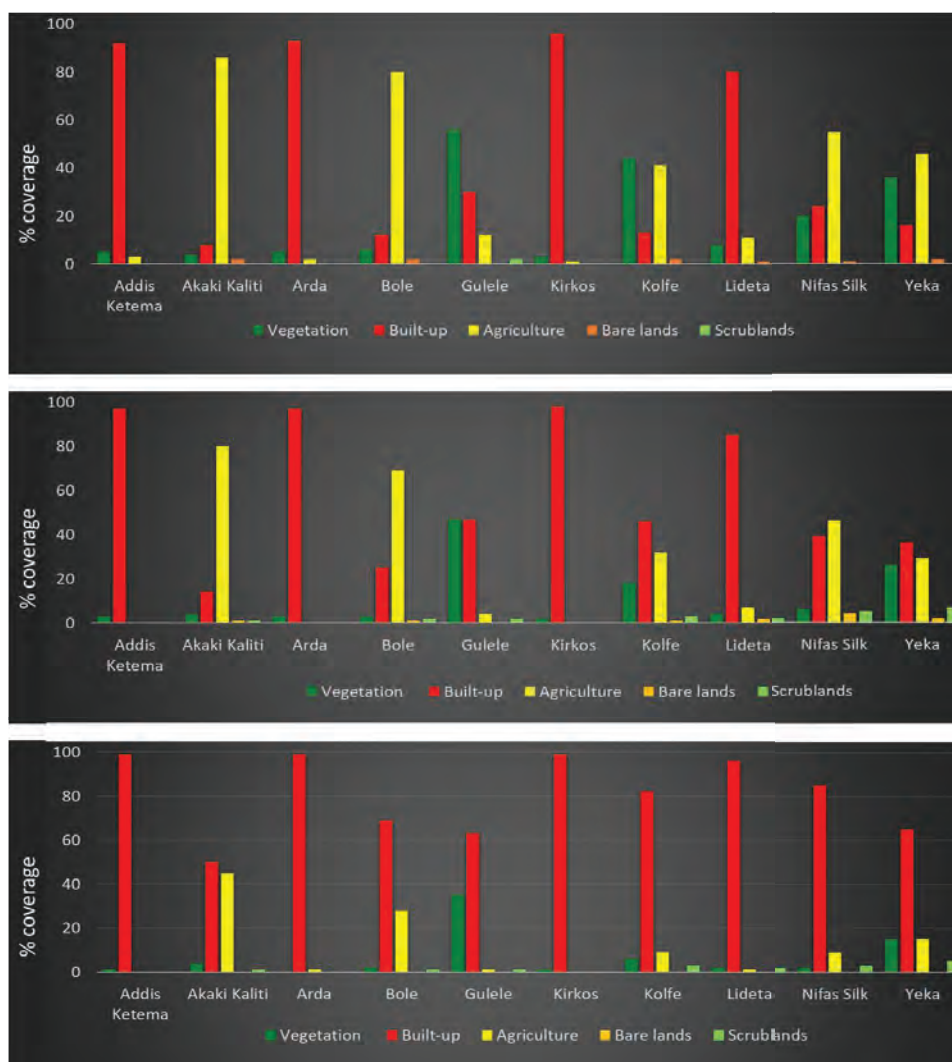


Fig. 3: The distribution of LULC types among the sub-cities of Addis Ababa: a) top is 1985; b) middle is 2003 and bottom is 2017

less green. For example, Addis Ketema, Arada, Kirkos and Lideta are least green with more than 95 % of the landscape being Built-up areas, whereas Gulele and Akaki-Kaliti sub-cities, are 43 – 50 % green or open. These sub-cities are where, much of the Addis Ababa’s greenness is coming from. On the other hand, in 1985 and 2003, relatively human footprint on the city’s environment is further smaller. Built-up areas occupied only 20 and 35 % in 1985 and 2003; respectively, and yet this is extremely localized to few sub-cities (i.e., Addis Ketema, Arada, Lideta and Kirkos) and small geographical areas (i.e., 42 km²)

(Fig. 5; Table 4). Vegetation areas and/or agricultural lands are dominant in 6 out of the 10 sub-cities in 1985 and in half of sub-cities in 2003. Additionally, there is variability in LULC type diversity among the sub-cities. Generally, more developed sub-cities have less diverse LULC types than less developed. For example, developed sub-cities such as Addis Ketema, Kirkos and Arada are less diverse, consisting of only 2 of the 5 LULC types vis-à-vis peripheral less urbanized sub-cities of Akaki-Kaliti, Gulele, Kolfe, Nifas Silk, and Yeka, which consisted of at least 4 of the 5 identified LULC types.

Monitoring 32 years of urbanization

Table 3: LULC types detected and mapped from 2017 Landsat imagery and their corresponding coverages in Addis Ababa sub-cities

	Sub cities	Vegetation (km ²)	Built-up (km ²)	Agriculture (km ²)	Bare lands (km ²)	Scrublands (km ²)
1985	Addis Ketema	0.37	6.73	0.22	0	0
	Akaki Kaliti	5.1	9.16	109	2.54	0
	Arda	0.46	8.2	0.19	0	0
	Bole	7.68	11.3	102	2.56	0
	Gulele	19.36	9.3	3.7	0	2.62
	Kirkos	1.44	13.9	0.15	0	0
	Kolfe	28.6	8.5	26.7	1.3	0
	Lideta	1.88	8.8	1.2	0.11	0
	Nifas Silk	11.68	14	32	0.6	0
	Yeka	32.7	11.7	39.3	1.7	0
	Total	109.27	101.59	314.46	8.81	2.62
2003	Addis Ketema	0.22	7	0	0	0
	Akaki Kaliti	5	17.8	101.6	1.27	1.27
	Arda	0.28	8.2	0	0	0
	Bole	3.8	32	88	1.28	2.56
	Gulele	14.6	14.6	1.24	0	0.62
	Kirkos	0.3	14.2	0	0	0
	Kolfe	11.7	29.9	21	0.65	1.95
	Lideta	0.44	9.4	0.77	0.22	0.22
	Nifas Silk	3.5	22.8	26.8	2.3	2.92
	Yeka	22.2	30.7	24.8	1.7	6
	Total	62.04	187.4	264.21	7.42	15.54
2017	Addis Ketema	0.07	7.25	0	0	0
	Akaki Kaliti	5.1	63.5	57.1	0	57.1
	Arda	0.0	9.2	0.1	0	0.1
	Bole	2.6	88.3	35.8	0	35.8
	Gulele	10.9	19.5	0.31	0	0.31
	Kirkos	0.15	14.4	0	0	0
	Kolfe	3.9	53.3	5.9	0	5.9
	Lideta	0.22	10.6	0.11	0	0.11
	Nifas Silk	1.17	49.4	5.2	0	5.2
	Yeka	12.8	55.5	12.8	0	12.8
	Total	36.7	370.9	117.32	0	11.23

Change detection and analysis

The assessment of land transformations and urbanization thereof, on Addis Ababa landscape, is shown in Fig. 4. Accordingly, the 32 years' land change assessment, approximately 296 km² lands, were changed in one form or another, which is 55 % of Addis Ababa. Urbanization accounted for 271 km² of the land transformation, i.e., 92 % of the overall land change, while the remaining 8 % (i.e., 25 km²) is attributed to changes from vegetation to Agriculture and/or Agriculture to badlands. Generally, the Built-up areas grew to 189 km² and 373 km² in 2003 and 2017, respectively; from what was 101 km² acreage in 1985. Therefore, the process of urbanization took place at rates of 180 % between 1985 -2003; and 370

% between 1985– 2017.

Further analysis of land change was also enumerated areas that gained, lost or maintained Built-up areas (Table 4). From 1985 to 2003 and 2003 to 2017, Addis Ababa gained 89 km², and 189 km² lands of Built-up areas, respectively. In general, there is an overall gain of 271 km² Built-up areas over the 32 years. On the other hand, although small, 2 km² and 4 km² of Built-up areas were transformed into other LULC types between 1985 to 2003 and 2003 to 2017; respectively. These losses amount to, approximately, 2 % of gains made by Built-up areas demonstrating a rather intensive e processes of urbanization of Addis Ababa. Built-up areas remained intact on 101 km² and 185 km² of lands between 1985 – 2003 and 2003

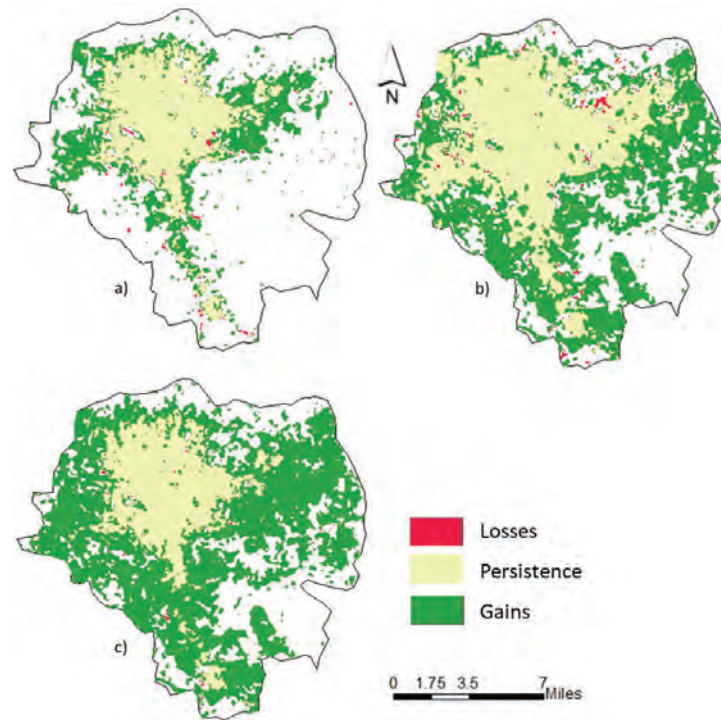


Fig. 4: Losses and gains of Built-up areas in Addis Ababa: a) 1985 – 2003; b) 2003 – 2017 and c) 1985 - 2017

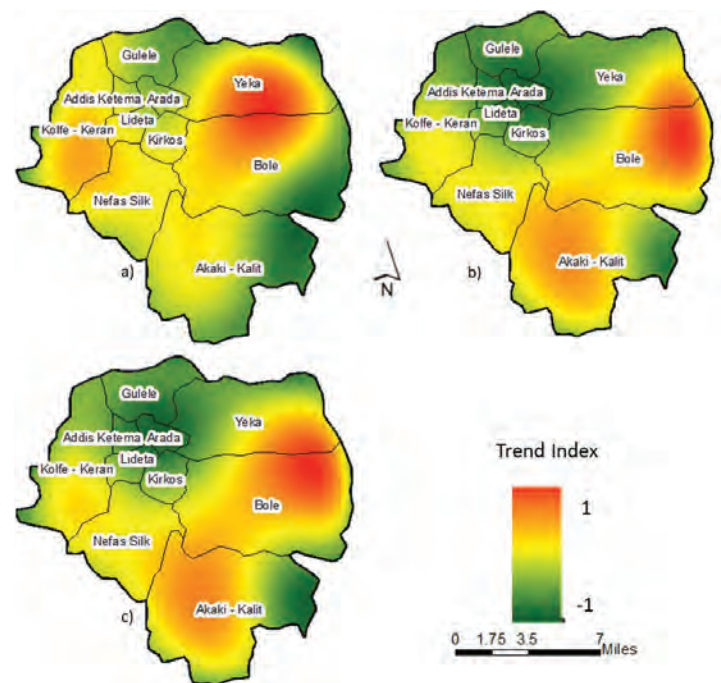


Fig. 5: Spatial trend analysis of 32 years Addis Ababa Urbanization: a) 1985 – 2003; b) 2003 – 2017 and c) 1985 - 2017.

– 2017, respectively. These are 54 % and 49 % of the Built-up areas in 2003 and 2017; indicating a relative speedier urbanization process in the second half of the study period (i.e., 2003 – 2017) versus the first half (i.e., 1985 – 2003).

Moreover, the analysis of LULC types contributing to the net urbanization of Addis Ababa city is shown in Table 5. Accordingly, the major LULC type contributing to the gains of Built-up areas is Agricultural lands. Approximately, 64 km², and 211 km² of Agricultural areas have turned into Built up areas between 1985 – 2003 and 1985 – 2017, respectively. From 2003 – 2017, Agriculture lands contributed 159 km² towards Addis Ababa Built up areas indicating again the higher rate of urbanization in the second half of the study period (2003 – 2017). The contribution of Agricultural lands is roughly 74 % - 85 % of the urbanization, which are 200 % - 560 % more than the contribution Vegetation areas. Vegetation areas contributed only 21 km², and 24 km² areas of lands toward Built-up areas between 1985 – 2003 and 2003 – 2017, respectively. Both Agricultural lands and Vegetation areas together, contributed to 99 % of gains made by Built up areas, while the remaining bare lands, and Scrublands contributed infinitesimal land towards Addis Ababa urbanization.

Lastly, the analysis of spatial trend of Addis Ababa urbanization is shown in Fig. 5. Accordingly, in 2003, the hotspots of Addis Ababa urbanization were areas in the northeastern part, specifically regions of Yeka and Bole sub-cities. Additionally, a mild rate of urbanization is noted in the western part (i.e., south of Kolfe Keranio and northeast of Nifas silk sub-cities). However, during the same time, the central, northern,

southern and southeastern parts of Addis Ababa have shown no sign of urbanization. While the central part of the study area is already developed, topographies of the north parts may have limited the process of urbanization this region. On the other hand, in 2017, the urbanization hotspots shifted towards the west and southern parts, particularly Bole and Akaki-Kaliti sub-cities. During the same period, urbanization of Kolfe-Keran, Nifas silk and Yeka were relatively mild, while again the northern part of the city shown no sign. The reason could be that areas of Nifas Silk and Kolfe-Keran have already developed fully by 2003 that urbanization shifted further south in 2017. In general, Addis Ababa urbanization took place in the northeastern, eastern, southern, south western and western part of the city, while the north (i.e., Gulele and northern Yeka) and central (i.e., Addis Ketema, Arada, Lideta and Kirkos) are least influenced.

The economic, social and environmental implications of the urbanization

The global phenomenon of rapidly growing urban population is pronounced on Addis Ababa. Addis Ababa, being the capital city of Ethiopia, as well as Oromia regional state, is attracting massive influx of people. Consequently, unsustainably rapid Addis Ababa population growth and urbanization thereof, is effecting city's poor social services and infrastructures, while also engulfing the lands of surrounding farmers, thereby risking fierce land competition and local food security. Five major LULC types were detected, recognized and mapped; demonstrating a strong capability of Landsat data for assessing and monitoring urban landscape. These

Table 4: Land change types of Built-up areas 1985 to 2003

Change types	1985 - 2003	2003 - 2017	1985 - 2017
Losses	2 km ²	4 km ²	0.7 km ²
Persistence	101 km ²	185 km ²	101 km ²
Gains	89 km ²	189 km ²	271 km ²

Table 5: Land use and land cover types contributing to increase in Built-up areas

LULC Types	1985 - 2003	2003 - 2017	1985 - 2017
Vegetation	21 km ²	24 km ²	59 km ²
Agriculture	64 km ²	159 km ²	211 km ²
Bare lands	0.32 km ²	2.3 km ²	0.5 km ²
Scrublands	-0.2 km ²	0 km ²	-0.2 km ²

are Vegetation areas, Built-up areas, Agricultural lands, Bare-lands and Scrublands, Built-up areas are the dominant LULC types followed by Agricultural lands and Vegetation areas; together covering 98 % of Addis Ababa landscape. The distribution of contemporary (i.e., 2017) LULC types of Addis Ababa is a departure from historical LULC, indicating the impact of urbanization. Historically (i.e., 1985), Agricultural lands dominated the landscape followed by Vegetation areas and then Built-up areas. However, with almost a third of its land currently covered by Vegetation areas, Agriculture and Scrublands, Addis Ababa is apparently green; although distributions of green and open spaces are geographically variable. Additionally, urbanization has impacted the diversity of the city's LULC types. In general, the 32 years' monitoring of Addis Ababa Built-up areas detected a rapid process of urbanization taking place at the expenses of Agricultural lands and Vegetation areas, mainly in the south and southwestern part of the city.

The LULC types detected on Addis Ababa landscapes is consistent with other studies (Wang and Murayama, 2017; Fenta *et al.*, 2017; Miheretu *et al.*, 2018). In the LULC change studies of Tianjin city, china; Wang, and Murayama (2017) found five types of LULC: Built-up, Cropland, Grass, Forest, and Water; whereas, Fenta *et al.*, (2017), detected similar 5 LULC for Mekelle city of northern Ethiopia, namely: Agricultural lands, Built-up areas, Plantation, Shrublands and Waterbody. Similarly, the pattern and process of Addis Ababa urbanization is also comparable to experiences of other cities of developing countries (Oyugi *et al.*, 2017; Rimal *et al.*, 2018; Habila, 2018). According to Oyugi *et al.*, (2017), the east African city of Nairobi increased by 238 % over 22years (i.e., 1988 – 2010); while the capital city (i.e., Abuja) of Africa's populous nation (i.e., Nigeria) reported to have grown by 426 % over 28 years (i.e., 1988 – 2016) (Habila, 2018) and Nepal's cities of the Kathmandu valley expanded at by 346 % over 28 years (i.e., 1988 – 2016) (Rimal *et al.*, 2018). Moreover, the urban encroachment on Agricultural lands is also commensurable to impacts seen on another cities' expansion (Prakasam, 2010; Friehat *et al.*, 2015; Habila, 2018; Rimal *et al.*, 2018). Accordingly, urbanization of Abuja-Nigeria (Habila, 2018), northeastern Illinois (Friehat *et al.*, 2015) and Kathmandu valley city-Nepal (Rimal *et al.*, 2018), took place at the expenses of reductions

in Agricultural lands by 31 %; 26 % and 16 %; respectively. Additionally, Pribadi and Pauleit (2015) indicated that a rapid urbanization of Jabodetabek city, Indonesia, to have been possible due to city's extensive encroachment on surrounding farmlands. Addis Ababa's rapid urbanization is having various implications (Young, 2014; Tarekegn and Gulilat, 2018; Birhanu *et al.*, 2016; Derara and Tolosa, 2016; Bimerew, 2015). According to Young (2014), the city is under massive construction activities to meet rapidly growing demands for housing and infrastructure, which area causing various environmental problems. For the construction, the city is acquiring materials such as aggregates, gravels, sands, concrete and clays by mining the landscape and leaving behind environmentally degraded excavated lands, pits and quarries. These are scars on the environment causing devalued aesthetic, loss of biodiversity, change in natural topography and drainage (Young, 2014; Tarekegn and Gulilat, 2018). Emission and aerosols from construction and mining sites are also responsible for air pollutions and some respiratory diseases. According to Tarekegn and Gulilat (2018), in 2017 fiscal year alone, more than 800,000 Addis Ababa residents were stricken by respiratory diseases from air pollution. In addition, increasingly expanding impervious surfaces associated with urbanization is causing various flood hazards (Bimerew, 2015; Birhanu *et al.*, 2016). According to Birhanu, *et al.*, (2016), there is a 10 % to 25 % increase in peak flow of the Addis Ababa rivers causing erosion of unsealed roads and embankments, overflow, sedimentation, clogging of sewerage systems, and disruptions to energy and other utility supplies. On the other hand, urban encroachment on surrounding agricultural lands is undermining the productivity and food security of the farmers surrounding Addis Ababa (Derara and Tolosa, 2016). Farmers of surrounding Oromia zone are known for producing surplus agricultural products to feed the city in particular and the country in general. According to the household food security assessment conducted (Derara and Tolosa, 2016), for the farmers in Becho Woreda, 38 % of households are now experiencing food insecurity due to shortage of farmland, lack of grazing land and poor soil fertility. Besides, unplanned urbanization is guilty of widespread peri-urban slums, which are often built on riverbanks, risking flood hazards and exposure to shortage of reliable and secure potable

water, sanitation and waste management services (Bimerew, 2015; Birhanu, *et al.*, 2016). According to Bimerew (2015), the slum population in Addis Ababa suffers from various community health issues such as, but not limited to, Typhoid, Diarrhea, Cholera, and other parasitic diseases. In August 2016, a cholera (Acute Watery Diarrhea (AWD)) outbreak was reported in Ethiopia, the majority of the cases were reported in this communities of the capital, Addis Ababa. Lastly, rapid urbanization is blameworthy of de-indigenization process. The Oromo farming communities, the indigenous to Addis Ababa and its environs, is increasingly being pushed out of their lands as the city grows. This phenomenon has caused social instability and has a reputation of bringing widespread civil unrest and violence. According to the 2016 report of Amnesty international (Amnesty International, 2016), protests reverberated hundreds of towns across Oromia, Ethiopia largest region, in 2015. The protest was in response to a master plan that aimed at the de-Oromization of the region. It was also aggravated by resentment built from an already existing stark rural-urban inequality, acute competition over land, land grab, evictions and the social exclusion of Oromos over years (Fleischman and Peck, 2015). Therefore, in a country where 80% of the country's population lives in the rural area, the relative economic opportunities are continue attracting considerable rural-urban migration, it is critical to consider sustainable urban planning such as but no limited to Secondary cities, Compact city, and Edge city.

CONCLUSION

In this study, archived Landsat images were used to monitor the pattern and process of Addis Ababa urbanization. Five LULC types (i.e., Vegetation areas, Built-up areas, Agricultural lands, Bare lands, and Scrublands) were identified, recognized, classified and mapped from Landsat images. There is spatiotemporal variability in the LULC distributions, although, currently, Built-up areas covering the 69 % dominate the landscape, following by Agricultural lands (i.e., 22 %) and Vegetation areas (i.e., 7 %). With an approximately 31% of open and greenspaces, the city is apparently green. Addis Ababa urbanization has significantly transformed the landscape since 1985. For instance, in 1985, Addis Ababa landscape was dominated by Agricultural lands (i.e., 59 %),

whereas the current dominant Built-up areas were only covering 19 % of the landscape. Fifty five percent of Addis Ababa landscape are changes over the study period and 92 % of the changes are due to urbanization. Urbanization took place on the lands that were originally agricultural lands and Vegetation areas, indicating impacts on urban quality of life, food security and biodiversity degradation. In the country where 82 % of the employer is the government, Addis Ababa status as the capital city of Oromia regional state, the nation and continent will continue to draw massive people into the city. Additionally, with nearly 80 % of the population living in the rural area, the relative economic opportunities in the city vis-a-vis rural will likely attract considerable rural-urban migration for a foreseeable future. Hence, the ongoing and anticipated rapid urbanization would call for Addis Ababa sustainable urban planning and designs. Finally, although, the study has established Landsat remotely sensed data were helpful for mapping historical, contemporary LULC types as well as changes, there are some limitations. For example, the image classification made to map the LULC types was based on the ground truth data collected by the help of high-resolution images of Google earth and authors versed knowledge about the landscape. This is without actually visiting the study area to collect ground truth data for using as training samples as well as reference data. Therefore, a visit to Addis Ababa for ground truths could further improve the quality of the results.

AUTHOR CONTRIBUTIONS

T. Gala performed the literature review, experimental design, analyzed and interpreted the data, manuscript preparation and manuscript edition. On the other hand, M. Boakye performed the data acquisition and pre-processing for quality control, data compilation, literature review, and analyzed the data.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

X	Brightness values
CSA	Central Statistical Agency
$ v_i $	Determinant of the covariance matrix
ETM+	Enhanced Thematic Mapper Plus
Eq.	Equation
ERDAS	Earth Resources Data Analysis System
μ	Estimated mean of the values
σ	Estimated standard deviation
ECA	Economic Commission for Africa
GIS	Geographical Information System
v_i^{-1}	Inverse of the covariance matrix
\hat{K}	KAPPA Index
Km^2	Kilometers square
LCM	Land Change Modeler
LULC	Land Use Land cover
MLC	Maximum Likelihood Classifier
$(x - M_i)$	Mean of the vectors
e	Natural logarithms
OLI	Operational Land Imager
OA	Overall accuracy
PAr	Percent Area
PC	Percent Change
P	Probability density function
PA	Producers accuracy
P_o	proportion of correctly classified pixels

P_c	proportion of pixels correctly classified by change
Sq	Square
RS	Remote Sensing
TM	Thematic Mapper
$(x - M_i)^T$	Transpose of the vector
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
UA	User accuracy
v_i	Variance matrix for training sites of each category

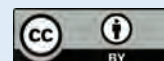
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ORIGINAL RESEARCH PAPER

Climate change effects on economic growth: mixed empirical evidence

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ABSTRACT

West Africa is vulnerable to the effects of climate change. This paper analyzed the impacts of climate change on economic growth in Anglophone West Africa with similar background, during the periods 1969-2016. Five growth model equations have been developed to incorporate climate change variables into the model. Panel data estimations such as the fixed effect model, random effect model and Hausman test were used. The results generated show that four equations required the use of the fixed effect, the agriculture equation model required the use of the random effect model. In the fixed effect models, the results show that the growth of human capital has a negative (-0.08 and -0.23) and significant (0.09* and 0.023*) impact on the growth rate of the services and manufacturing sectors. In Anglophone West African countries, the growth rate of the agriculture sector and temperature are statistically significant (0.008 ** and 0.089*) and have a negative impact (-2.04 and -17.7) on the growth rate of GDP. In the random effect model for agriculture, the growth rate of rainfall has the highest impact on the growth of agriculture in Anglophone West Africa than the impact of temperature on the region. Lack of sufficient rainfall reduces growth of the agriculture sector. In relative terms, change in rainfall pattern is more harmful to agriculture in comparison to the change in temperature in this region. The consequences of climate change in the region are sluggish economic performance and growth, underdevelopment, poverty and human misery.

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INTRODUCTION

Climate change is one of the existential threats confronted by human beings that permeate all aspects of human life be they political, social, ecological, economical etc. The impact of climate change is felt at varying magnitudes across the globe. The focus of

this paper is on climate change economic effects on Anglophone West African countries. The materials and methods section of the paper gives an insight on the geographical background and economic trends of Anglophone West African countries. The paper commences with a brief review of the literature on the subject matter. Sillah, (2016), assessed the economic impact of climate change on the Islamic Development Bank (IsDB) member states using cross-

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sectional data and concluded that an increase in Carbon dioxide (CO₂) emission by 1% will result in a decline of real GDP by an average of 0.47% for the dataset. The study found that Sub-Saharan Africa (SSA) member states are the worst region affected by CO₂ emission. It should be noted that 3 out of the 5 Anglophone West African countries are IsDB member. Organization for Economic Co-operation and Development (OECD, 2015), noted that doubling CO₂ emission will cause a GDP loss of about 0.6% to 4.4% by 2060. Consequently, it is vital for emitter of CO₂ to be cognizant of the indirect relationship between CO₂ emission and GDP growth. Numerous studies have pointed out that an increase in temperature has an impact on growth. Abidoye and Odusola, (2015) assert that a 1°C increase in temperature reduces GDP growth by 0.27%. The paper further posits that the impact of climate change is not homogeneous across SSA. This is because SSA is diverse and the countries have their unique geographic and atmospheric features as highlighted in the materials and methods section of the paper. Stern, (2007), further explains that an increase in temperature of 4°C and above will seriously affect global food production thus resulting in a decline in food crop yield, especially in Africa. The rise in temperature will have global ramifications but the severity of the problem will have a huge effect on Africa than other regions in terms of food security. Studies on Africa's rainfall projections are difficult to predict. Pereira, (2017) note that there is a mixed signal of rainfall increases and decreases. The study points out that rainfall projections for West Africa and the Sahel regions are indeterminate. Coulibaly et al., (2017) point out how the adverse effects of precipitation will affect Ivorian cocoa export revenue, some of the Anglophone West African countries are neighbours to Ivory Coast i.e. Ghana and Liberia, hence similar conditions may prevail. Mehmood-ul-Hassan and Leeuw, (2015) , stress that African farmers will face challenges of erratic rainfall, frequent and severe droughts in dry lands and savanna areas. Thus, the change in weather patterns will alter the timing and length of cropping seasons which will affect the lives and livelihoods of inhabitants of those settlements in the long run. Bulut and Gürkan, (2017), buttress the need for the development of new species using biotechnological approaches and drought resistance varieties that will possess high water use efficiency characteristics. The

foregoing, according to the paper, will make provision for future food production in light of climate change. Abidoye and Odusola, (2015), suggest the need for Africa to use research and development for adaptive measures to cultivate drought-resistant crop varieties. The study also stresses the need for the promotion of effective water resource management infrastructure to enhance African agricultural development for economic growth. The implication of delay or inaction in implementing climate policy has serious consequences. Luderer et al., (2013), note that a delay in adopting comprehensive climate policies will result in not only higher costs for reaching a given climate target but also an increase of the lower level of climate targets achievable within the range of acceptable cost levels. This emphasizes the urgent and immediate action necessary to reduce the higher cost of inaction or delay in acting. According to the (OECD, 2015), if no policy actions are undertaken, the combined effect of the impact on global GDP is projected to decline by 1% to 3.3% by 2060. It is, therefore, imperative that the necessary policy measures are taken to lessen the cost of inaction or delay which will be colossal for SSA. On the issue of inefficient climate mitigation policies Mendelsohn, (2019), elucidate that the biggest threat climate change poses is not climate-related disasters, but rather aggressive and inefficient mitigation policies which could increase mitigation cost to US \$28 trillion. Stern, (2007), point out that inefficient mitigation policies could be costly to society; it can be 14 times higher than optimal mitigation costs. Hence, as demonstrated, misguided inefficient climate change programs and policies will pose a serious threat to economic growth. The threat of climate change in West Africa is aggravated by limited access, awareness of and education about family planning, especially in rural communities, thus contributing to a rapidly growing population in the region. While food production has remained almost constant or increased slowly, therefore food production has not been able to keep up with population growth, resulting in a higher demand for and supply of imported food (Jalloh et al., 2013). This situation has increased poverty and deprivation on the continent, thus hindering economic growth significantly in many countries in SSA. United States Aid (USAID, 2011) elucidated that due to climate change in West Africa 3 key sectors will be seriously affected: (1) Food security will be a serious challenge by 2020, with a

potential decrease of about 50% in yields from rain-fed agriculture. (2) The health sector will witness extreme weather events such as droughts, heatwaves and storms, thus leading to an increase in the incidents of meningitis, malaria and acute respiratory infections. (3) Water resources will be affected by declines in rainfall, increases in temperature and more frequent droughts which will result in a decrease in surface and groundwater availability and accessibility causing loss of life, decline in agricultural production and the few areas that will be exposed to flooding will experience health and sanitary problems coupled with dilapidated infrastructure.

The current study have been carried out in Anglophone West Africa in 2019.

MATERIALS AND METHODS

Geographical background of Anglophone West Africa

Anglophone West Africa comprises 5 countries (The Gambia, Ghana, Liberia, Nigeria and Sierra Leone) out of the 15 countries that make up the Economic Community of West African States (ECOWAS), i.e. one-third of the countries in the sub-region. These countries were former British colony except Liberia. All of them are located on the west coast of Africa along the Atlantic Ocean where their major seaports and capital cities are also located except Nigeria's capital city, thus making their capital cities and seaports prone to sea-level rise which is a long-term effect of climate change. The total landmass of Anglophone West Africa is 1,503,099 km², with a combined population of 246.51 million and an average population growth rate of 2.47% (Fage and McCaskie, 2019). All of these countries have a high population density in their urban areas because their rural communities in most cases lack basic social amenities and infrastructure. Anglophone West Africa is home to Africa's most populous country, Nigeria, and the smallest country on mainland Africa, The Gambia. The topography of Anglophone West Africa is heterogeneously characterized by a diverse terrain of flood plains, lowland plains with dissected plateaus, upland plateaus, coastal plains, hills, mountains, mangroves etc. All these countries have bountiful natural resources. Nigeria and Ghana are endowed with petroleum, whilst Liberia and Sierra Leone are endowed with diamonds and other precious mineral reserves, yet poverty is highly prevalent in these counties. In light of climate variability, the

poverty rate in Anglophone West Africa will continue to increase if appropriate policies are not taken. These counties are faced with various degrees of environmental challenges such as drought in the case of The Gambia and Ghana, dust storms in Liberia and Sierra Leone and flooding in parts of Nigeria Central Intelligence Agency (CIA, 2019). Climate change will further exacerbate these environmental problems unless effective remedial measures are taken. Sylla *et al.*, (2016) elucidate that West African countries have recorded in recent decades warming temperatures, which increased between 0.3°C and 1°C. On the precipitation front Sylla *et al.*, (2016), buttress that precipitation tends to have increased in some parts of the Sahel by about 0.2-1.0 mm per day per decade. Pointing out that in general, the Sahel (which constitutes The Gambia and parts of Nigeria) has experienced wetter conditions while a small part of the Gulf of Guinea (which comprises Ghana, Liberia and Sierra Leone) has recorded drier conditions in recent years. The foregoing is an indication of the erratic nature of climatic conditions in the sub-region. This has serious repercussions on the inhabitants who directly or indirectly depend on the natural environment for their sources of livelihood. Hartley *et al.*, (2016), projected that the temperature in West Africa is expected to increase by 1.5°C to 4°C by 2050 especially in the Sahel compared to the Gulf of Guinea. On the precipitation side, changes in rainfall are not as certain as temperature. In the Sahel, July to September by 2050 will be experiencing rainfall in the range of -40% to +20% in the western Sahel, and between -20% and +40% in the central and eastern Sahel. The study points out that there will be a delay in early rainy season (June and July), particularly in the west of the Sahel, and an increase in late rainy season (September and October), particularly in the central and eastern Sahel. The Sahel projected rainfall uncertainty was also buttressed by (Serdeczny *et al.*, 2016). This expected future situation will further aggravate the conditions of rural dwellers of Anglophone West Africa who depend on agriculture as their means of sustenance and income generation.

Economic trends in Anglophone West African countries

Fig. 1 shows the Gross Domestic Product (GDP) percentage growth for the past two decades in Anglophone West African countries. It could

Climate change effects on economic growth

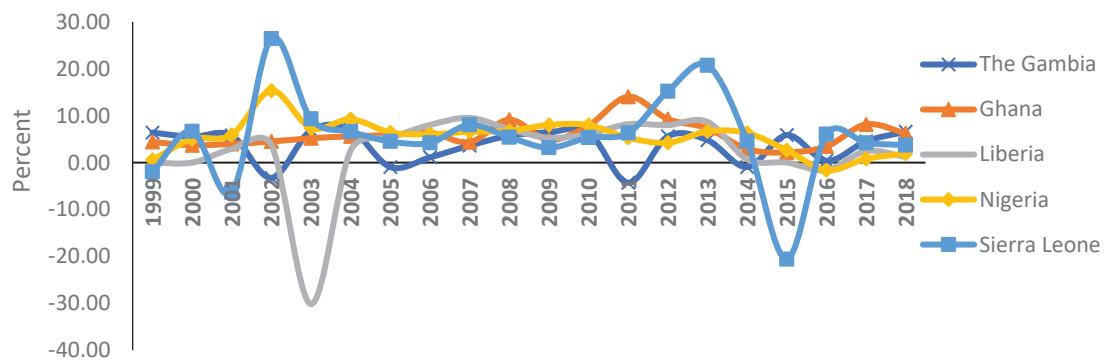


Fig. 1: GDP Percentage Growth Rate in Anglophone West Africa (World Bank, 2019)

be observed that these countries experienced fluctuations in growth over the periods as a result of both internal and external economic shocks. Nigeria, the biggest economy in the sub-region, has not registered an impressive growth since 2015. In 2016 the Nigerian economy contracted to -1.6% due to attacks on petroleum facilities in the Niger Delta. As a result, in 2017 the country had a GDP growth of only 0.81%. Liberia and Sierra Leone have in the past decades been recovering from political and economic challenges that plagued them. In 2014 the outbreak of the Ebola disease in West Africa slowed their growth.

By 2015 Liberia registered 0% growth and Sierra Leone contracted to -20%. However, both countries saw a rebound in 2017 and 2018. The Gambian economy is showing signs of recovery after the political impasse between December 2016 and mid-January 2017. Ghana's GDP showed signs of buoyancy in 2017 and 2018 (World Bank, 2019). Given the economic vulnerability of Anglophone West African countries, its policymakers should be cognizant of the impact of climate change on growth since a larger number of dwellers of the sub-region depend on nature (climate) for their survival, hence the motivation for the study.

Table 1: Sectorial composition of value-added percentage GDP

Country	Sector (% of GDP)	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Gambia	Agriculture, Forestry and Fishing	25.20	26.22	28.95	18.89	20.34	25.33	22.30	23.55	24.96	23.04
	Manufacturing	5.79	4.98	4.73	5.16	4.89	5.65	6.34	6.11	5.48	4.48
	Services	55.57	54.96	53.09	62.05	60.96	57.12	56.94	53.15	52.85	56.55
Ghana	Agriculture, Forestry and Fishing	29.41	30.99	28.04	23.66	22.13	20.45	20.00	20.25	20.98	19.70
	Manufacturing	7.54	6.77	6.39	6.42	5.66	11.75	11.33	11.37	11.12	10.89
	Services	46.17	47.94	48.18	45.84	47.58	39.15	36.11	39.54	43.09	42.35
Liberia	Agriculture, Forestry and Fishing	65.17	58.04	44.80	44.30	38.80	37.23	35.77	34.37	37.24	37.09
	Manufacturing	2.96	2.81	2.61	2.28	2.12	1.93	2.26	2.14	1.95	1.84
	Services	27.73	36.95	50.20	47.40	44.80	47.01	48.53	53.09	50.34	48.24
Nigeria	Agriculture, Forestry and Fishing	25.28	26.75	23.89	22.23	21.86	20.76	19.99	20.63	20.98	20.85
	Manufacturing	8.17	7.84	6.55	7.17	7.72	8.93	9.64	9.43	8.68	8.74
	Services	48.98	50.98	50.79	49.24	50.19	52.37	54.15	58.12	59.79	55.80
Sierra Leone	Agriculture, Forestry and Fishing	53.65	55.26	52.94	54.59	50.59	47.98	51.79	58.65	58.21	60.28
	Manufacturing	2.44	2.13	2.18	2.25	2.02	1.64	1.53	1.77	1.82	1.96
	Services	35.10	34.60	35.26	35.25	32.56	28.48	29.83	33.87	33.29	32.38

According to the African Development Bank Group (ADBG, 2019), the services sector of West Africa remains the dominant sector in value-added contribution to GDP, accounting for half of the region's GDP in 2018, which was the trend since 2015. Manufacturing accounts for a small share of industry and is limited to light processing of primary products and the production of consumer commodities. The trend in Anglophone West Africa is reflective of the sub-region. In The Gambia, Ghana, Nigeria and Liberia the services sector is the main driver of their economies, whilst for Sierra Leone agriculture is the main driver as indicated in Table 1. Agriculture remains a vital sector contributing on average about 20% of GDP in Anglophone West Africa. In most of these countries, the agriculture sector is the dominant employer; the sector is seen as the most vulnerable to climate change relative to other sectors. The services sector will also be affected by climate change especially the tourism industry which is vital in Anglophone West African countries. Nwamarah *et al.*, (2012) point out that climate change will cost Africa about 3% of the continent's GDP valued at US \$ 40 billion per annum. Given that Anglophone West African countries are prone to the effects of climate change they will incur a share of this colossal amount which will divert resources needed for development into combating climate change.

Theoretical framework

The theoretical framework of the study follows a dual approach using enumerative and dynamic approaches to study climate change impact on economic growth in Anglophone West Africa. Akram, (2013) elaborate that the enumerative approach mostly focuses on sectorial (agriculture, services etc.) impact of climate change. This approach is done by doing a short run analysis; it ignores intertemporal effects and sectorial linkages. Conversely, the dynamic approach can use different accounting growth models to assess the effects of climate change on growth. Akram, (2013), buttress the assumption of a constant savings rate using the dynamic approach, which has found that climate change has a negative impact on productivity and investment, which in the long run will cause capital stock, consumption per capita and aggregate demand to decline, eventually resulting in unfavorable GDP.

Theoretical model

The production function is used as a model with climate change variables, which forms the baseline for the study. The theoretical underlining for introducing climate change variables into the growth accounting model is for the comprehension of the decomposition of the effects of variations in the weather on economic growth. The basic production function derived by (Dell *et al.*, 2008), with some modifications, are demonstrated in Eqs. 1 and 2.

$$Y_{it} = e^{\alpha T_{it}} A_{it} L_{it} K_{it} \quad (1)$$

$$\frac{\Delta A_{it}}{A_{it}} = g_{it} + \beta T_{it} \quad (2)$$

Where Y is GDP, L is measure of population, K is measure of capital, A is technology and can be referred to as labour productivity and T is a measure of climate. Equation 1 illustrates the direct effects of climate on economic growth, e.g. effects on labour productivity. Equation 2 illustrates the indirect (dynamic) effects of climate, e.g. the effects of climate on other variables that indirectly impact GDP. By introducing logs in Eq. 1 and differentiating with respect to time, the Eq. 3 is proposed.

$$g_{it} = g_{i+(\alpha+\beta)T_{it}} + \alpha T_{it-1} \quad (3)$$

Where g_{it} is the growth rate of output. Direct effects of climate change on economic growth are accounted for by α and indirect effects are accounted for by β and g_{it} is the fixed effects.

Interest in the relationship between the growth of an economy and climate change concerns (pollution, rainfall, temperature, soil degradation, deforestation, erosion etc.) has increased in recent decades. Empirically, several estimation techniques are used to address this important phenomenon. The study used the panel data techniques such as fixed effect, random effect and dynamic panel; Generalized Method of Moments (GMM) and GMM differences. As mentioned previously, the production function incorporates climate change variables and determinants of a country's growth sectors such as agriculture, services and manufacturing into the Cobb-Douglas production function where capital, labour and technology are fixed over time. The

economic growth depends on the following variables in the models: population and population growth rate, human capital and human capital growth rate, rainfall and rainfall growth rate, temperature and the rate of growth in temperature. The sectors affected by climate change were regressed by their growth rate. Researchers that used Cobb-Douglas production function include (Hall and Mairesse, 1995), in which they added capital as another factor of production in the model. The paper adopts a model by Mohamed and Sami, (2015). To set out the production function for climate change as Eq. 4.

$$Y = b^\beta K^\tau L^\delta CLM^\varphi e^\varepsilon AW^\alpha \quad (4)$$

Where Y is the GDP, A is a given technology which is fixed, CLM is climate change variables (rainfall + temperature), K is capital, L is labour, and W contains population, e is exponential, ε is the idiogratric error term, and τ, δ, φ are parameters which are proportion. Incorporating climate change variables into the model to account for endogenous growth theory developed by (Romer, 1958) in which Romer incorporated human capital into the production function, the same as Eq. 4 using Eq. 5.

$$Y = b^\beta K^\tau L^\delta CLM^\varphi e^\varepsilon AW^\alpha \quad (5)$$

Dividing both sides by population to account for per capita terms, the assumption is the production function is constant return to scale i.e. $\tau + \delta + \varphi + \alpha = 1 \leftrightarrow \tau = 1 - \delta - \varphi - \alpha$, using Eq. 6.

$$\frac{Y}{L} = b^\beta A \left(\frac{K}{L}\right)^\tau \left(\frac{L}{L}\right)^\delta \left(\frac{CLM}{L}\right)^\varphi \left(\frac{W}{L}\right)^\alpha e^\varepsilon \quad (6)$$

Taking the natural logarithm of both sides of the Eq. 7,

$$\log(Y) = \log(b^\beta A) + \tau \log(K) + \alpha \log(W) + \varphi \log(CL M) + \varepsilon \log(e) \quad (7)$$

Note: Exponential and log cancel out and let $\log(b^\beta A) = \beta_0$, the resultant is as Eq. 8.

$$\log(Y) = \beta_0 + \tau \log(K) + \alpha \log(W) + \varphi \log(CL M) + \varepsilon \quad (8)$$

Transforming equation 8, for the growth model at time t and individual I, Eq. 9 is obtained.

$$g(Y)_{it} = \beta_0 + \tau_{it} g(K)_{it1} + \alpha_{it2} g(W)_{it2} + \varphi_{it3} CLM_{it3} + a_i + \varepsilon_{it} \quad (9)$$

Taking the first difference or fixed effect transformation or within transformations, Eq. 10 is obtained.

$$g(\bar{Y})_i = \beta_0 + \tau_{i1} g(\bar{K})_i + \alpha_{i2} g(\bar{W})_i + \varphi_{i3} \bar{CLM}_i + a_i + \bar{\varepsilon}_i \quad (10)$$

Arranging the like terms together and subtract Eqs. 9 and 10, Eq. 11 was obtained.

$$\ddot{Y}_{it} = \tau_{it} \ddot{K}_{it} + \alpha_{it} \ddot{W}_{it} + \varphi_{it} \ddot{CLM}_{it} + \varepsilon_{it} \quad (11)$$

This is the fixed effect transformation or within transformation. The unobserved factors in the model disappeared. This suggests that we should estimate the model by pooled Ordinary Lease Square (OLS). The pooled OLS estimator i.e. based on time demeaned variables is called Fixed Effect Estimator or Within Estimator.

Assumption

$Cov(\varepsilon_{it}, CML_{it}) = 0$, uncorrelated with all the explanatory variables in the model $\forall FE$

The model takes the form of Eq. 12.

$$Y_t = \beta_0 + \beta_1 POP_t + \beta_2 HC_t + \beta_3 T_t + \beta_4 RF_t + \varepsilon_t \quad (12)$$

In the log-log form we transformed the model as Eqs. 13, 14, 15, 16, 17, 18. 19 and 20.

$$\text{Model5(LnGDP): } \ln Y_t = \beta_0 + \beta_1 \ln POP_t + \beta_2 \ln HC_t + \beta_3 \ln T_t + \beta_4 \ln RF_t + \varepsilon_t \quad (13)$$

$$\text{Model4(Lnclm): } \ln Y_{clm_t} = \beta_0 + \beta_1 \ln HC_t + \beta_2 \ln M_t + \beta_3 \ln Ag_t + \beta_4 \ln S_t + \varepsilon_t \quad (14)$$

$$Ag_t = \beta_0 + \beta_1 POP_t + \beta_2 HC_t + \beta_3 T_t + \beta_4 RF_t + \varepsilon_t$$

$$\text{Model1(LnA): } \ln Ag_t = \beta_0 + \beta_1 \ln POP_t \quad (15)$$

$$+\beta_2 \ln HC_t + \beta_3 \ln T_t + \beta_4 \ln RF_t + \varepsilon_t \quad (16)$$

$$M_t = \beta_0 + \beta_1 POP_t + \beta_2 HC_t + \beta_3 T_t + \beta_4 RF_t + \varepsilon_t \quad (17)$$

$$\text{Model3(LnMN)}: \ln M_t = \beta_0 + \beta_1 \ln POP_t + \beta_2 \ln HC_t + \beta_3 \ln T_t + \beta_4 \ln RF_t + \varepsilon_t \quad (18)$$

$$S_t = \beta_0 + \beta_1 POP_t + \beta_2 HC_t + \beta_3 T_t + \beta_4 RF_t + \varepsilon_t \quad (19)$$

$$\text{Model2(LnS)}: \ln S_t = \beta_0 + \beta_1 \ln POP_t + \beta_2 \ln HC_t + \beta_3 \ln T_t + \beta_4 \ln RF_t + \varepsilon_t \quad (20)$$

Where:

$Y_t = \text{GDP growth}$; $\ln Y_t = \text{GDP growth rate}$; $Ag_t = \text{Agricultural Growth}$

$\ln Ag_t = \text{Agricultural growth rate}$; $M_t = \text{Manufacturing growth}$

$\ln M_t = \text{Manufacturing growth rate}$; $S_t = \text{Service growth}$

$\ln S_t = \text{Service growth rate}$

Data and data sources

A brief description of the data, the name of the variables and data sources used in the study is presented in Table 2.

Table 2: Data sources

Name of variable	Source	Comment
GDP current (\$US)	World Bank, WDI	Current GDP
Human capital (Proxy)	World Bank, WDI	Enrollment in secondary school
Agriculture	World Bank, WDI	Agriculture value added in \$US
Manufacturing	World Bank, WDI	Manufacturing value added in \$US
Service	World Bank, WDI	Service value added in \$US
Temperature	World Bank	Total average temperature
Rainfall	World Bank	Total average rainfall
Climate Change (RF +TEM)		Total climate change variable

WDI= World Development Indicator, RF=Rainfall and TEM=Temperature

Table 3: Descriptive statistics

Variables	Observation	Mean	Standard Deviation
LnH	138	3.178522	0.615652
LnS	182	3.714403	0.356525
LnA	197	3.503667	0.3839572
LnMN	195	1.850174	0.6348749
LnRF	240	4.789997	0.4916931
LNGDp	209	22.0129	2.162124
Lnclm	199	-1.049777	0.252329

LnH=Growth rate of human capita; LnS= Growth rate of Service sector; LnA= Growth rate of agriculture sector; LnMN= Growth rate of manufacturing sector; LnRF = Growth rate of rainfall; LNGDp= Growth rate of GDP; Lnclm= Growth rate of Climate change.

RESULTS AND DISCUSSION

Descriptive statistics

Table 3 contains the descriptive statistics of the study. The number of observations fluctuates over time. Panel estimation is used for Anglophone West African countries with comparable CO₂ emission per capita and similar vulnerability to climate change. The study logarithmized the variables to interpret them as elasticity or rate of change over time. The change in the growth rate of the services sector has the highest mean in comparison with the other 2 sectors. This means that the services sector is the highest growing sector and therefore it contributes more to the growth of the observed countries. The second highest growing sector is the agriculture sector, which is just 0.2 lower than the services sector. This is not astonishing since the agriculture and services sectors play a vital role in sustaining the economies of Anglophone West Africa as shown in Table 3.

Correlation

Table 4 contains the correlation results, which illustrates the relationship between variables under investigation. The growth rate of rainfall is positively correlated with the growth rate of the agriculture sector. Thus, in Anglophone West Africa more

rainfall will result in greater agricultural output thereby increasing the incomes of those dependent on agriculture for their livelihoods. The growth in temperature has a negative impact on the growth rate of rainfall, hence in Anglophone West Africa, as temperature increases rainfall will decrease over time. The growth rate of climate change variables which combines both rainfall and temperature growth rate manifests a negative relationship with the growth of the GDP; therefore, as climate change intensify economic growth in Anglophone West Africa may contract. Thus, there exist an inverse relationship between climate change and growth. The services sector is negatively correlated with growth rate of the agriculture sector, growth rate of rainfall and growth rate of GDP. In Anglophone West Africa as the services sector grows the agriculture sector will experience a decline. As observed earlier in Table 1 the services sector is the dominant sector in almost all the Anglophone West African countries performing better than all the other sectors with the exception of Sierra Leone. The growth rate of the manufacturing sector negatively correlated with the growth rate of rainfall. This implies that if the manufacturing sector is thriving the agriculture sector will not perform.

Panel unit root test

The questions that arise for the panel unit root

test (Fisher type unit root test for the coefficients) was based on the Augmented Dickey-Fuller (ADF) tests. Does the data contain a unit root? How to know the confidence level at which to reject the null hypothesis or accept the alternate vice versa. For the growth rate of GDP, does the panel contain a unit root? Given the results, the study failed to reject the null hypothesis, since all the values in this test for the growth rate of GDP are greater than 1%, 5% and 10%. This means there is a unit root in the panel under the given test condition (including panel time, trend and mean). This also answers the second question, because the p-value indicates at which level of significance to reject or accept the null hypothesis. Table 5 contains all the variables with corresponding t-ratios and p-values with drift and trend. There is no unit root for the growth rate of rainfall. The study rejected the null hypothesis at 1%, 5% and 10%. The p-value is smallest and the study rejected the null hypothesis of no unit root in the panel.

Estimation results

The estimated empirical model using the growth rate of agriculture, services, manufacturing, climate change and GDP is illustrated in Table 6. The Hausman test was used for the five equations, which determined the selection of either the fixed effect model or the random effect model. In the Hausman

Table 4: Correlation of variables

Variables	LnH	LnS	LnA	LnMN	LnTM	LnRF	Lnclm
LnA	0.0184	-0.5961	-				
LnTM	0.5035	0.2439	-0.2746	0.371	-		
LnRF	-0.0885	-0.4952	0.4650	-0.41	-0.7733	-	
LNGDp	.6870	-0.2320	-0.3544	0.6279	0.2662	0.0639	-0.1582
Lnclm	-0.2672	0.2159	-0.3227	0.2426	-0.0921	-0.1077	-

Table 5: Panel unit root test (Fish test in the first difference)

Variables	T-Ratios		P-Value	
	Drift	Trend	Drift	Trend
LnH	-3.4077	2.5093	0.0012**	0.9904
LnS	-3.4073	-0.0171	0.0010**	0.4932
LnA	-3.8000	-1.6581	0.0003***	0.0540**
LnMN	-4.1926	-0.3310	0.0001***	0.3715
LnRF	-12.4402	-8.8001	0.0000***	0.0000***
LNGDp	-1.5014	0.8013	0.0720*	0.7853
Lnclm	-6.9391	-1.9464	0.0000***	0.0307**
LnTEM	-4.7105	-11.0444	0.0000***	0.0000***

Computation using Stata 13 Ntes: *, ** and *** denote significance at 10%, 5% and 1%, respectively.

Table 6: Hausman Test Results

Equations	Probability of Chi-square	Chi-square statistic
Model 1 (LnA)	4.22	0.5185
Model 2 (LnS)	58.78	0.000***
Model 3 (LnMN)	-10.13	0.000***
Model 4 (Lnclm)	28.78	0.000***
Model 5 (LnGDP)	-236.66	0.000***

Table 7: Fixed Effect Model Results

Variable	Model 2 (LnS)		Model 3 (LnMN)		Model 4 (Lnclm)		Model 5 (LnGDP)	
	t-ratio Std E S.E.	P-value Coef.	t-ratio S.E.	P-value Coef.	t-ratio S.E.	P-value Coef.	t-ratio S.E.	P-value Coef.
Constant	-0.38 (3.98)	0.707 -1.50	0.99 (8.96)	0.32 8.92	1.93 (1.7)	0.057* 3.28	1.93 (36.2)	0.054* 69.79
LnH	-1.68 (0.05)	0.09* -0.08	0.101 (-2.3)	0.023* -0.23	2.42 (0.1)	0.018* 0.29	9.10 (0.35)	0.000*** 3.17
LnA	-7.70 (0.06)	0.000*** -0.44	0.13 (-6.9)	0.000*** 0.94	-2.65 (0.2)	0.010* -0.42	-2.65 (0.77)	0.008** -2.04
LnMN	-3.43 (0.04)	0.001*** -0.15			2.25 (0.1)	0.027* 0.18	4.63 (0.39)	0.000*** 1.82
LnRF	1.03 (0.12)	0.31 0.12	-1.11 0.26	0.268 -0.299			1.32 (0.73)	0.185 0.96
LnTEM	1.74 (1.18)	0.09* 2.05	0.13 (2.71)	0.89 0.36			-1.70 (10.4)	0.089* -17.70

Using Stata 13, standard errors between parentheses * p=0.10, ** p=0.05, *** p=0.01

test, the Chi-square test suggests the use of the fixed effect model for the four equations, i.e. models 2 to 5 and one equation for the random effect model, i.e. model 1, meaning the error term is uncorrelated with explanatory variables in the agriculture equation model.

Fixed effect model

The fixed effect model results are contained in Table 7. The results show that the growth of human capital has a negative and significant influence on the growth rate of services and manufacturing while human capital has a positive impact and significant influence on the growth rate of climate change variables. Human capital has a significant and positive relationship with the rate of growth of GDP, thus strengthening the vital role of human capital on the growth and development of Anglophone West Africa. In these countries, the growth rate of agriculture, manufacturing and temperature are all statistically significant on the growth rate of GDP. The variable

Table 8: Random effect model results

Variable	Model 1(LnA)	
Dependent variable LnA	z-ratio S.E.	P-value Coef.
Constant	0.27 (4.73)	0.78 1.30
LnH	-1.98 (0.04)	0.05* -0.09
LnS	-11.02 (0.08)	0.000*** -0.918
LnMN	-10.67 (0.03)	0.000*** -0.37
LnRF	-0.38 (0.09)	0.70 -0.04
LnTEM	1.52 (1,35)	0.129 2.04

Using Stata 13, standard errors between parentheses * p=0.10, ** p=0.05, *** p=0.01

that is not statistically significant but positively impact on growth rate of GDP is the growth rate of rainfall. Hence astonishingly, as observed, agriculture is statistically significant on GDP growth whilst rainfall

is insignificant but has a positive impact growth unlike agriculture. Agriculture and rainfall are least impact variables on GDP growth in comparison to human capital. The severe effect of climate change on agricultural was done by (Relly, 1999), (Mendelsohn and Dinar, 1999). In the services sector, rainfall is insignificant but positively impacts on services. Temperature is significant in the services sector model. In the manufacturing sector model both rainfall and temperature are insignificant, negatively and positively impacting the manufacturing sector respectively. Finally, manufacturing, agriculture and human capital growth rates are statistically significant with the growth rate of climate change variable in Anglophone West Africa. The results found out that GDP and agriculture negatively impacted on the growth rate of climate change in Anglophone West Africa. Manufacturing and human capital are significant and have a positive impact on the growth rate of climate change.

Random effect model

The results based on the Hausman test suggest that the random effect model is more appropriate than the fixed effect model in the case of the model growth rate of agriculture. In Table 8, the results reveal that the growth rate of the services sector and the growth rate of the manufacturing sector are highly statistically significant and negatively impact on the growth rate of the agriculture sector. The growth rate of human capital is moderately statistically significant and negatively affects the growth rate of the agriculture sector. As the growth rate of human capital increases by 1%, the growth rate of agriculture reduces approximately by 0.089%. Thus, in Anglophone West Africa's human capital investment has an inverse relationship with agricultural output. This phenomenon is also true for growth rates in both the services and manufacturing sectors. The growth rates of temperature and rainfall are statistically insignificant but associated positively and negatively on the growth rate of the agriculture sector respectively. The growth rate of rainfall has a higher impact on the growth of agriculture in Anglophone West Africa than the impact of temperature. Lack of sufficient rainfall reduces the growth of agriculture. In relative terms, change in rainfall pattern is more harmful to the agriculture sector in comparison to the change in temperature in this region.

CONCLUSION

This research attempts to explain the impact of climate change on economic growth in Anglophone West African countries with similar CO₂ emission per capita and vulnerability to climate change. The results generated shows that the agriculture sector is affected negatively by rainfall. The growth rate of rainfall has a higher impact on the agriculture sector than temperature has on the agriculture sector. In relative terms, manufacturing, agriculture and human capital growth rates are statistically significant with the growth rate of climate change variables in Anglophone West Africa. The growth rate of the agriculture sector, manufacturing sector and temperature are all statistically significant with GDP growth rate whilst the growth rate of the services sector, the agriculture sector and temperature have a negative impact on the growth rate of GDP. The rainfall growth rate is not statistically significant but positively impacts on the growth rate of GDP. The consequences of climate change in Anglophone West African countries have far-reaching problems for its over 240 million inhabitants. In the medium and long run, the region will be affected by the scourge of climate change which will result in sluggish economic performance and growth, underdevelopment, poverty and human misery. Given the foregoing pending consequences in the region, the following policy recommendations are proffered in light of the results generated from the study: 1. Anglophone West African countries should endeavour to legislate laws that will prohibit human activities that will result in decline in rainfall in the region since changes in rainfall patterns have the highest impact on the agriculture sector. 2. Governments in Anglophone West Africa must devise policies that will continuously boost the manufacturing sector since the sector has a positive impact on economic growth in the region. 3. Given that climate change variables negatively impact on agricultural growth as manifested by the results of the study, agricultural experts should proffer solutions to remedy the situation. 4. It is vital for the growth and development of Anglophone West Africa that governments continue to invest in the human capital since there exists a significant and positive relationship between human capital and the rate of growth of GDP. 5. To alleviate poverty in the region Anglophone West Africa governments should formulate policies that will reduce the vulnerability

of the agriculture sector to climate change, given the inverse relationship that exists between climate change and the agriculture sector.

AUTHOR CONTRIBUTIONS

C. Belford commenced the process by conceptualizing and formulating the research idea, followed by data collection and cleaning and was also extensively involved in reviewing literature and preparing the manuscript. H. Delin reviewed and edited the final manuscript. E. Ceesay performed the data analysis, results interpretation and discussion. Y. Nasr Ahmed reviewed the analyzed data and helped in the data interpretation. R. Happy Jonga did the proofreading and literature review.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

<i>ADBG</i>	Africa Development Bank Group
<i>ADF</i>	Augmented Dickey-Fuller
<i>CAAS</i>	Chinese Academy of Agricultural Sciences
<i>CIA</i>	Central Intelligence Agency
<i>CLM</i>	Climate Change Variables
<i>CO₂</i>	Carbon dioxide
<i>ECOWAS</i>	Economic Community of West African States
<i>GDP</i>	Gross Domestic Product

<i>GMM</i>	Generalized Method of Moments
<i>IAED</i>	Institute of Agricultural Economics and Development
<i>IsDB</i>	Islamic Development Bank
<i>OECD</i>	Organization for Economic Co-operation and Development
<i>OLS</i>	Ordinary Lease Square
<i>SSA</i>	Sub-Saharan Africa
<i>USAID</i>	United States Aid

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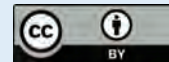
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ORIGINAL RESEARCH PAPER

Effect of financial development and institutional quality on the environmental degradation in developed and developing countries

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ABSTRACT

Environmental pollutants have become a dreadful problem and burning issues for the present world irrespective of a country who is responsible for it. The objective of the study is to investigate impact of financial development and institutional quality on environmental degradation. The study is based on panel data for developing and developed countries over the time of 1996-2016. For the empirical analysis fixed effect and the random effect is carried out. Results show that institutional quality, economic growth, foreign direct investment, gross primary enrolment, and industrial growth have significant positive effect on carbon emissions whereas financial development, population growth, trade openness, urban population and R&D expenditures have significant negative effect on carbon emissions. One percent point increase in the index of institutional quality leads towards 0.006 percent points increase in the level of CO₂ emissions. One percent point increase in the economic growth lead to increase the CO₂ emissions by 0.39 percent points. One percent point increase in inflows of foreign direct investment increase the level of CO₂ emissions by 0.016 percent points. One percent point increase in industrial growth leads to a 0.38 percent points increase in the level of CO₂ emissions. Furthermore, one percent point increase in the index of financial development leads to 0.05 percent points decrease in the level of CO₂ emissions. One percent point increase in urban population leads to almost 0.05 percent points fall in the level of CO₂ emissions. Finally, one percent point rise in R&D expenditures leads to decrease in the level of CO₂ emissions by 0.068 percent points.

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INTRODUCTION

Environmental degradation has become a dreadful problem and burning issues for the present world irrespective of a country who is responsible for it. Environmental degradation is a global issue and all countries are facing serious threats from environmental

deterioration. Increasing human activities, the use of fossil fuels in the part of industrial production and energy consumption has raised the anthropogenic impacts and uplift the global temperature and put maximum pressures on earth resources in direct and indirect ways. The environmental degradation is connected with the ineffective and worse quality of institutes which are caused by the weak implementation process of these regulations. Economist, social scientist and

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policymakers have shown extensive interest in the relationship between the quality of institutional and environmental degradation as shown in Fig. 1.

The system of government that has a significant and direct impact on the quality of the environment is the control of corruption rule of law, government productivity, voice and accountability, and political constancy, shown in Fig 2. The presence of rule of law minimizes the effect of market failure.

The quality of the political institution is helpful in productive cooperation so it is an essential element in term of CO₂ emissions. The emission of carbon in the environment depends upon a number of factors which are responsible for the environmental pollution likewise energy consumption, openness to trade, education level, urban population, foreign direct investment, growth in Gross domestic product (GDP), industrialization, and population growth rate. According to North (1990) through the structure of

incentives, the good quality of institutions enhances the productivity of inputs. More progress and development will lead to a hazardous impact on the environment. Financial development performs a dynamic role in the utilization and mobilization of savings, control of resources toward productive sectors and facilitation of transactions. The economic development has increased the income level of the individual at the cost of a clean environment. Environmentalists explain that the Environmental Kuznets Curve (EKC) hypothesis offers U-shape relationship between degradation of environmental and income of per-person. In the initial stage of the economic evolution process, the environmental degradation would flourish; then after reaching a certain level of per capita income, the environment starts improving. The theoretical studies are inspired by North (1990) and the study explores that the economic exchange and economic development is

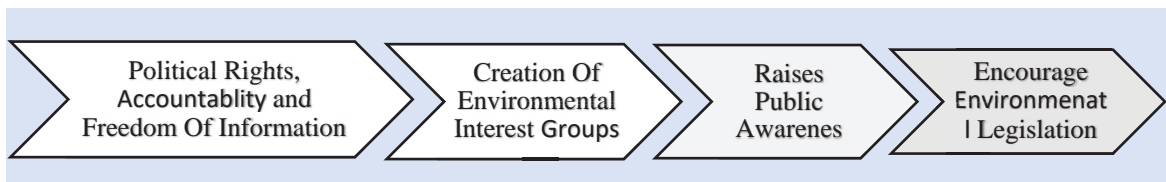


Fig. 1: Link of institutional quality in improving environmental degradation

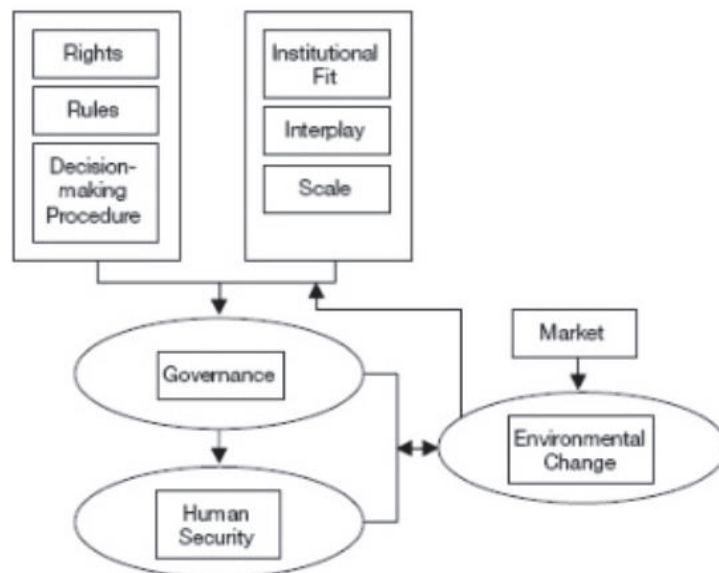


Fig. 2: Interaction between environment and institutional quality (Egbetokun et al., 2016)

enhanced by strong formal legal rule. The reason is that at very low cost strong formal institutions like a property right boost up investment, innovations and enhances market exchanges. In the viewpoint of [Aron \(2000\)](#), its responsibility of the government of a state to enforce sanctions and laws are necessary to be implemented in order to lessen the uncertainty, improved the regulatory quality and implementation of effective enforcement of rules. Thus, the important aspects of growth-enhancing institutions are accountability, contract enforcement, the rule of laws, regulatory quality, property right protections, political stability and control of corruption. From this framework, inefficient institutions are responsible for high transaction costs and, they are not able for the provision of private activities, market exchanges, and economic growth. In this sense quality of better settings of institutions are extremely important for fast economic development. Economic growth is often linked with the environment and has influences on it. The pace of economic development of any country is dependent on several factors. These studies shows that to lift the high rate of growth each country used different mechanism and exploitation of natural resources. This type of growth via over-exploitation of natural resources, degradations, and loss of natural habitat usually produces a harmful effect on the environment. These empirical studies shows positive, negative and ambiguous effect of economic development on environmental pollutants ([Bruyn et al., 1998](#); [Tamazian et al., 2009](#); [Ozturk and Acaravci, 2013](#); [Shahbaz et al., 2013](#); [Moghadam and Lotfalipour, 2014](#); [Li et al., 2015](#); [Özokcu and Özdemir 2017](#)). Financial development is another factor that may explain the environmental degradation. The inverted U-shape relationship between financial development and environment can also be expressed. So, in the initial stage of financial development due to high priority of economic growth over clean environment the financial development increases the volume of industrial activities but after reaching the favorable economic growth in the next stage, the financial development start improving the environmental degradation by investing in environmentally friendly project and introducing such a technology which reduces the number of emissions in the atmosphere ([Shahbaz et al., 2013](#)). Most of the countries emphasized on the financial sector development to have stable economic expansion and environmental

degradation. According to the study, this sector is a high value-added and green industry. While analyzing the impact of financial development and environmental degradation the particular indicators such as income level, trade openness, energy consumption and financial reforms are used by different studies. The negative relationship is supported by the following studies ([Jalil and Feridun, 2011](#); [Yuxiang, Chen, 2011](#); [Shahbaz, 2013](#); [Charfeddine, Khediri, 2016](#)). On contrary, another important fact is that financial development in the context of economic growth is responsible for industrial pollution and environmental degradations ([Sehrawat et al., 2015](#)). Financial development lead to increase in the CO₂ emissions because when the financial systems are sound and efficient it makes the procedure of getting loans more convenient and easier as a result of which consumer buys those products which emit more carbon dioxide such as vehicles, generator, air conditioners and construction of houses ([You et al., 2011](#)). The studies ([Tamazian, Rao, 2010](#); [Karimzadeh et al., 2014](#); [Moghadam; Lotfalipour, 2014](#); [Gokmenoglu et al., 2015](#); [Sehrawat et al., 2015](#); [Ayeche et al., 2016](#)) find positive relationship between financial development and environmental deterioration. In the same context, institutional quality plays a most imperative character in increasing the environmental quality. Better policies and regulations compensate the adverse impact of climate change and decrease CO₂ emissions. The poor institutional quality failed to implement stringent environmental policies. The environmental standard cannot be achieved without the political will and financing of high-income countries. The government effectiveness is also play an important role in this regard because the rate of investment slow down when there are excessive red tape, poor public goods provision and inefficient bureaucracy. This means the presence of good governance can minimize the effect of market failures. It facilitates good and effective cooperation in the markets ([Olson, 1996](#)). The following studies [Ulman and Bujancă \(2014\)](#) and [Sahli and Rejeb \(2015\)](#) explore positive relationship of environmental quality with institutional quality. While most of the studies explored negative relationship of institutional quality with the environmental degradation such as that when the people have freedom of information and political rights, it will create groups having environmental interest and they raise the awareness among the public regarding environment which

encourages and promote environmental legislation (Bernauer, Koubi, 2009; You *et al.*, 2015; Sulaiman *et al.*, 2017; Abid, 2017; Bhattacharya *et al.*, 2017; Dhrifi, 2018). There exists extensive literature on the association between economic growth and environmental pollutants but the relationship and influence of financial development institutional quality on environmental degradation are still largely absent. There are lots of factors working behind it. So, the question is what makes the quality of institutions and financial development so essential when it comes to environmental quality and economic growth? This study jointly links the effect of financial development, the role of institutional quality, and economic growth with environmental degradation in both developed as well as in developing countries. This study encompasses the linkage of socio-economic determinants of environmental degradation. Moreover, none of the studies incorporated the index of financial development and mostly used a proportion of private credit to GDP and stock market capitalization as a proxy of financial development but with the passage of time, it becomes a modern and multi-dimensional process. So, it is reasonable to use the index for financial development which incorporates the indicators of both the financial market and financial institutions. In the last, the study also includes six indicators of institutional quality because in recent years most of the countries comprehend the importance of institutions in tackling the pollution. There is a general belief of policymakers of many countries that good institution has a central role in combating against pollution. Good political institutions such as political stability, property right, rule of law, voice and accountability, and control of corruption are important determinants for mobilizing resources and providing opportunities to the citizens to become more productive and for better environmental standards. This study has been carried out in Islamabad, Pakistan during 2018-2019.

MATERIAL AND METHODS

Model and estimation methods

Environment Kuznets Curve is originally presented by (Kuznets, 1995). Explaining that at the initial stage of economic development the income inequality tends to rises at a low level of income but after a certain threshold level its declines. The number of researchers focused on the sources of environmental degradation. Following the methodology of Abid

(2017), the model investigates the link and impact of socio-economic determinants on environmental pollutants and check whether it is significant or not. For this purpose, Eq. 1 is raw mathematical equations which will pass through different stages.

$$CO_2 = f(EG, IFD, IQ) \quad (1)$$

Here, CO_2 is measured in per capita metric tons and its proxy for environmental degradation. According to (Foster and Bedrosyan, 2014) 80% of greenhouses emissions are represented by CO_2 emissions. To adjust the effect of the growth of population on the population level the CO_2 per metric ton emission is used. To measure the economic growth log of GDP is incorporated. IQ is the index of institutional quality to measure the performance of governance six indicators are incorporated i.e. rule of law, voice, and accountability, regulatory quality, control of corruption, the absence of violence and political stability. Whereas the construction of an index of financial development is discussed in later section. For the empirical investigation, the objective of the study is to apply the econometrics techniques to explore the impact of economic growth, institutional quality and financial on environmental degradation. For the more sophisticated analysis for the determinants of environmental degradation, following specification has been incorporated and the main equation is adopted from (Hsiao, 1986) is stated as Eq. 2.

$$LCOPC_{i,t} = \alpha_0 + \alpha_1 LGDP_{i,t} + \alpha_2 FDI_{i,t} + \alpha_3 IQ_{i,t} + \alpha_4 X_{i,t} + \varepsilon_{i,t} \quad (2)$$

Where, $i = 1, 2, 3, \dots, 122$ are countries in a panel data or cross sections and $t = 1, 2, 3, \dots, 21$. It is already discussed IFD, and IQ above. So, LGDP is log of Gross Domestic Product, X is vector of control variables such as foreign direct investment net inflows, trade openness percentage of GDP, population growth, education as primary gross school enrollment, urbanization percentage of the total, R&D is used as a proxy of technological development, the share of industrialization in GDP and log of energy consumption and $\varepsilon_{i,t}$ is error the term. The main goal of the study is to explore the relation of socio-economic indicators of environmental degradation so, the appropriate econometric technique is required to assess this relationship. For the estimation technique, the study used panel data estimation

technique. Unlike the cross-sectional analysis, the panel data methodology has been adopted because it has an advantage that to control for individual heterogeneity, more variability, more degree of freedom and high efficiency and less collinearity among the variables. Panel data also called cross-sectional time series data and longitudinal panel data is a set of data of different entities in which characteristics and behavior of different groups are observed across the time. Most of the researchers examining panel data choose between Fixed Effect Model (FEM) and Random Effect Model (REM). Panel data consist of unobserved heterogeneity because the mean of the dependent variable is not constant across the country and each country has its own special characteristics which may not be same with other factors. It is allowed to control of variables which are not possible to measure and or observe due to different cultural factors. For this purpose, the study estimate the models with different techniques such as FEM, REM, and Common Effect Model (CEM) in a panel data. The basic assumption of Common Effect Model (CEM) is that X is exogenous variable and error term is normally distributed having a constant mean and constant variance. Fixed effect model is used in analyzing the effect of variables which are not constant over time. Each group has individual characteristics which may or may not have an influence on the predictor variables. One of the assumptions of FE model is that error term of the entity and the predictor variables have not correlated each other, and the individual may impact the independent variables so there is need to control for this. The net effect of independent variables on the outcome is asses by removing the effect of time invariants characteristics. Another assumption of the FE model is that error term of each entity is not correlated with individual's error term because individuals have unique characteristics and they are time invariant. Fixed effect model is used to study the causes of change within the individual characteristics.

Data

For the empirical analysis panel data is formed and based on data availability 122 countries are selected. The data on the institutional quality is extracted from the Worldwide Governance Indicators (WGI). The time is taken over the period of 1990-2016 due to limited availability of the data the study restricted the time for the estimations. Following the definitions of variables are provided for better understanding.

CO₂ emissions (metric tons per capita)

CO₂ per capita is calculated by total national CO₂ emissions per year divided by total population. The data has been published by Global Carbon Project. The benefit of using this is that it incorporates the emission of CO₂ by per person and takes it to account the nation's population size. The source of CO₂ emission is from [Le Quéré et al. \(2017\)](#).

Financial development

By defining financial development as it is a mixture of the *depth* that is the magnitude and market liquidity, *accessibility* means how easily firms and the individual can access funds and finally base on *efficiency* means how financial institutions can provide fund at the minimal cost with sustainable returns and multidimensional activities in the capital market. Stock and bonds markets are part of the financial market whereas insurance companies, mutual and pension funds, banking sector etc. are part of financial institutions ([Levin et al., 2012](#)). Lots of the literature used a different proxy to measure the financial development. Most of the study used the ratio of private credit to GDP and stock market capitalization but with the passage of time financial systems have become a modern and multidimensional process. It does consist of companies, mutual funds, capital market, the stock market, insurance companies etc. financial markets allow individuals to channelize their savings into a different form and the ability of firm increases to raise funding and money through the stock market, bonds, and wholesale market. It is crucial and mandatory part of a financial system that it must be accessible and efficient. The reason is that even the financial market is large and sizeable but if they are not easily accessible to the general public and firms then their role in economic development become limited and wasteful ([Aizenman et al., 2015](#)). Financial development index can be shown in the form of a pyramid as shown in [Fig. 3](#). The below pyramid shows that financial development is categorized into two parts. Each part has further sub three indices.

Financial development index

After understanding the meanings of financial market and financial institutions depth, access and efficiency one can drive the index of financial development index. Different indicators are used to check efficiency, depth, and accessibility of financial market and institutions. These indices are denoting

FMD, FMA, FME, FID, FIA, and FIE. These indices are combined into two indices known as the financial market (FM) and Financial Institutions (FI) to observe how much developed and efficient these markets are. In the last stage, these two indices FM and FI are gathered to formulate index of financial development FD-index (Svirydzienka, 2016).

Institutional quality (IQ)

Similarly, index of institutional quality includes six variables extracted from World Governance Indicator namely voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law and control of corruption. Following are the brief details of the indicators: Voice and accountability mean that how much a citizen of a country has freedom of speech, association, and expressions. It also means to which extent a person has a choice in electing the government. Political stability means the perception of the probability that the existing government will overthrow by illegal ways like terrorism. Government effectiveness mean the provision of public good, quality of public service, degree of freedom from political pressure, the implementations of the policies and the government commitments towards them. Rule of law mean rules of society which must be abide by the agent of the. It is in the form of property right, contract enforcements the judiciary and the police. Regulatory quality mean for the development process the ability of government to formulate regulations, the rule and implementation of policies. In the last, control of corruption mean how public power is used for private and personal gain.

Gross domestic product per capita (GDP)

GDP per capita used as a proxy for economic growth measures the overall wealth of individual in the country. The gross domestic product is the value added of all resident plus the amount of taxes on the product minus the amount of the subsidies of the product. This variable is included in the study because the relationship between carbon emission and economic growth is incorporated in the hypothesis of EKC which was originated by (Grossman and Krueger, 1995).

RESULTS AND DISCUSSION

Descriptive Statistics

For the empirical study, the description of data in the precise form is essential because the descriptive coefficient gives the summary of the data set. It is the representative of the sample for the given population. It allows the reader to extract the required information from the data so the accurate and appropriate information can be extracted from the sample. For the dispersion from the mean value standard deviation and arithmetic mean is calculated. For the developing and developed countries Table 1 consist of mean, minimum, maximum and standard deviation of the given dataset. For overall countries developed and developing one's Table 1 is composed and it shows that the mean value of the variable is greater than the standard deviation. Standard deviation is calculated to check the dispersion in the data. A higher value of standard deviation means high dispersion. Overall there are variations in the data. The average of the data for high-income countries is better as compared to developing countries. The

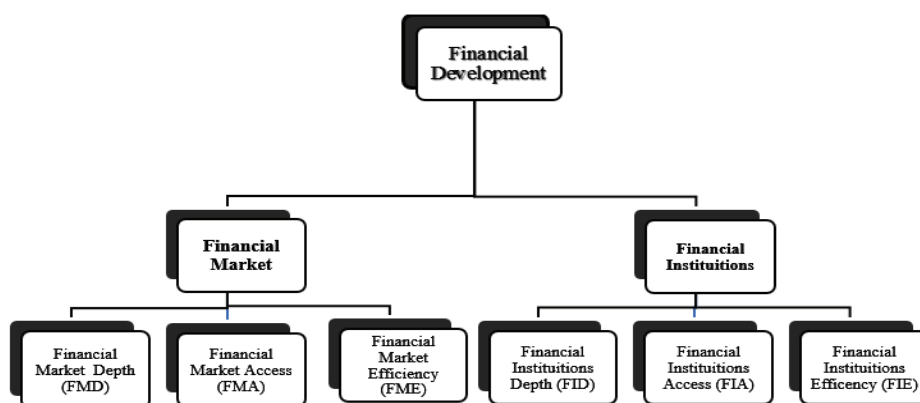


Fig. 3: Components of financial development index (Svirydzienka, 2016)

variables like GDP, energy consumption, and industrial growth shows that growth in these variables leads to more emissions. Fig. 4 shows the emission of carbon in different regions of the world. The data is taken from "The Global Carbon Atlas". It can be seen from the figure that China is on top of the list and contributes a large amount of CO₂ emission, emitting 24% of the total world CO₂. Moreover, 11% of the emission is done developing regions of the world. Similarly, the carbon emission done by individuals can see from Fig. 5. It is clear that much of emission

per person is done in Oceania, North America, Middle East, and Europe.

Regression results

To analyze the socio-economic determinant of environmental degradation different econometrics test, scheme and methodology are incorporated. To check the reliability of the data that none of the variables is the non-stationary various test is applied. In the panel data to check whether the data has a unit root or stationary Fisher PP, LLC and IPS test is applied.

Table 1: Descriptive statistics

Variables	Obs.	Mean	S.D.	Min..	Max
Overall data					
LCOPC	2,436	0.8323	1.51	-3.03	4.24
LGDP	2,562	24.84	2.12	19.87	30.4
LECON	2,289	7.324	1.03	4.73	9.99
FDI	2,437	20.94	2.35	6.90	27.3
IQL	2,562	53.86	15.4	19.4	84
POPG	2,562	0.012	0.01	-0.03	0.16
UPOP	2,562	0.579	0.22	0.11	0.99
ED	2,478	1.012	0.14	0.28	1.65
TO	2,541	0.84	0.44	0.00	4.10
IFD	2,477	0.361	0.23	0	1
INDG	2,394	0.301	0.1	0.02	2.13
R&D	1,449	1.094	0.95	0.004	4.40
High income countries					
LCOPC	1,554	1.616	1.03	-2.74	4.24
LGDP	1,680	25.37	2.17	19.87	30.4
LECON	1,533	7.839	0.79	5.91	9.99
FDI	1,593	21.59	2.29	6.91	27.3
IQL	1,680	60.61	14.0	24.8	84
POPG	1,680	0.009	0.01	-0.03	0.16
UPOP	1,680	0.687	0.17	0.18	0.993
EDU	1,617	1.03	0.08	0.68	1.65
TO	1,680	0.897	0.48	0.156	4.10
IFD	1,637	0.453	0.23	0	1
INDG	1,596	0.319	0.16	0.05	2.13
R&D	1,197	1.255	0.97	0.03	4.40
Low income countries					
LCOPC	882	-0.55	1.21	-3.03	2.60
LGDP	882	23.82	1.58	19.95	28.53
LECON	756	6.28	0.61	4.73	8.017
FDI	844	19.72	1.95	11.89	24.51
IQL	882	40.98	7.92	19.4	57.9
POPG	882	0.019	0.01	-0.025	0.053
UPOP	882	0.373	0.16	0.113	0.83
EDU	861	0.977	0.19	0.28	1.49
TO	861	0.726	0.33	0.001	1.99
IFD	840	0.180	0.10	0	0.59
INDG	798	0.264	0.08	0.03	0.522
R&D	252	0.332	0.27	.0004	1.19

Macroeconomic determinants of environmental degradation

The null hypothesis is that the data is stationary or have no unit root against the alternative that data is non-stationary or have a unit root. The panel regression results of the model are presented in Table 2. The F-statistics of overall goodness of fit model shows whether the linear regression is a better fit on overall data. In choosing between CEM and FEM model the P-value is less than 0.05. So, F-statistics reject the null hypothesis i.e. common effect is preferred over of data fixed effect and accept the alternative hypothesis that is the FEM is preferred over the Common effect model. Likewise, deciding between CEM and REM the values

of the Breusch-Pagan LM test indicate that the REM perform better than CEM. The P-value of F-statistics demonstrates that the H_0 is rejected at 1% the REM perform better than CEM. The P-value of F-statistics demonstrates that the H_0 is rejected at 1% level of significance. In the last, Hausman test is employed between fixed effect model and the REM. The P-value of F-statistics is highly significant and the study reject the null hypothesis that is the differences in the coefficient is not systematic against the alternative hypothesis i.e. differences in the coefficient is systematic. Results of the Hausman test reveals that the FEM is relatively

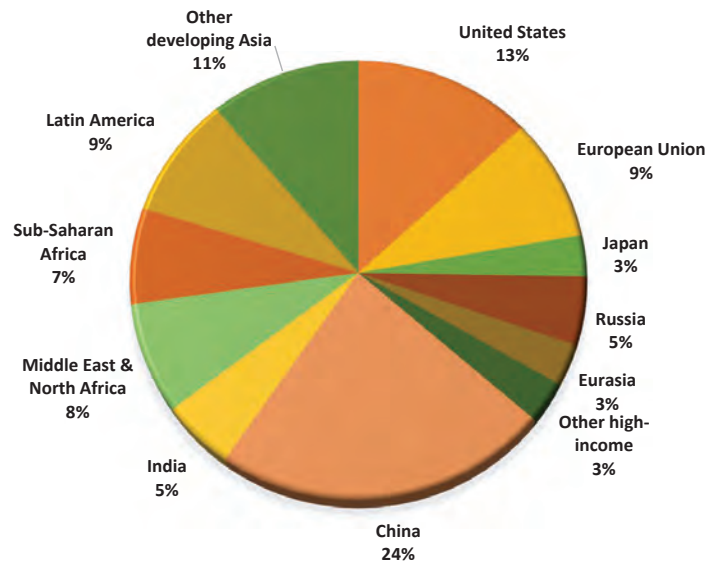


Fig. 4: Annual emissions produced by developing and developed countries

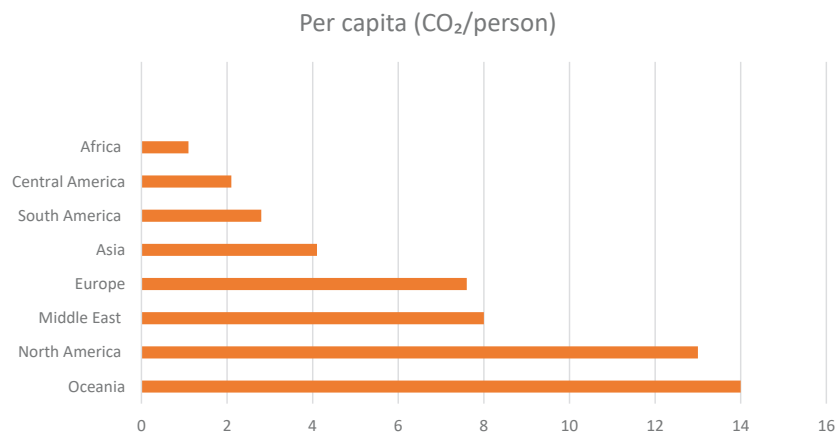


Fig. 5: Carbon emission Per Capita (CO₂/person)

Table 2: Results for macroeconomics determinates of environmental degradation

Variables	Common Effect Model				Specific Fixed Effect				Specific Random Effect			
	Reg-1	Reg-2	Reg-3	Reg-4	Reg-1	Reg-2	Reg-3	Reg-4	Reg-1	Reg-2	Reg-3	Reg-4
LGDP	0.388*** (16.5)	0.386*** (16.20)	0.309*** (14.22)	0.203*** (8.10)	0.343*** (21.99)	0.340*** (21.16)	0.331*** (20.73)	0.330*** (19.09)	0.343*** (22.61)	0.338*** (21.75)	0.328*** (21.16)	0.319*** (19.22)
FDI	0.030 (1.57)	0.025 (1.25)	-0.022 (-1.23)	-0.014 (-0.76)	0.015*** (4.08)	0.013*** (3.52)	0.014*** (3.76)	0.015*** (3.99)	0.015*** (4.11)	0.013*** (3.56)	0.014*** (3.89)	0.015*** (3.97)
TO	1.100*** (17.62)	1.060*** (16.82)	0.624*** (10.40)	0.511*** (8.35)	0.004 (0.20)	0.001 (0.05)	0.006 (0.28)	0.008 (0.36)	0.014 (0.64)	0.011 (0.48)	0.018 (0.81)	0.020 (0.86)
GPOP	-15.32*** (-8.80)	-16.11*** (-9.21)	-8.81*** (-5.47)	-10.2*** (-6.30)	-1.31** (-2.56)	-1.352*** (-2.62)	-1.550*** (-3.01)	-1.300** (-2.52)	-1.387*** (-2.71)	-1.43*** (-2.77)	-1.683*** (-3.25)	-1.452*** (-2.80)
EDU		0.211 (1.18)	0.052 (0.33)	0.083 (0.52)	0.044*** (2.75)	0.144*** (2.82)	0.147*** (2.82)	0.127*** (2.41)	0.147*** (2.73)	0.143*** (2.81)	0.147*** (2.81)	0.130*** (2.47)
IQ		0.038*** (22.64)	0.038*** (22.64)	0.028*** (10.51)	0.028*** (10.51)	0.028*** (10.51)	0.028*** (10.51)	0.006*** (4.00)	0.007*** (4.00)	0.008*** (6.04)	0.007*** (5.35)	0.007*** (5.35)
IFD				1.420*** (6.59)				-0.051 (-0.69)				-0.000 (-0.01)
Constant	-10.21*** (-29.32)	-10.21*** (-25.81)	-8.97*** (-24.82)	-6.37*** (-12.59)	-8.03 (-23.07)	-8.04*** (-22.52)	-8.24*** (-23.03)	-8.06*** (-21.10)	-8.01*** (-22.62)	-8.02*** (-22.08)	-8.24*** (-22.94)	-7.80*** (-20.83)
T	21	21	21	21	21	21	21	21	21	21	21	21
N	115	115	115	115	115	112	112	109	115	112	112	109
N	2,297	2,240	2,240	2,178	2,297	2,240	2,240	2,178	2,297	2,240	2,240	2,178
F-stat	289.01	289.01	381.38	340.99	241.23	182.68	157.51	126.56	[1007.24]	[951.51]	[1001.31]	[937.67]
[Wald χ^2]												
P-Value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Diagnostic tests												
F-test (H ₀): Common effect model is better than Fixed effect model	1042.15	1024.39	838.19	824.64	57.96	70.84	62.44	69.96	20142.70	19663.21	20186.92	19577.09
Hausman test (H ₀): Random effect is preferred over Fixed effect model	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Breusch-pagan test (H ₀): Common effect model is better than Random effect model												

t-values are in parentheses. Whereas, ***, **, * indicates significance at 1%, 5% and 10% level of significance, respectively.

better in all cases. Diagnostic tests indicated that, in all the specifications, the fixed effect model performs better than CEM and REM. In Table 2 signs of most of the coefficients of the variables are according to theory. Moreover, most of the coefficients are statistically highly significant. except for trade openness results of fixed effect postulates a significant and positive relationship of all variables on CO₂ emission while population growth exerts a negative relationship on CO₂ emission. Among the contributors to environmental degradation, economic growth appeared to be highly significant. In all the specifications, growth indicated positively and significantly affecting environmental degradation. The results for economic growth depicts 1% increase in the log of GDP will lead to increase the CO₂ emission by 0.39%. The reason is that economic growth usually changes the style of the production process, industrialization, and urbanization. The positive relationship between economic growth and CO₂ emission is supported by the following studies (Soytas, Sari, 2009; Shahbaz et al., 2013; Moghadam and Lotfalipour, 2014). Similarly, the effect of foreign direct investment is highly significant at 1% level of significance. The results depict that 1% increase in inflows of foreign direct investment will increase the level of CO₂ emission by 0.016%. Our results are in accordance with (Bakhsh et al., 2017). Likewise, the population growth exerts a negative relationship i.e. 1% increase in growth of population leads to almost 1.3% decrease in the level of carbon emission. The reason is that developing countries are labor abundant and lack behind in capital accumulation. Most of the production processes involved the labor participation rather than machinery unlike in developed countries which are capital intensive. The developing countries mostly specialized in the production of agricultural goods in which they have the comparative advantage as stated by the Heckscher-Ohlin theorem. Likewise, gross primary enrollment is highly significant i.e. 1% increase in gross primary enrolment leads to 0.127% increase in the level of CO₂ emission. The reason is that when a person is educated it will enhance its level of productivity, skills, and information which eventually boost up the income level and consequently the purchasing power and consumption increases (Jorgenson, 2003). The empirical analysis shows that a 1% increase in institutional quality leads towards 0.006% increase in the level of emission also the presence of good governance plays a vital role in the

growth of the economies. The reason is FDI is attracted by the good institutional quality which causes more pollution in the economy, moreover weak institutional quality failed to imposed better environmental policies which cause the deterioration of the environment. It also attracts FDI and other developmental projects. In the last, results show that 1% increase in the index of financial development leads to 0.05% decrease in the level of carbon emission. There is a negative relationship between carbon emission and financial development. The reason is that developed financial sector channelizes the savings of household and offer

them to keep the assets in liquid form and invest in those companies which used clean, efficient and environment-friendly (Birdsall, Wheeler, 1993). Similarly, the impact of socioeconomic determinants on environmental degradation can be seen by introducing R&D, urbanization, industrialization and energy consumption. The purpose of the construction of this model is that the study have few cross-sections. So, the study makes separate analysis for it. Table 3 provides the basic results and shows that on the basis of Hausman test FEM is preferred over random effect model. The results for economic growth depict 1% increase in the log of GDP will lead to increase the CO₂ emission approximately by 0.1%. Similarly, FDI is statistically significant at 1% level of significance only in the first model. 1% increase in FDI leads to 0.014% increase in the level of carbon emission. On contrary, trade openness is statistically not significant in the second model and fourth but become significant in the third model i.e. 1% increase in trade openness leads to 0.04% fall in the carbon emission. Trade openness declines carbon emission, the pattern of goods production usually ends up towards those technologies which are environmentally friendly, energy efficient and emits less emission. This implies the technical effect is significant in context trade for environmentally friendly technologies, which shows, that exchange and trade of better technologies reduce the level of emission in the production process of various goods across the borders. Likewise, urban population have a negative relationship with the carbon emission and statistically significant in the models. 1% increase in urban population leads to almost 0.05% fall in the level of CO₂ emission. According to Martínez-Zarzoso (2011), the impact of urbanization varies across different income groups. The EKC hypothesis also holds in this case, i.e. as the share of urban population

Table 3: Results for impact of R&D, industrial share, urban population and energy consumption on environmental degradation

Variables	Common Effect Model				Fixed Effect Model				Random Effect Model			
	Reg-1	Reg-2	Reg-3	Reg-4	Reg-1	Reg-2	Reg-3	Reg-4	Reg-1	Reg-2	Reg-3	Reg-4
LGGDP	0.222*** (11.55)	0.017 (1.09)	0.002 (0.13)	-0.032* (-1.72)	0.329*** (17.91)	0.154*** (9.90)	0.178*** (11.52)	0.038** (2.44)	0.299*** (16.97)	0.131*** (9.03)	0.155*** (10.59)	0.037*** (2.50)
FDI	-0.036** (-2.32)	0.014 (1.21)	0.024** (1.93)	0.044*** (3.02)	0.013*** (3.77)	0.002 (0.89)	0.003 (1.04)	0.003 (1.28)	0.013*** (3.54)	0.002 (0.83)	0.003 (1.11)	0.003 (1.25)
TO	0.693*** (13.66)	-0.049 (-1.25)	-0.089** (-2.14)	-0.297*** (-6.55)	0.004 (0.22)	-0.010 (-0.55)	-0.043** (-2.36)	-0.024 (-1.44)	0.015 (0.65)	-0.007 (-0.38)	-0.037** (-2.06)	-0.025 (-1.53)
UPOP	3.988*** (38.01)	0.943*** (8.90)	1.031*** (9.36)	0.005 (0.04)	0.218 (1.37)	-0.607*** (-4.66)	-0.558*** (-4.42)	-0.482*** (-4.00)	0.719*** (4.70)	-0.387*** (-3.13)	-0.364*** (-3.01)	-0.457*** (-3.90)
EDU		0.244** (2.21)	-0.084 (-0.68)	-0.098 (-0.44)		0.254*** (5.68)	0.277*** (6.26)	0.085* (1.71)		0.256*** (5.72)	0.278*** (6.28)	0.086* (1.72)
LECON		1.024 (42.76)	0.999*** (38.42)	1.078*** (31.09)		0.920*** (37.50)	0.871*** (34.60)	0.981*** (41.89)		0.944*** (39.85)	0.895*** (36.69)	0.984*** (42.96)
INDG		.219** (2.06)				0.376*** (9.65)					0.363*** (9.32)	
R&D				-0.089*** (-3.46)				-0.064*** (-5.27)				-0.064*** (-5.29)
Constant	-6.815*** (-23.60)	-7.978*** (-32.28)	-7.398*** (-27.42)	-6.429*** (-15.60)	-7.786*** (-20.45)	-9.543*** (-30.01)		-6.738*** (-20.73)	-7.312*** (-19.47)	-9.280*** (-30.12)	-9.652*** (-31.47)	-6.738*** (-20.97)
T	21	21	21	21	21	21	21	21	21	21	21	21
N	115	102	95	65	115	102	95	65	115	102	95	65
N	2,297	2,040	1,903	1,301	2,297	2,040	1,903	1,301	2,297	2,040	1,903	1,301
F-stat [Wald χ^2]	950.50	1326.71	908.99	333.89	239.55	480.83	416.37	385.97	[1023.75]	[3212.47]	[3156.49]	[2814.02]
P-Value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diagnostic test

F-test (H ₀): Common effect model is better than Fixed effect model	Hausman test (H ₀): Random effect is preferred over Fixed effect model	Breusch-pagan test (H ₀): Common effect model is better than Random effect model
652.31	117.60	20550.23
0.000	0.000	0.000
964.32	29.98	18667.76
0.000	0.001	0.000
0.000	0.934	17556.74
0.000	0.000	0.000

t-values are in parentheses. Whereas, ***, **, * indicates significance at 1%, 5% and 10% level of significance, respectively.

percentage of the total is achieved at the certain point, its start reducing the environmental destructions. The elasticity of urbanization is highest and positive for low-income countries, for middle-income countries its start falling and for developed countries the sign of elasticity turns to negative. The industrial growth as a share of GDP is included which is statistically highly significant at 1% level of significance. 1% increase in industrial growth leads to a 0.38% increase in the level of carbon emissions. The reason is that economic development leads to change in the pattern of and industrialization. Generally, the rise in income is due to the large-scale withdrawal of labor from rural primary agriculture sectors to the industrial sector in urban areas. In the last, the coefficient of Research and Development (R&D) is statistically significant at 1% level of significance. Means that a rise in (R&D) leads to a decrease in the level of carbon emission up to 0.068%. High and latest technologies reduce the cost of pollution abatement, save non-renewable resources and shift to the cleaner production process. Technological development through R&D encourages that technology which is environment-friendly and creates less pollution in the atmosphere (Sanstad, 2006).

CONCLUSION

Environmental degradation has become a burning issue in the present world irrespective of a country who is responsible for it. Environmental degradation is a global issue and all countries are facing serious threats from environmental destructions. Several empirical studies justify the relationship of economic growth with the environmental degradation but there are a lot of factors working behind it. The present study aims to justify how these socio-economic indicators namely institutional quality, financial development and economic growth have an impact on environmental degradation. The objective of the study is to evaluate the impact of economic growth, financial development and institutional quality on environmental degradation. The annual data is taken from 1996-2016 for the panel of developed and developing countries. There are numbers of studies which explore the linked between economic growth and environmental degradation but the role of developed financial sector and impact of institutional quality on environmental destruction is not jointly explored for the panel of developed and developing countries. Moreover, most of the studies

used one indicator credit to private sector as a proxy for financial development. This study incorporated the index of financial development because it' a broad and multidimensional concept. Different indicators for the financial market (FMD, FME, and FMA) and financial institutions (FID, FIE and FIA) are incorporated. Likewise, the index of institutional quality comprises of six indicators namely, rule of law, political stability and accountability, regulatory law, control of corruption, government effectiveness and absence of violence. The good institution has a central role in combating against pollution. So, the null hypothesis of the study is that financial development and institutional quality has an insignificant impact on environmental degradation against the alternative that it postulates a significant relationship with the environmental degradation. Results of this study are based on panel data of developed and developing countries classified by the World Bank. For this purpose, different well-known econometric technique of panel data i.e. CEM, FEM and REM is used. The outcome of a socio-economic indicator revealed a significant impact of the variables on environmental degradation. The study accepts the alternative hypothesis in our study. In most of the cases, FEM is chosen instead of REM. For economic growth, scale effect dominates in all the specifications. In general, economic growth has a positive, significant and direct relationship with the carbon emission level but the contribution for CO₂ emission is more in the case of industrialization, urbanization and energy consumption. Likewise, the Pollution Haven Hypothesis (PHH) is supported because FDI has a direct link with CO₂ emission. Trade openness provides us with interesting outcomes which are supported by the theories. Moreover, population growth has an indirect relationship with the carbon emission. The index of financial development postulates a negative relationship with carbon emission and the index of institutional is positive in all cases. The presence of good governance minimized the effect of market failure and promote cooperation among the players. The educational level has imperative importance in case of developed and developing countries and in all cases it is significant. Similarly, for the urban population, the study gets mixed results and it is significant in all the specifications. The sign of the urban population depends on diversified income groups. In the last, the captivating results for R&D show a significant relationship. For developed countries, R&D leads to a reduction in the carbon emission while it exerts

positive relation in the context of developed countries. Though, need for additional empirical analysis and investigation remain pertinent and hopefully improved further. It can be expanded by changing the size of the data, applying different estimation techniques and by making decomposed analysis for financial development and institutional quality. The study will also be extended to make a comparison of different regions of the world.

AUTHOR CONTRIBUTIONS

M. Batool performed conceptualization, methodology, software, literature review and manuscript preparation. Y. Jehan performed data curation, writing original draft preparation, writing reviewing and editing references. Naveed Hayat helped in the visualization, investigation, software validation.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

<i>FEM</i>	Fixed Effect Model
<i>IPS</i>	Im-Pesaran-Shin
<i>LLC</i>	Levin-Lin-Chu
<i>GDP</i>	Gross Domestic Product
<i>REM</i>	Random Effect Model
<i>CO₂</i>	Carbon Dioxide
<i>EKC</i>	Environmental Kuznets Curve
<i>CEM</i>	Common Effect Model
<i>PHH</i>	Pollution Haven Hypothesis

<i>FMD</i>	Financial Market Depth
<i>FME</i>	Financial Market Efficiency
<i>FMA</i>	Financial Market Access
<i>FID</i>	Financial Institutions Depth
<i>FIE</i>	Financial Institutions Efficiency
<i>FIA</i>	Financial Institutions Access
<i>WGI</i>	World Governance Indicators

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ORIGINAL RESEARCH PAPER

Appraisal of compliance with land subdivision planning regulations in residential neighbourhoods

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ABSTRACT

Although previous studies have attempted to address the challenge of land subdivision, there is still a scarcity in the literature on how the extent of conformity to land subdivision planning regulations may be statistically and spatially analyzed. This study, therefore, explores the extent to which residential developers comply with land subdivision planning regulations in Kenya, a case study of Kisii Town. It was guided by the public interest theory of regulation with a target population of 7,430 residential developments from the seven sublocation neighbourhoods of Kisii Town. Four administrative sublocations were used as strata out of which proportional random samples were drawn from their respective residential neighbourhoods to attain a sample size of 364. Structured checklists were used to collect data on the extent of conformity. Results revealed that although the recommended minimum plot size in Jogoo, Nyamataro and Nyanchwa neighbourhoods was 0.1 ha, 84%, 100% and 88% of developers did not respectively comply. Further, although the recommended minimum plot size for Egesa, Daraja Mbili, Mwembe and Nyamage neighbourhoods was 0.05 ha, 83%, 46%, 58% and 63% of developers failed to, in that order, comply. The problem continues notwithstanding the legal framework that grants the County Government of Kisii powers of development control. Key recommendations comprised establishing a coordinating committee to harmonize agencies that deal with land subdivisions and ensuring that only registered persons' process of land subdivisions. This study generally benefits international readers by highlighting how compliance with recommended land subdivision planning regulations may be statistically and spatially analyzed.

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INTRODUCTION

Every person has at least some affiliation with the land. As a factor of production, it enables its owners to access loans, build shelter and establish businesses in urban areas. Conversely, in rural

areas, the land is acknowledged as fundamental in promoting food security, employment creation and daily subsistence (the Republic of Rwanda, 2017; UN-Habitat, 2012; FAO/UNEP, 1997). Because land acts as an important facet of development (Oluwatayo *et al.*, 2019; Chitonge and Mfunne, 2015), it remains an indispensable necessity for survival by not only

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embodying the foundation upon which individual activities are anchored but also presents economic and social opportunities (Kuma, 2017). This evidence suggests that a country's potential for realizing its social and economic development is largely dictated by its physical resource base as may be substantiated by the amount of land under its spatial jurisdiction (Jin *et al.*, 2018). From the human settlement point of view, since land supports development, social justice and delivery of decent housing; it should be used to address the general interest of the society (the Republic of Kenya, 2007). As a natural resource, land presents a multiplicity of uses that may be grouped into categories that consist of the environment, economics, society and spirituality. Regarding the environment, some may regard it as soil and habitat, thus denoting the nexus between atmospheric, hydrological and climatic systems. To an economist, land may be considered as a scarce space for locating activities that are intended to support economic production, housing and attendant infrastructure. Socially, ownership of land signifies prestige, hence, a symbol for socioeconomic affluence (Hubacek and van den Bergh, 2002; Mwangola, 2001). Land use, therefore, emerges as a product of human activities operating within the political, social, institutional and legal context. More often than not, this results in spatial competition among multiple interests (Omollo, 2020; Hermunen, 2004). If the status quo continues in the absence of planning and development control, the quest is bound to attract unregulated land subdivisions leading to unsustainable spatial development. Because of this, Nha (2017) suggested that land-use planning should be used as a tool for allocating and reallocate land resources for sustainable development. This, without doubt, includes subdivision control. From the introductory overview, this study examines the extent to which residential developers in Kenya comply with approved land subdivision planning regulations. It is undertaken in Kisii Town as a case study. It addresses the limitations of earlier approaches by filling the current research gap in land use planning literature through a demonstration of how compliance with land use subdivision regulations may be statistically and spatially analyzed. It further links the theoretical and philosophical approaches to land subdivision development control in the context of a developing country that hopes to attain a middle-income country by the year 2030.

Regulation of Land Subdivision: A Literature Review

Unsustainable land subdivision is a common challenge that occurs in developing countries (Cengiz, 2013). Thus, in an attempt to propose an orderly development within the selected Sub-Saharan African cities (Kihonda, Tanzania; Kumasi, Ghana; Dar es Salaam, Tanzania; and Benin City, Nigeria), Agheyisi (2018) established that the lack in the enforcement of the approved regulatory framework on land subdivision contributed to land-use conflicts. The study recommended that the growth of urban centres should be planned and regulated to promote a healthy and safe environment. A further suggestion was made for stringent regulation of the land subdivisions to ensure that new areas added to the towns form an integral part of the overall urban spatial structure that does not compromise the tenets of sustainable development. An earlier study by Agheyisi (2016) attempted to evaluate if informal land subdivisions in Benin metropolis, Nigeria, conformed with the existing planning law. The results of the independent-sample t-test from the selected neighbourhoods, however, showed no statistically significant difference in the mean scores of the two variables. In Massachusetts, Ben-Joseph and Phelan (2005) argued that inadequate streamlining of land subdivisions resulted in unnecessary delays in the approval process, a subject further linked with developers' inability to present adequate documentation. The problem was heightened by the revelation that since subdivisions were concurrently approved by multiple government agencies, this increased bureaucracy and red tape, thus encouraging noncompliance by developers. In a different context, Musambayi (2013) found out that there was a link between the land subdivisions and performance of the agricultural sector. In this case, unregulated subdivisions in Kenya were significantly correlated with a decline in agricultural productivity, thus a key determinant of food security. This line of argument relates to that of Museleku (2018) who validated that economic variables were the leading drivers of agricultural land subdivision. These drivers included agricultural land inheritance practices, the price of agricultural land and demand for urban housing. A related study at Kaputiei North, Kenya by Kebaso (2017) additionally found a significant association between the increase in settlements as a function of land subdivisions and food security. In the end,

subdivisions of less than one ha pointedly increased by 411%, while those of over 100 hectares reduced by 89%. During the same period, meat production, notably reduced by 78%. Another comparative finding was reported by [Ram et al., \(1999\)](#) whose study in Khabra Kalan village, India, also found out that the landholding size halved every 20–30 years due to uncontrolled subdivisions. As such, [Boob and Rao \(2014\)](#) established that inadequate monitoring and enforcement of subdivision regulations provided room for developers who violated building regulations in India. Generally, 75 % of open spaces were not developed as required. At the same time, the minimum width of access roads, side and rear margins were also grossly violated. In the same way, most developers disregarded floor space index owing to the excessive coverage on the ground floor. A similar challenge was raised by [Mwesige \(2007\)](#) who established that 80% of the developers in Kampala City, Uganda, did not comply with the subdivision requirements. Research findings specifically showed that informal land subdivision was responsible for the disorderly spatial development, consequently resulting in the non-attainment of the city's development plan. These challenges were attributed to inadequate enforcement of approved planning regulations. Although reviewed studies have so far attempted to enrich the literature on unregulated land subdivisions, there is still a scarcity in knowledge on how compliance with prescribed land subdivision planning standards may be both statistically and spatially assessed, a gap filled in the current study. The objective of this study was therefore to determine the extent to which residential developers in Kenya comply with land subdivision planning regulations, a case study of Kisii Town. It was undertaken between 13th September 2019 and 28th November 2019. The study begins by appraising the regulation of land subdivisions in Kenya as enshrined under enabling legislation and policy documents.

Land Subdivision in Kenya: Legislative and Policy Framework

The first reference point for land use regulation in Kenya is provided for under article 60 of the Kenya Constitution ([the Republic of Kenya, 2010](#)) that sets the principles of land policy to include, among others, sustainable and productive management of land resources, transparent and cost-effective

administration of land, and sound conservation and protection of ecologically sensitive areas. Article 61 further provides three classifications for land in Kenya. These include public land, community land and private land. To ensure they are sustainably used, article 66 (1) gives the State the power of regulating the use of any land, a requirement reinforced by Section 2 of the Physical and Land Use Planning Act (PLUPA) ([the Republic of Kenya, 2019a](#)) that defines development to include carrying out any works on land or making any material change in the use of any structures on the land. Section 56 (b) the Act, empowers county government to control the subdivision of land. Besides the Constitution and PLUPA, the land subdivision in Kenya is also regulated by the Land Control Act ([the Republic of Kenya, 2012](#)). Section 6 requires that the subdivision into two or more parcels is invalid unless the Land Control Board for the land control area in which the land is situated has given its consent. Further, Regulation 43 (2) (a) of the Land Registration (General) Regulations, 2017 ([the Republic of Kenya, 2017a](#)) requires any developer who applies to the Land Registrar for the consent to combine or subdivide parcels of land to obtain a copy of the approved development application from the relevant county government. This includes approval for land subdivisions. Notwithstanding the existing legal framework, the need to control land subdivisions in Kenya has also been addressed in key national policy documents. For example, in 2017, the Government of Kenya developed the first National Land Use Policy ([the Republic of Kenya, 2017b](#)). The policy commits the development of a framework that will facilitate the attainment of orderly and sustainable land use. Moreover, to provide a national spatial vision, the Government of Kenya in 2015 prepared the first National Spatial Plan (2015-2045) ([the Republic of Kenya, 2017c](#)) which proposes a land development strategy that regulates the subdivision of land. It is, therefore, apparent that regulation of land subdivision in Kenya is sufficiently addressed under various enabling legislative and policy instruments. An immediate query at this juncture is whether the provided instruments are adequately being utilized in controlling land subdivision with a specific case study of Kisii Town in Kenya. However, to guide this interrogation, the paper commences by giving a deeper insight into the study's theoretical context.

Theoretical context

Regulation of the economy by the state intervention has existed since time immemorial. The notion of public interest is, therefore, as old as the political viewpoint of the state regulation. Consequently, both state intervention and public interest exist in the philosophical, political, and legal spheres (Hantke-Domas, 2003). From this background, this study is anchored in the Public Interest Theory of Regulation (PITR) which explicates that regulation should protect and benefit the public instead of only favouring a section of the society. The theory was developed by Pigou (1932) who argued that the regulations are developed in the interest of the public interest as a necessity for addressing inefficient undertakings in the economic markets. In this case, the regulations are perceived to benefit the entire society as opposed to a person's interest. Applied to the current study, PIRT vindicates why land subdivision in Kenya with a specific reference to Kisii Town needs regulation by the County Government of Kisii (CGOK). The aim is to safeguard statutory compliance with approved subdivision regulations. In this circumstance, the CGOK carry out enforcement by restricting rights to land subdivision and in so doing, development control intercedes in

the processes of land subdivision. This is because land subdivision development control is enforced through obligatory edicts solely issued and enforced by the CGOK. Failure to conform subsequently attracts penalties as may be specified in the applicable legislation. To further contextualize the theory as it relates to compliance with land subdivision regulations in the study area, PLUPA grants county governments in Kenya the powers to control the use and development of land by prescribing a stiff penalty for anybody who subdivides land without development permission. PITR, therefore, provides a theoretical foundation expounding why the CGOK should consistently regulate land subdivision in Kisii Town, a scheme towards achieving a sustainable land use as enunciated under Kenya's National Spatial Plan, 2015-2045.

MATERIALS AND METHODS

Study area description

Kisii Town is located in the south-western part of Kenya (Fig. 1). It is the current administrative headquarter of Kisii County, one of the 47 county governments that constitute the Republic of Kenya as per the Constitution of Kenya (Omollo, 2020; the Republic of Kenya, 2010). The town is situated



Fig. 1: Geographic location of Kisii Town, the study area, in Kenya (Encyclopædia Britannica, 2011)

approximately 300 km from Nairobi, the capital city of Kenya, and about 120 km from the shores of Lake Victoria, the second-largest freshwater lake in the world. Although the town spatially covers an area of 34 km², only 4.35 km² is planned, an indication that much land use development is taking place in the absence of an updated land use development plan.

The population in 2018 was 93,959, which is further projected to 140,118 by 2032 ([the Republic of Kenya, 2019b](#)). In the national context, the town is ranked as the third most densely populated urban area after Nairobi City County (4,515 persons per square kilometre) and Mombasa County (4,292 persons per km²). Further, according to Kenya Population and Housing Census Survey of 2019 ([the Republic of Kenya, 2019b](#)), the town's annual population growth rate of 2.7% is ranked among the highest in Kenya, in fact, higher than Kenya's annual average of 2.6%. A combination of these variables continues to intensify land use development, which in the absence of effective land-use planning has given rise to unsustainable land use development such as unregulated land subdivisions and conflicting land uses.

Population, Sample and Sampling Design

The target population comprised 7,430 residential developments from the seven sublocation neighbourhoods of Kisii Town. As suggested by [Saunders et al., \(2016\)](#), the choice of sample size was informed by the confidence level, the margin of error and the target population from which the sample was drawn. The selection of sample size was guided by the Sample Size Determination Table as recommended by [Krejcie and Morgan \(1970\)](#). According to the table, at a 95% confidence level, if the population (N) falls between 7,000 and 7,999, the sample size (N) should be 364. The sample size for the study was, therefore, 364 residential building developments whose plot coverage in terms of the acreage was empirically measured to determine the extent to which they were complying with the recommended land subdivision planning regulations issued and enforced by the CGOK. This sample size was above 357 as suggested by [Saunders et al., \(2016\)](#) at a margin error of 5%. Four administrative sublocations of Kisii Town were used as strata out of which proportional random samples were drawn from their respective residential neighbourhoods to attain

the sample size of 364. These neighbourhoods were Jogoo, Egesa, Nyamataro and Daraja Mbili (located in Mwamosioma sublocation), Nyanchwa (located in Nyanchwa sublocation), Mwembe (located in Nyaura sublocation) and Nyamage (located in Bobaracho sublocation). [Escamilla et al., \(2014\)](#) suggested that because obtaining sampling frames for urban residential developments is a challenge because such records are seldom maintained by relevant authorities, high-resolution satellite images and spatial analysis software may be used to digitize each development within an area of interest to generate an accurate list in the form of a representative sampling frame, which can be used to draw random samples. Based on this recommendation, given that there were no records maintained by the CGOK on the number of residential building developments in Kisii Town, their numbers were first identified using a high spatial resolution satellite image (QuickBird 2, 0.34-metre spatial resolution) obtained from the Regional Centre for Mapping of Resources for Development, Nairobi City County, and thereafter digitized to generate a sampling frame in the form of the feature attribute table. The process entailed delineation of sublocation boundaries of Kisii Town, followed by the digitization of all building developments and thereafter spatial segregation of neighbourhood boundaries from respective sublocations. This was attained through the adoption of participatory mapping exercises incorporating Assistant Chiefs drawn from respective sublocations, thus giving credence that there were no overlaps in data collection. As justified by [Natarajan \(2017\)](#) and [Warner \(2015\)](#), such participatory mapping has the advantage of collecting and agglomerating local knowledge of different people to create a high-resolution composite map that serves to provide a greater level of knowledge than can be achieved from traditional mapping methods. Ground truthing exercises to ascertain that delineated boundaries were accurate in addition to confirming that digitized developments were residential was additionally undertaken. As a whole, 7,430 residential developments were successfully mapped from the neighbourhoods of the four sublocations. This formed the target population as well as provided the sampling frame ([Table 1](#)).

To obtain a proportional representative sample size for residential developments per respective stratum (sublocation neighbourhoods), the number

of buildings from each stratum was divided by the total number of buildings for all strata (7,430) and the product multiplied by the desired sample size of 364 (Table 1). Because Mwamosioma sublocation (stratum) was the largest, its four neighbourhoods (substratum) were further demarcated for sampling. These included Jogoo (1,551 buildings), Nyamataro (808 buildings), Egesa (821 buildings), and Daraja Mbili (1,301) totalling to 4,481 buildings. Since the desired sample size for the sublocation was 220, to get the corresponding sample size for each neighbourhood, their respective number of buildings were further divided by the total number of buildings in the sublocation (4,481) and the product multiplied by 220, resulting to sample sizes of 76, 40, 40 and 64 respectively for Jogoo, Nyamataro, Egesa and Daraja Mbili. As regards other sublocations, in Nyaura, Mwembe was the only dominant neighbourhood. The same occurred in Bobaracho and Nyanchwa sublocations where Nyamage and Nyanchwa were respectively the only dominant neighbourhoods. To safeguard credible representation, samples from each stratum and substrata were afterwards drawn using a random number table. According to Saunders *et al.*, (2016), random numbers allow a selection of

the desired sample without bias in a situation where an accurate sampling frame has been provided.

Data Collection and Analysis

Structured observational checklists were used to collect data on conformity with recommended land subdivision planning regulations. While the first column gave the name of the residential neighbourhood, the second column denoted the standard value of the recommended planning regulation. The third column recorded the observed value concerning the recommended standard value of the planning regulation. The last column reported deviation, indicating the extent to which each regulation was complied with by the sampled residential developers. During data collection, the size of each residential plot was physically measured after permission was sought from the respective developers and results recorded on the checklist. Compliance with recommended standard value for land subdivision denoted accordance while noncompliance indicated deviation. The recommended planning regulations regarding the minimum plot size in Kisii Town are presented in Table 2.

Table 1: Neighbourhood sampling proportion

Sublocation /Strata	Sublocation Residential Neighbourhood	No. of Developments/ Residential Plots	Proportional Sample size
Mwamosioma	Jogoo	1,551	76
	Nyamataro	808	40
	Egesa	821	40
	Daraja Mbili	1,301	64
Nyaura	Mwembe	1,105	54
Bobaracho	Nyamage	1,171	57
Nyanchwa	Nyanchwa	673	33
Total		7,430	364

Table 2: Recommended minimum plot size in Kisii Town

Sublocation /Strata	Sublocation Residential Neighbourhood	Recommended Minimum Plot Size (Ha.)
Mwamosioma	Jogoo	0.1
	Nyamataro	0.1
	Egesa	0.05
	Daraja Mbili	0.05
Nyaura	Mwembe	0.05
Bobaracho	Nyamage	0.05
Nyanchwa	Nyanchwa	0.05

Data were analyzed using descriptive and inferential statistics that included means, standard deviation, one-sample t-test, paired sample t-test, correlation analysis and GIS. To spatially illustrate the extent to which developers were complying with the recommended subdivision planning regulations, Registry Index Maps (survey maps) for selected parts of the neighbourhoods were obtained from the Kisii County Survey Office and thereafter scanned, georeferenced and digitized using QGIS software version 3.6.0. This enabled an accurate computation of the area (in hectares) covered by each sampled residential plot.

RESULTS AND DISCUSSIONS

This section concurrently presents the results and discussions of the research findings. To attain this, it is systematically organized into two broad subsections. These include a test for normality and response rate; and extent of compliance with the recommended minimum plot size per sublocation neighbourhood.

Test for Normality and Response Rate

The normality assumption assessment in the collected data is a criterion when undertaking any parametric statistical tests. This is because data validity depends on it (Meterko *et al.*, 2015; Ghasemi and Zahedias, 2012; Hoekstra *et al.*, 2012). In the current study, the test for normality was undertaken using the Kolmogorov-Smirnov Test which reported a p-value of 0.316. The alternative hypothesis was, therefore, rejected and a conclusion made that the collected data on the extent of compliance with the recommended land subdivision regulations come

from a normally distributed population. In addition to the test for normality, the survey response rate is likewise regarded as a key data-quality indicator (Meterko *et al.*, 2015). In the current study, out of the 364 checklists used to collect data, 290 were completed representing a response rate of 80%. This was above the minimum of 50% as suggested by Mugenda and Mugenda (2003) and 55.56% by Baruch (1999). Based on these suggestions, the response rate of 80% was considered adequate for subsequent data analysis and reporting.

The extent of Conformity with Subdivision Regulations in Kisii Town

Minimum plot size is determined by the user, type of waste disposal, availability of water and the level of building technology applied (the Republic of Kenya, 2007). The objective is to control the subdivision of private land to ensure that such land is held in economically viable parcels, contributing to the attainment of development control principles of access, aesthetics, conformity, efficiency, convenience, suitability, safety, and environmental conservation. Assessment of compliance was undertaken per sublocation neighbourhood in the following order: Nyanchwa Sublocation (Nyanchwa Estate), Mwamosioma Sublocation (Jogoo, Egesa, Nyamataro, and Daraja Mbili estates), Nyaura Sublocation (Mwembe Estate), and Bobaracho Sublocation (Nyamage Estate).

Nyanchwa neighbourhood

Recommended minimum plot size in Nyanchwa was 0.1 hectares. Descriptive statistics conversely demonstrated that the mean for the observed plot

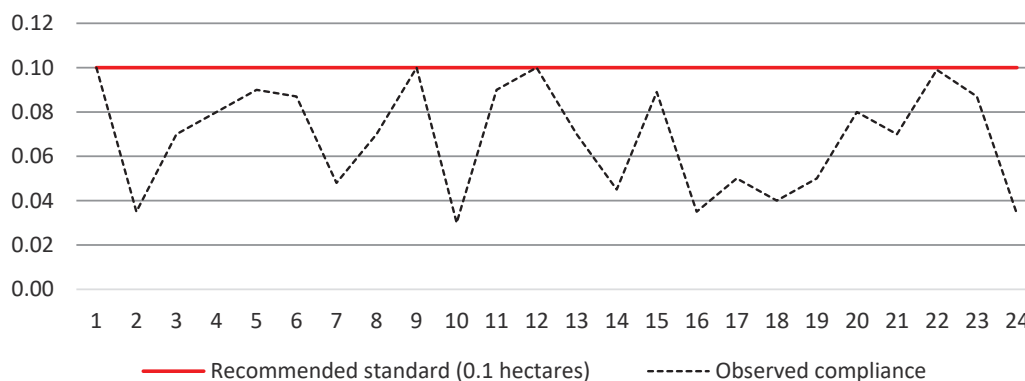


Fig. 2: Graphical depiction of the extent of compliance in Nyanchwa neighbourhood

sizes ($M = 0.068$, $SD = 0.224$) was lower than that of the recommended plot size/test value of 0.1 hectares. This difference was further subjected to a one-sample t-test to determine its statistical significance. The test demonstrated that the differences between observed and recommended compliances were statistically significant, $t(23) = -6.305$, $p = .000$. Furthermore, the mean difference between the two variables (observed compliance and recommended standard) was $-.0312$, implying that compliance declined by an average of $-.0312$ hectares. The extent of compliance is further depicted graphically (Fig. 2) with an indication that most plots did not comply with the recommended planning regulation of 0.1 hectares.

A further analysis was undertaken on a case by case basis to determine the extent to which each developer had disregarded the planning regulation on the minimum plot size of 0.1 hectares. Results indicated that while 8.3% of plots had areas of 0.03 hectares and 0.08 hectares respectively, a majority (20.8%) had an area of 0.09 hectares compared to 12.5% that had an area of 0.04 hectares. Conversely, 16.7% had respective areas of 0.05 hectares and 0.07 hectares. Generally, it can be construed that 83.3% of the sampled plots in Nyanchwa failed to comply with the recommended minimum plot size of 0.1 ha.

Mwamosioma sublocation

The recommended minimum plot size for Jogoo, Nyamataro, Egesa, and Daraja Mbili were 0.1 hectares (Jogoo and Nyamataro) and 0.05 hectares (Egesa and Daraja Mbili). From this background, analysis commenced by spatially representing the extent of compliance, using Jogoo neighbourhood as a case example (Fig. 3). The GIS spatial analysis makes evident that while most noncomplying residential plots were located along the Kisii – Nyamira transportation corridor, those complying were mainly located within the neighbourhood's interior. This underpins the primacy role that this corridor has occasioned on land subdivisions. As a consequence, in the absence of effective development control initiative by the CGOK, the trend is bound to replicate in other plots at the disadvantage of sustainable spatial development.

Although it was established that some sampled residential developments in Daraja Mbili complied with the prescribed minimum plot size, analysis of each plot showed that 46% failed to meet the set minimum threshold of 0.05 hectares. The significance of this observed noncompliance was tested statistically. The one-sample t-test results indicated that in Jogoo, the mean difference (0.03) was statistically significant, $t(69) = -8.35$, $p = .00$, likewise, at Nyamataro, the mean



Fig. 3: Noncomplying land subdivisions in Jogoo neighbourhood

difference (-0.03) was significant, $t(34) = -2.24, p = 0.03$. This significant trend was simulated in Egesa (mean difference = -0.01), $t(30) = -3.30, p = 0.00$. Nonetheless, as mentioned before, in Daraja Mbili, though the mean difference (0.01) was not unfavourable, it was still statistically significant, $t(59) = 2.56, p = 0.01$. A summary of the observed extent of mean compliance regarding plot size and their corresponding test values were further demonstrated graphically (Fig. 4).

Nyaura and Bobaracho Sublocations

Compliance with recommended land subdivision regulations in Nyaura and Bobaracho sublocations were jointly analyzed because their applicable planning regulations on minimum plot size were the same. Whereas the notable residential urban neighbourhood in Nyaura sublocation is Mwembe, Nyamage, on the other hand, is the major neighbourhood in Bobaracho sublocation. The descriptive one- sample statistics showed that the mean size of plots in Mwembe and Nyamage were within the recommended minimum standard of 0.05 hectares (M = .065, SD = .087 and M = .16, SD = .25). Results of significance using one-sample t-test further demonstrated that both respective mean differences for the minimum plot size in Mwembe and Nyamage

(0.06 and 0.16), were significant, $t(39) = 4.75, p = 0.00$ and $t(29) = 3.51, p = 0.00$ suggesting general compliance (Table 3).

Given the above results, the study examined each sampled plot to determine the extent to which they were independently complying with the recommended regulations. Results disclosed that in Mwembe and Nyamage, 57% and 45% of the plots were respectively less than 0.05 hectares. This confirmed that enforcement was ineffectual at the disadvantage of effective development control in Kisii Town. From the foregoing, the study sought to investigate the implication of uncontrolled land subdivision in Mwembe and Nyamage. To achieve this, a particular reference was made to the Building Coverage Ratio (BCR) as a key land use planning standard. The justification for this choice is that uncontrolled land subdivisions in urban areas potentially contribute to the uneconomical size of land, consequently resulting in inadequate space within a plot. This, in turn, negates the land use development control objectives of access, convenience and aesthetics. The BCR refers to the size of the constructed building floor plate (that is, first-floor total area) as compared to the total size of the plot of land. This is demonstrated in Fig. 5.

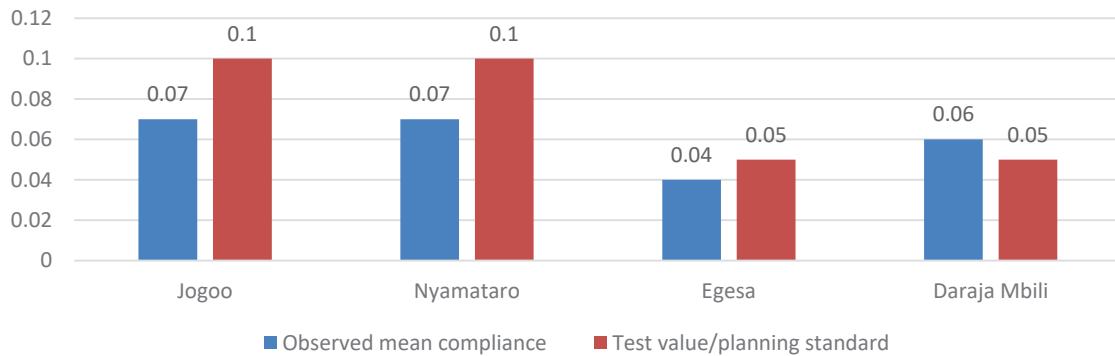


Fig. 4: Compliance with minimum plot size in Mwamosioma sublocation neighbourhoods

Table 3: Test on compliance with the minimum plot size in Mwembe and Nyamage residential neighbourhoods

Residential Neighbourhood	Test Value = 0.05 Hectares			
	t	df	Sig. (2-tailed)	Mean Difference
Mwembe	4.75	39	.00	.06
Nyamage	3.51	29	.00	.161

The recommended BCR for Nyamage and Mwembe neighbourhoods by the CGOK is 70%. Enforcing the standard is largely intended to contribute towards the following urban sustainability benefits: 1) Establishing increased provision of essential services such as on plot parking; 2) Providing planners with options to design additional habitable and open spaces, in consequence enhancing the quality of buildings by maintaining the ratio of open space to built-up space; 3) Increasing mandatory open spaces around the domestic building which enables sufficient natural lighting and ventilation by reducing the amount of built-up environment, and so positively impacting on urban microclimate. From the foregoing, the study consequently explored the correlation between BCR and plot sizes in Nyamage and Mwembe neighbourhoods (Table 4).

Results demonstrate that in Nyamage, a negative and significant correlation emerged between BCR and plot size ($r = -.594$, $n = 30$, $p = .001$), suggesting that plots with higher BCR tended to be smaller in size. The same was, however, not observed in Mwembe

($r = -.064$, $n = 40$, $p = .694$). Spatial distribution of noncomplying plots, a case of Mwembe was further undertaken (Fig. 6). Though noncompliance with recommended minimum plot size seems to have affected less than 50% of plots, the situation could have changed by the time the current study was completed in October 2019, since the Preliminary Index Diagram (PID) sourced from the Kisii County Survey Office was last updated in 2001. In the absence of effective land subdivision control by the CGOK, challenges such as provision for adequate access roads and optimal densities are predicted to soon escalate.

Table 5 presents a summary (%) of non-compliance with the recommended minimum plot size per neighbourhood in the study area. This is based on the field measurements undertaken in the respective neighbourhoods. The highest noncompliance has been registered in Nyamataro (100%), followed by Nyanchwa (88%) and Jogoo (84). This gives a clear indication that enforcement of subdivision regulations remains inadequate in the entire Kisii Town.

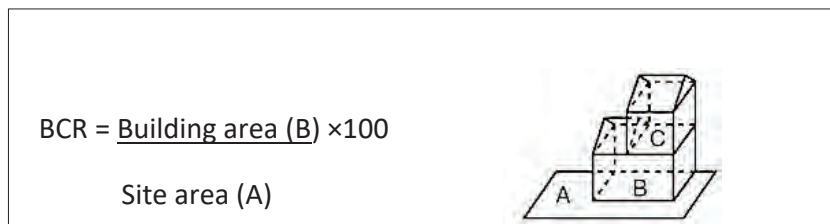


Fig. 5: Illustration of BCR (UN-Habitat, 2013)

Table 4: Correlation between BCR and plot size in Mwembe and Nyamage neighbourhoods

Nyamage			
		BCR	Plot size
BCR	Pearson Correlation	1	-.594**
	Sig. (2-tailed)		.001
	N	30	30
Plot size	Pearson Correlation	-.594**	1
	Sig. (2-tailed)	.001	
	N	30	30
Mwembe			
BCR	Pearson Correlation	1	.064
	Sig. (2-tailed)		.694
	N	40	40
Plot size	Pearson Correlation	.064	1
	Sig. (2-tailed)	.694	
	N	40	40



Fig. 6: Noncompliance with minimum plot size in Mwembe neighbourhood

Table 5: Summary of noncompliance with subdivision regulations

Sublocation	Sublocation Residential Neighbourhood	Recommended Minimum Plot Size (Ha)	% of non-compliance
Mwamosioma	Jogoo	0.1	84
	Nyamataro	0.1	100
	Egesa	0.05	83
	Daraja Mbili	0.05	46
Nyaura	Mwembe	0.05	58
Bobaracho	Nyamage	0.05	63
Nyanchwa	Nyanchwa	0.1	88

The findings of this study agree with that of [Agheyisi \(2018\)](#) who found out that inadequate implementation of the existing legal framework on land subdivision encouraged land-use conflicts in the urban areas of developing countries. The findings further relate to that of [Kiama \(2010\)](#) who established that although there were subdivision regulations which guided land use in Karen Langata, Nairobi, Kenya, irregular subdivisions persisted resulting in negative impacts to the environments. The research findings further confirm the arguments by [Boob and Rao \(2014\)](#) who established that insufficient

enforcement of land subdivision regulations in India provided room for developers who violated building regulations. Nonetheless, while [Agheyisi \(2018\)](#); [Boob and Rao \(2014\)](#) and [Kiama \(2010\)](#) were limited to descriptive analyses, the current study addresses its self to the positivist research philosophy, a deductive method of inquiry through factual field measurements to determine the extent to which developers complied with recommended land subdivision regulations by working on quantifiable and measurable observations where spatial and statistical analyses were used.

CONCLUSION

The objective of this paper was to determine the extent to which residential developers in Kenya were complying with land subdivision regulations, a case study Kisii Town. The study findings have demonstrated that most land subdivisions from the neighbourhoods of the four sublocations in Kisii Town do not comply with the recommended land subdivision planning regulations attributable to inadequate enforcement by the CGOK. The scope of this study was limited to the subdivision of land planned for residential use. To further contribute to the discourse on land use planning, a suggestion for further research is made for other categories urban land uses such as commercial, educational and industrial. This will ensure that challenges afflicting subdivision of all categories of urban land are exhaustively addressed through research, hence informing academia, governance and policy. The problem continues unabated notwithstanding the existing legal and policy framework that grants the CGOK the powers to regulate land subdivisions to attain a sustainable spatial urban development. In the end, uncontrolled land subdivisions in Kisii Town has hastened land use planning challenges that include, but not limited to the uneconomic size of land, especially in the peri-urban areas; encroachment on road reserves; the proliferation of informal settlements; the diminishing of planned urban green spaces; high BCR and inadequate on plot parking in residential areas. If the status quo remains, these problems are anticipated to further escalate owing to increased demand for land on the account of the ever-increasing population in the study area. The following recommendations are, therefore, made towards land subdivision control in Kisii Town: 1) There is a need for the CGOK to adopt strict enforcement and monitoring regime that ensures total compliance with recommended land subdivision regulations in Kisii Town; 2) The CGOK should regularly mount sensitization campaigns to enlighten members of the public on development control procedures concerning land subdivisions; 3) The public/developers should frequently be educated on the dangers of involving incompetent/non-accredited persons in the processing of land subdivisions in Kisii Town; 4) At the same time, the CGOK should deliberately establish a County Spatial

Planning Coordinating Committee to harmonize and coordinate institutions and related agencies that deal with development control processes and management such as land subdivisions; 5) To ensure that only registered professionals undertake consultancy on land subdivision development control, the CGOK should form a collaborative partnership with relevant professional associations and Boards that regulate professional practice such as the Physical Planners Registration Board, Institution of Surveyors of Kenya, and Land Surveyors Registration Board; 6) The CGOK should ensure that only registered persons are involved in the development control process of land subdivision. It should, therefore, implement more rigorous mechanisms for detection of frauds in the preparation of land subdivision proposals, including implementation and supervision of these proposals.

AUTHOR CONTRIBUTIONS

W.O. Omollo sought for the study authorization from the relevant government institutions. He developed the study methodology that also comprised preparing a checklist that was used in data collection. He further interpreted and analyzed the data. R.O. Opiyo undertook a literature review that included the introductory background information and the theoretical context. He trained and supervised the research assistants as well as coordinated primary data collection. He also coded the collected questionnaires and thereafter undertook data entry using SPSS. Both authors, edited the paper to ensure completeness and consistency with the journal's formatting guidelines.

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CONFLICT OF INTREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript. In addition, the ethical issues; including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy has been completely observed by the authors.

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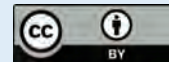
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ORIGINAL RESEARCH PAPER

Application of remote sensing and geographical information system in mapping land cover of the national park

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ABSTRACT

The study was conducted with the objective of mapping landscape cover of Nechisar National park in Ethiopia to produce spatially accurate and timely information on land use and changing pattern. Monitoring provides the planners and decision-makers with required information about the current state of its development and the nature of changes that have occurred. Remote sensing and Geographical Information System have gained importance as powerful and efficient tools for land cover mapping of inaccessible area. Digital image classification is generally performed to produce land cover maps from remote sensing data, particularly for large areas. In this project, LANDSAT 7 ETM+ 2000 data was prepared for producing land cover map of study area, Nechisar National Park. Digital image processing techniques were conducted for the processes of radiometric and geometric correction and classification for land cover analysis. Additionally, training data for supervised classification were collected in the study area. Signature development was carried out and evaluated. Training sites were re-defined such that significant separability was obtained for all six bands of LANDSAT 7 EMT+. Finally, Supervised Classification was applied to classify the satellite image using Maximum Likelihood Classifier and five major land class cover were identified and mapped for the Nechisar National park. These are: grassland, forest land, deciduous bush land, thickets, and water bodies.

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INTRODUCTION

Although the benefits of integrating GIS and remote sensing data for more effective ecological mapping and monitoring are many, the time, money and expertise required taking full advantage of the technology can be initially discouraging. The information used for scientifically valid ecological mapping and monitoring needs to be frequently

updated, sufficiently detailed and spatially continuous. Ecological inventories have historically been conducted through field survey a time-consuming and expensive endeavor, particularly when study sites are large and/or remote, and when long-term monitoring is a concern to resource managers (Rogan and Chen, 2004). This field work paradigm has implicitly affected both the typical study area size and the spatial scale of observations associated with ecological research. Field data are also typically collected based on some purposive sampling scheme, in which information

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on a specific ecological attribute is of primary interest, and therefore may not be appropriate for describing other attributes of subsequent interest. The availability of ecological datasets, collected through remote sensing or derived within a GIS at local to global scales, has revolutionized the way ecological research is conducted. GIS enhances the ability to derive information from remotely sensed data, and remotely sensed data can opened up wide range of avenues for effective land cover mapping providing efficient methods for analysis of land use issues and tools for land use planning and modeling (Pandian *et al.*, 2014). The synoptic perspective, temporal frequency and repeatability of remotely sensed measurements have been invaluable for detecting and monitoring change (Roganet *et al.*, 2008). The recent review of remote sensing applications in ecological research identified three main application focus areas: land cover classification, integrated ecosystem measurements and multitemporal change detection. And there are also four ways in which GIS and RS data can be integrated: a) GIS can be used to manage multiple data types; b) GIS analysis and processing methods can be used for manipulation and analysis of remotely sensed data (e.g. neighborhood or reclassification operations); c) remotely sensed data can be manipulated to derive GIS data; and d) GIS data can be used to guide image analysis to extract more complete and accurate information from spectral data (Rogan and Miller, 2006). Remote sensing also facilitates data collection in difficult or impossible-to-reach areas and provides an important synoptic and multitemporal perspective and now providing new tools for advanced ecosystem mapping. The collection of remotely sensed data facilitates the synoptic analyses of impossible areas function, pattern, and change at local, regional and global scales over time; such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of ecological diversity (Wilkie and Finn, 1996). Therefore, in this project attempt was made to map out land class cover map of Nechisar National Park (NNP) applying GIS and RS techniques.

Statement of the Problem

The ability to map and monitor ecological phenomena over large spatial extents has become a

focus of renewed research in the context of increasing awareness of human activities and environmental change. Human activities substantially impact most of the terrestrial biosphere, currently at rates and spatial extents far greater than in any other period in human history. Numerous organizations, disciplines and initiatives have formed in the last 15 years in response to the many challenges to sustainable resource management and ecological protection. Spatial and temporal characteristics to provide the scientific understanding required to measure, model, maintain and/or restore landscapes at multiple scales (EPA, 1998; EPA, 2002). Research efforts in support of sustainable ecosystem management have focused on characterizing ecosystem condition and change, exploring the effects of different management schemes, and understanding how natural and anthropogenic processes affect ecosystem functioning (ibid). Solutions to these problems require spatially explicit and timely ecological map, often combined with statistical models in a geographic information system (GIS). Current research illustrates how ecological problems ranging from biodiversity loss to land-use change have benefited greatly from advances in geospatial technologies such as GIS and remote sensing, both in the provision of data and access to spatial data analysis tools. The integration of GIS and RS for ecological mapping and monitoring, while addressed in earlier research (Goodchild, 1994), has become even more important as these data and technologies continue to evolve, and as ecological issues become more critical. While GIS technology facilitate ecological mapping and monitoring lack of familiarity and background knowledge, equipment cost and complexity of data-processing methods and inaccessibility of an areas are often cited as factors that prevent even wider use of remote sensing approaches for land class cover Mapping. It is evident that the ground methods have limitations as whole area may not be easily accessed in most cases and the information collected may not be as accurate as is possible through RS and GIS aided by few field surveys. RS and GIS can therefore be used to supplement or partially replace the classical ground survey methods (ibid). The integration of GIS and RS for land class cover mapping, as addressed by (Franklin 1995 and Goodchild, 1994) has become even more important as these data and technologies continue to evolve, and as ecological issues become

more critical. At present, most have very limited knowledge of inaccessible areas ecology, hence, peoples have been using the old topographic maps to generate management options and other maps of this areas in mapping and management, which possess a time consuming and expensive attempt, particularly when study sites are large and/or remote, and when long-term monitoring is a concern (Rogan and Chen, 2004). Therefore, the central purpose of this project was to identify the potential value of remote sensing and GIS techniques in mapping land class cover of inaccessible area so as to answer the questions of; what is the technology capable of? And what it is not capable? To access its advantages over other classical ground methods and its application limitations.

Study area

This project was conducted in Nechisar National Park. Nechisar National Park (NNP) is one of the National Parks of Ethiopia Fig. 1; located at about 510 km away from Addis Ababa Countries Capital in the Amaro Special Woreda and Arbaminch Zuria Woreda of the Southern Nation Nationalities and Peoples Regional State (SNNPRS) the east of Arbaminch. NNP was established in 1974. Since its establishment, NNP

has been managed in various ways. Administered by a warden and staffs responsible for Ethiopian Wildlife Conservation Organization (EWCO) until 1995, it was governed and looked after by Ethiopia Wildlife Conservation Organization (EWCO). Since 1995, the responsibility of administrating the Park was transferred to the Government of the SNNPRS. Like most other National Parks in Ethiopia, NNP was financed by public fund and operated like any other civil service department (Samson Shimles, 2010).

NNP is located at the eastern edge of Arbaminch town, southern part of Ethiopia. The Park is situated at $5^{\circ} 51' - 6^{\circ} 10' N$ and $37^{\circ} 32' - 37^{\circ} 48' E$. It is bounded by the Amaro mountain ranges on the east, Lake Abaya in the North and Lake Chamo in the South and Arbaminch town on the west. The Park is located in the very scenic part of the Rift Valley floor between the two lakes, lakes Abaya and Chamo and includes a good portion of the two, southern most lakes of Ethiopia and the chain of hills separating the two lakes called God's bridge by local people (Fetene, et al., 2011). In terms of vegetation and land cover NNP is categorized in to a) Grass Land b) Deciduous Bush land and Thickets) Forest (Ground water forest and Reverie forest) and water bodies(part of lake

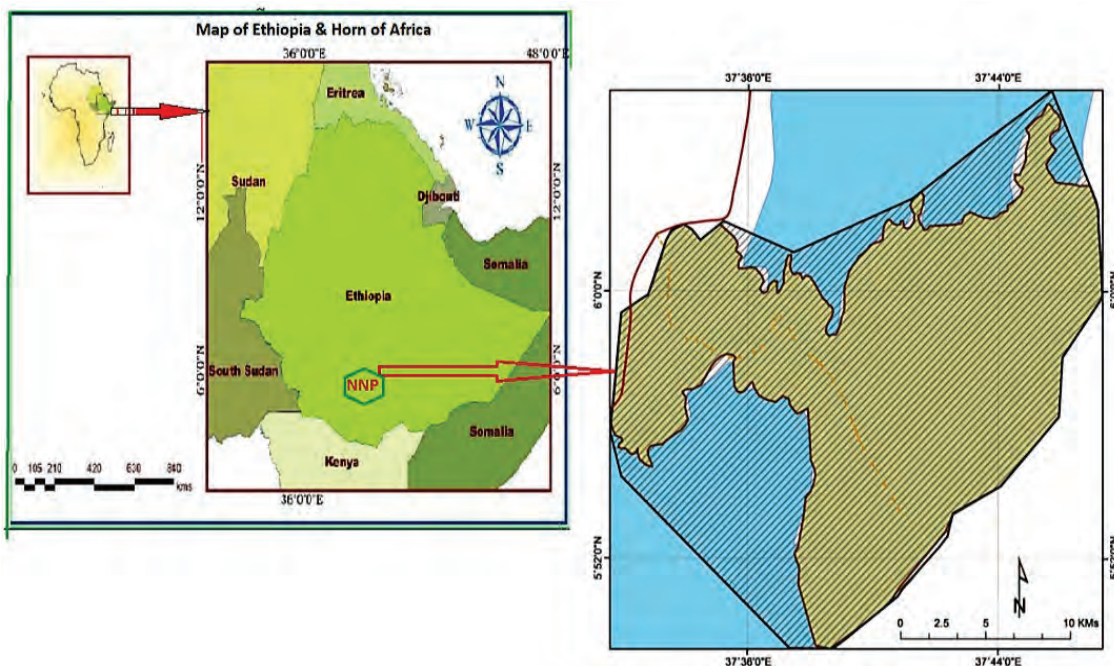


Fig.1 Location of Nechisar National Park (NNP)

Chamo and lake Abaya), (Datiko and Bekele,2011). The Arba Minch ground water forests, Kulfo and Sermele riverine forests are found within the vicinity of NNP. The ground water forests and the Sermele valley forests are located in the western and eastern part of the park, respectively, whereas, the Kulfo riverine forest is located in between the two forests but lose to the ground water forests. In this regard, the relevance of the study is to provide detailed information on land class cover maps for appropriate boundaries demarcation and accessing encroachments of NNP. The general objective of this study was to examine how RS and GIS techniques are used in land class cover mapping of inaccessible areas with particular reference to Nechisar National Park (NNP) Ethiopia. Specific objectives are; 1) To produce land class cover map of NNP using GIS and remote sensing techniques; 2) To identify other roles that this technology can perform in land class cover mapping practices, their advantages over other classical methods and their limitations/difficulties; 3) To demonstrate the power of GIS and RS techniques in land class cover mapping. This study has been carried

out in Addis Abeba University in 2012 as a mini project and finally completed in Arbaminch College of Teachers' Education with major modification inculcating significant image analysis process in 2019.

MATERIALS AND METHODS

The procedure used in the current study is shown in Fig. 2; which is beginning from the acquisition and classification of multitemporal satellite image of the study area to the extraction of the required land class cover classification map of the study area.

This is a type of case study attempt to map land class cover of NNP using RS and GIS techniques, therefore the followings are materials and methodology adopted for thematic data extraction from the Satellite Imageries. For this research, multi-temporal image, Landsat-7 ETM+ 2000 topographic maps, 1:50,000 (Fig. 5) and ASTER data, ASTER DEM (Fig. 3) were used. The 1:50,000 topographic maps of the study area were scanned, georeferenced and projected to UTM coordinate system, map zone 37N of WGS-84 spheroid and datum. The World Geodetic System 1984 (WGS-84) is the geodetic

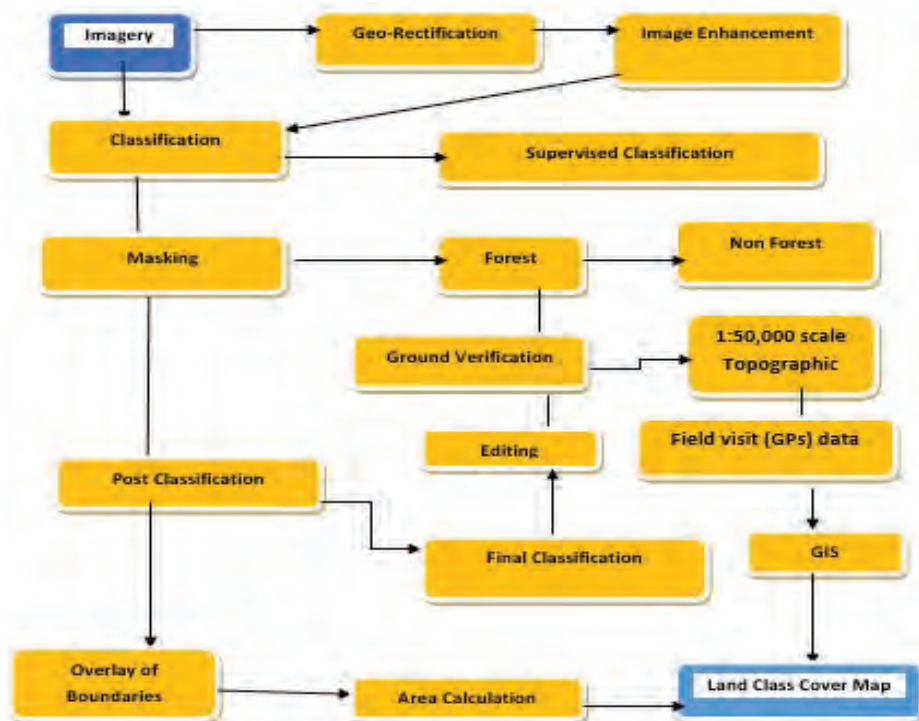


Fig. 2: Flow Chart Illustrating the Process of Digital Image processing

reference system used by GPS. It should be noted that all GPS receivers compute and store coordinates in terms of WGS-84, then transform to other datum when information is displayed. WGS-84 is also the default datum for many GIS software packages with data either being stored in or transformed via WGS-84 (Featherstone, 2007). The satellite images and the ASTER data were originally Ortho-rectified and therefore did not require georeferencing. Road and river layers were digitized from the georeferenced topographic maps. ERDAS Imagine (9.1) for image processing, ARC/GIS (9.3), and Arc/view (3.2) Software's for digitizing, editing, contour generation and mapping are the Software's used for digital processing of the spatial data. Digital image processing techniques were applied for the mapping of the land cover classes of the study area from the satellite data. The methodology applied comes under the following steps:

Geo-rectification and image extraction

Image rectification is an important procedure for many image processing applications. Simply put, it is the process of converting a raw image into a specified map projection (Sabins, 1999). The procedure involves the selection of distinguishable ground control points (GCP's) in the image. These points are then assigned

the appropriate reference information, such as latitude/longitude or Universal Transverse Mercator (UTM) coordinates. This reference data can be obtained from existing map sheets or from fieldwork utilizing Global Positioning Systems (GPS). After that a certain number of GCP's have been entered and referenced, the computer program resample's the original pixels into the desired projection. The importance of rectification is that the image can now be used in conjunction with other data sets. Landsat Satellite imageries are recommendable for Land Class cover mapping (Jensen, 1996). Thus, in this project, Landsat-7 Enhanced Thematic Mapper plus (ETM+) imagery of acquisition date of 27/01/2000 Row 169 and Path 056 was used. Even if the Landsat images were georeferenced before at hand, slight shift was recognized between them. This problem was addressed by geo referencing the satellite image based on the georeferenced topographic map through image-to-image registration technique. This task was accomplished by opening the geo referenced 1:50,000 topographic maps obtained from Ethiopian Mapping Agency, (2004) and Landsat image on different viewers of ERDAS Imagine software. Coordinate values of clearly recognized features were transferred from the georeferenced topographic map to the satellite image by mouse click. The geometric registration

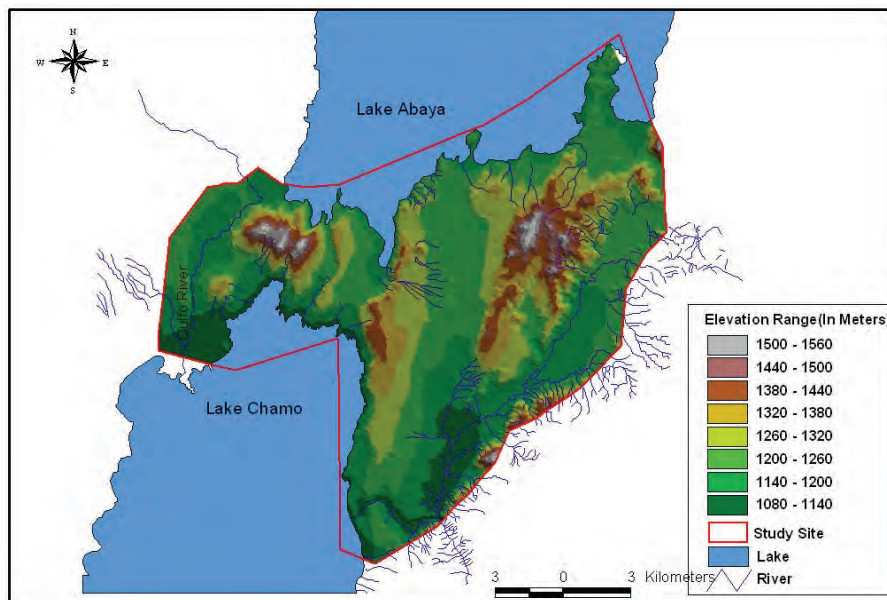


Fig. 3: Digital elevation model of Nechisar National Park with stream overlay

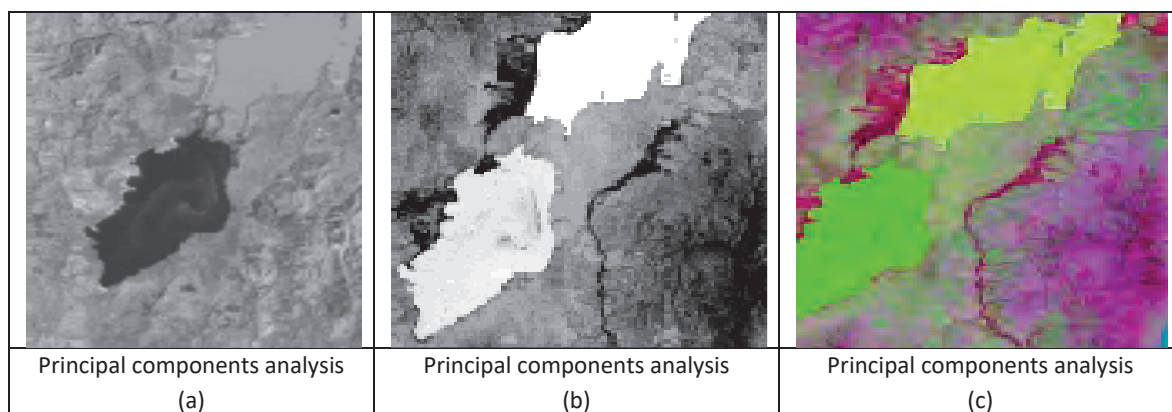


Fig. 4 Principal Components Analysis (PCA) processed for satellite image spectral enhancement

methods and output Root Mean Square (RMS) error is below 0.5. After registration the study area was subset for the areas of study on ERDAS 9.1 using the boundary of NNP. Boundary of NNP was obtained from the Journal of Nature and Science, 2011 (Fetene *et al.*, 2011). The boundary was converted into digital by scanning and imported into ERDAS 9.1 software. Control points (CP) for geo-referencing the scanned maps (images) were selected from the hardcopy maps. The transformation was done using the image analyst within ERDAS 9.1 software environment. The georeferenced boundary was displayed with interface of Arc view 3.2 and the process of boundary extraction from imageries was done using the on-screen digitizing method. Advanced Space born Thermal Emission and Reflection Radiometer (ASTER) is an advanced multispectral imager that was launched on board NASA's Terra spacecraft in December 1999 (Abrehams, 2000). ASTER covers a wide spectral region with 14 bands from the visible to the thermal infrared. An additional backward-looking near-infrared band provides stereo coverage. Because of the nadir looking and backward looking band 3 sensors can obtain data of the same area from different viewing angles, stereo ASTER data can be used to produce Digital Elevation Model (DEMs) (Omo-Irabor, 2016). The DEM derived from ASTER with a 30m resolution is used to generate slope map of the study area (Fig. 3). Therefore, elevation map of the study area is generated from ASTER digital elevation model. The digital elevation model (DEM) is a raster based digital dataset of the topography of the Earth, the pixels of the dataset are each assigned

an elevation value, and a header portion of the dataset defines the area of coverage, the units each pixel covers, and the units of elevation (Bastin, 1997). To generate the study are digital elevation model; the raw ASTER data is patched on 3D Visualization software in order to fill the missing data and exported into Arc map environment.

Then study area DEM is extracted by masking of study area shape file with the help of extraction tool in Arc GIS 9.3. The resultant map indicates that the study area has an altitude ranging from approximately 1080 to 1560 m above sea level. Then digital elevation model was classified to 6 classes with 60 m intervals and elevation map of the study area was produced. Using the drawing and editing tools of the above mentioned software's, each entity of the feature of interest was traced out. The predefined code for each entity was attached as attribute.

Image enhancement

The Landsat image was clipped to the study area to speed up the data processing. The Atmospheric Correction model (ATCOR2) developed by Richter (Richter, 1998) was utilized to perform radiometric calibration and remove the effects that change the spectral characteristics of the land features (Paolini, *et al.*, 2006). Image enhancement is one of the important image processing functions primarily done to improve the appearance of the imagery to assist in visual interpretation and analysis. The next step of this project was to perform various spectral enhancements on the rectified image. Spectral enhancements are modifications of the pixel

values of an image. They can be used to improve interpretability, reduce information redundancy, and extract information from the data which is not readily visible in its raw form (Beaubien, *et al.*, 1999). The enhancement techniques utilized for this project were Noise Removal and principal component Analysis. Principal Components Analysis (PCA) is a spectral enhancement which can be used to compress the information content of a multispectral data set (Sabin's, 1999). PCA uses mathematical algorithms to transform n bands of correlated data into n principal components which are uncorrelated, such that the coordinate axes of the components are mutually orthogonal. The principal component describes most of the variation of the brightness values for the pixels of the original bands (Jensen, 1996). Subsequent components explain less and less of the data corresponding to atmospheric noise in the data rather than any ground features (Gumeet and Rupinder, 2012).

The first principal component (Fig. 4a) describes most of the variation of the brightness values for the pixels of the original bands. Subsequent PCA-3 (Fig. 4b) components explain less and less of the data, with the final PC-3 (Fig. 4c) usually corresponding to atmospheric noise in the data rather than any ground features (Sabins, 1999). The main benefit of principal components analysis is that it can reduce the amount of data (bands) without losing much of the information and typically reducing redundancy (Jensen, 2005). For example, the three visible bands (1, 2, and 3) of TM images are usually highly correlated, meaning they look roughly the same and thus provide redundant information for classification purposes. After running a principal components analysis on these three bands, we would find that the majority of the information contained within the three bands would be explained by PC-1 or (PC-3) of the three visible bands looks pretty much the same as any of the three bands viewed individually in gray scale. Thus, this one layer of data could replace the three original bands without much loss of information.

Classification scheme, training site selection and data collection

Training site was selected based on the identified land cover and the true color composite images of band 1, 2, and 3. The training site selection criteria

is areas with extensive land cover categories and those areas not a big but among the pre-defined land cover categories was also included in the training site. Finally considerable amount of land cover categories were identified as "training" data set for supervised classification. Supervised classifications easily create training samples to represent the classes we want to extract. You can also easily create a signature file from the training samples, which is then used by the multivariate classification tools to classify the image (Gbola, *et al.*, 2017). For its accuracy the ground truth was also consulted on the different data set such as digital globe and Base map (topographic map of the study area).The topographic map of the study area with 1:50,000 scales was Obtained from Ethiopian Mapping Agency (EMA)on the sheet Kelle, Dilla, Arbaminch, and Nechisar National Park. After each sheet numbers were scanned, using ERDAS 9.1 software they are masking and georeferenced for image to image comparison.

Field surveys were also carried out. Ground truth was done by matching the pattern, texture association, shape and size of the features from the FCC for a particular topographic feature using GPS locations. The method used during the field visit was an "opportunistic transect method" as the study areas were not always accessible due to high density of under growth and absence of accessible tracks and roads. Image classification is the process of sorting pixels into a finite number of individual classes, or categories of data based on their data file values. If a pixel satisfies a certain set of criteria, then the pixel is assigned to the class that corresponds to those criteria (Richards, 1996).There are two primary types of classification algorithm applied to remotely sensed data. These are unsupervised and supervised. Unsupervised classification algorithms such as ISODATA (Iterative Self-Organizing Data Analysis) cluster data according to several user defined statistical parameters in an iterative fashion until either some percentage of pixels remain unchanged or a maximum number of iterations have been performed. This method of classification is most useful when no previous knowledge or ground truth data of an area is unavailable (Lu and Weng, 2007). Supervised classifications require a priori knowledge of the scene area in order to provide the computer with unique material groups or what are called "training sites". Regions containing a material of interest

Mapping Land Class Cover of Unapproachable Areas

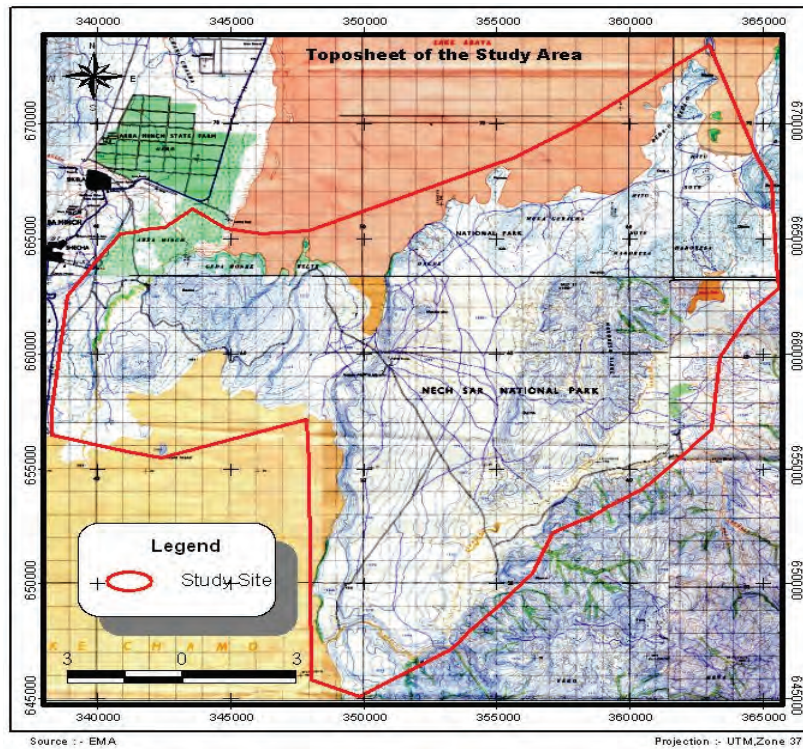


Fig. 5: Masked and Georeferenced Topographic sheet of NNP

within a scene are delineated graphically and stored for use in the supervised classification algorithm. It is the job of the user to define the original pixels that contain similar spectral classes representing certain land cover class. The most common supervised classification techniques are the Maximum Likelihood classifier for parametric input data and Parallelepiped classifier for non-parametric data (Dean and Smith, 2003). Maximum Likelihood Classifier (MLC) assumes that a pixel has a certain probability of belonging to a particular class. These probabilities are equal for all classes and the input data in each band follows the normal distribution function (Omo-Irabor, 2016). Maximum Likelihood Classifier functions by using the band means and standard deviations from field collected data in order to project land cover classes as centroids in feature space. These centroids of each land cover classes are circumscribed by probability contours. The probability density function assumes that the sample values for each class are normally distributed. The unclassified pixels are plotted in the same feature space and get a posteriori probability.

Usually the pixels are then assigned to the class for which they have highest membership probability. But it is possible to soften the maximum likelihood classification by using the a posteriori membership probability values as indices of class membership (Bastin, 1997). The strong advantage of Maximum Likelihood method is its use of well-developed probability theory. However, it has also serious known drawbacks under certain circumstances. First, if the histogram of the image does not follow normal distribution curve, the basic assumption of this classifier is violated and results in poor or misleading result. Moreover in case of high correlation between two bands, as it usually occurs in Landsat images, or when the data used for signature development is not sufficiently heterogeneous. Such redundancy should be removed through using (PCA) before proceeding to classification (Congalton and Poured, 2002). The method used in this study was supervised classification because of a priori knowledge of the scene area and ground truth data availabilities such as Digital Globe and Topographic Map of an area and

field visit. During the field visit various land cover classes were taken using Grami-GPS devise. Finally the imagery was classified using the Maximum Likelihood supervised classification using spectral information of the known land cover categories observed. Classified data often manifests a salt and paper appearance due to the inherent spectral variability encountered by the classifier when applied on pixel-by-pixel bases. To overcome the “salt-and-pepper” effect, object-based approaches have been increasingly implemented in remote-sensed image analysis (Costa, et al., 2014). Since object-based methods can avoid being affected by spectral similarity between different vegetation mosaicking variability, techniques based on objects become a more useful approach to map vegetation type types (Ning, et al., 2014). And In such situations, it is also desirable to smooth the classified output to show only the dominant class (Lillisand and Kiffer, 2004). Accordingly one means of classification smoothing involves the application of a major filter. In such operations, a moving window is passed through the classified data set and the majority class

within the window is determined. If the center pixel in the window is not the majority class, its identity is changed to the majority class. If there is no majority class in the widow, the identity of the center pixel is not changed. Thus, a 3*3- pixel majority filter algorithm on ERDAS 9.1 software has been applied on the classified images.

RESULTS AND DISCUSSION

From supervised classified imagery, five classes were identified as forest, grass land, deciduous bush land, thickets and water bodies but after field visit minor corrections were made because in the certain places some part of thickets were classified as deciduous bush land while certain part of forest is classified as deciduous bush land. Finally after their boundaries are overlaid and there total coverage of each land cover class was calculated Land Class cover Map of NNP was prepared. The land cover map was prepared through digital analysis of satellite data (Fig. 8) using supervised maximum likelihood classification technique. Supervised classification is a procedure

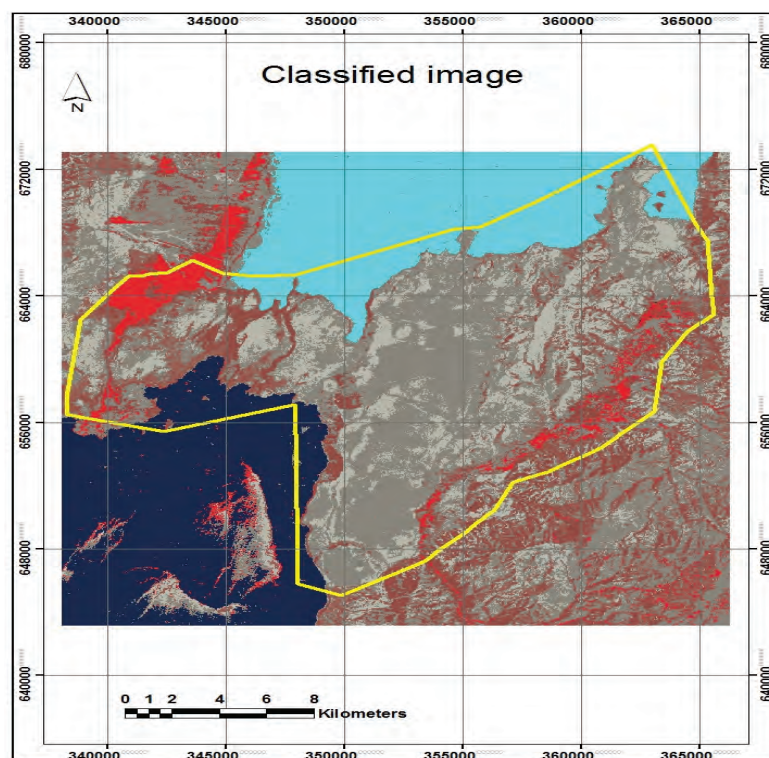


Fig. 6: Classified image with false color composite

for identifying spectrally similar areas on an image by identifying ‘training’ sites of known targets and then extrapolating those spectral signatures to other areas of unknown targets and accuracy assessment results were based on reference data that were independent of data used in the training phase of the classification (Khatami, *et al.*, 2016). Supervised classification relies on the previous knowledge of the location and identity of land cover types that are in the image. This was achieved through field visits of the study area. Training areas were used to “train” the classification algorithm to recognize land cover classes based on their spectral signatures, as found in the image (Lillisand and Kiefer, 1994). The maximum likelihood classifier (MLC) assumes that the training statistics for each class have a normal distribution. The classifier then uses the training statistics to compute a probability value of whether it belongs to a particular land cover category class. This allows for within-class spectral variance. In this the image analyst uses a prior knowledge to weight the probability function. The MLC provides the highest classification accuracies (Lillisand and Kiefer, 1994). After different pre-processing image enhancement techniques such as geometric and radiometric correction techniques

were employed, Maximum likelihood classification was performed using the developed signatures of the land cover categories. Other methods like minimum distance to means and parallelepiped classifiers which is used by determining the parallelepiped- shaped boxes for each pre-defined class (Sunitha and Suresh, 2015). The parallelepiped boundaries for the classes are determined by the minimum and maximum of pixels in a particular class. These boundaries help in assigning a pixel to a given class (Nupur and Maheshwari, 2017). Thus parallelepiped classifiers was also tested but their results were not any more convincing. As the result the MLC i.e. the most commonly used parametric classifier in practice (He *et al.*, 2015). Thus, because of its optimal result and its easy availability in almost any image-processing software was applied and five land class cover types were identified, including: deciduous bush land, forest, grass land, water bodies, and thicket.

Accordingly as shown in (Fig. 7) the main land class cover of the NNP consists of Deciduous Bush Land (35.53 km²), Forest (82.99 km²), Grass Land (237.51 km²), Thickets (52.2 km²) and Water Bodies made up of Lake Abaya and Lake Chamo covers 49.01 and 30.74 (km²) respectively. On the different

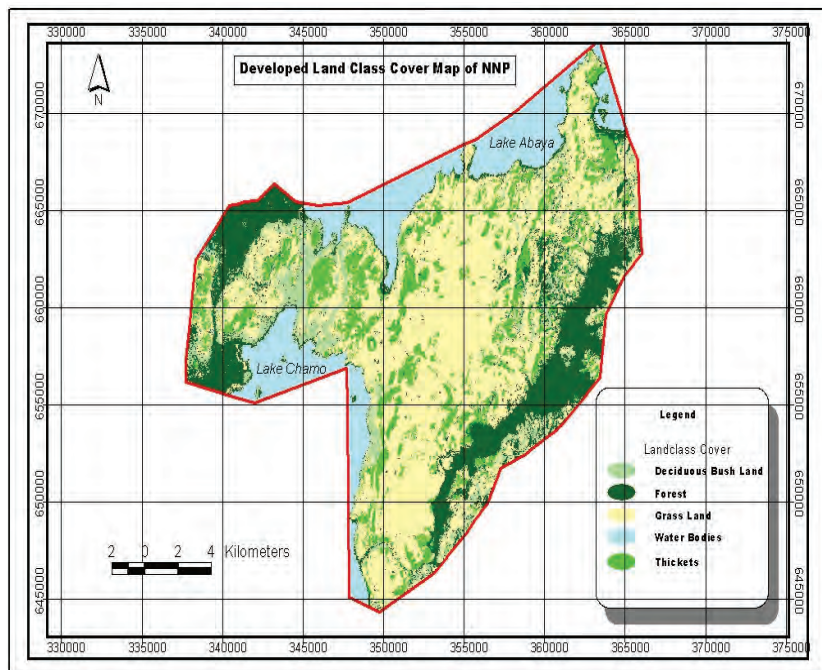


Fig. 7: Developed Land Class Cover map of the NNP

Table 1: Area covers by each “Land Cover” category

Sr. No	Land Cover Class	Area in Sq. Km	Percentages
1	Deciduous Bush land	35.53	7.28
2	Forest	82.99	17
3	Grassland	237.51	48.67
4	Lake Abaya	49.01	10
5	Lake Chamo	30.74	6.69
6	Thickets	52.2	10.69
Total area		488	100

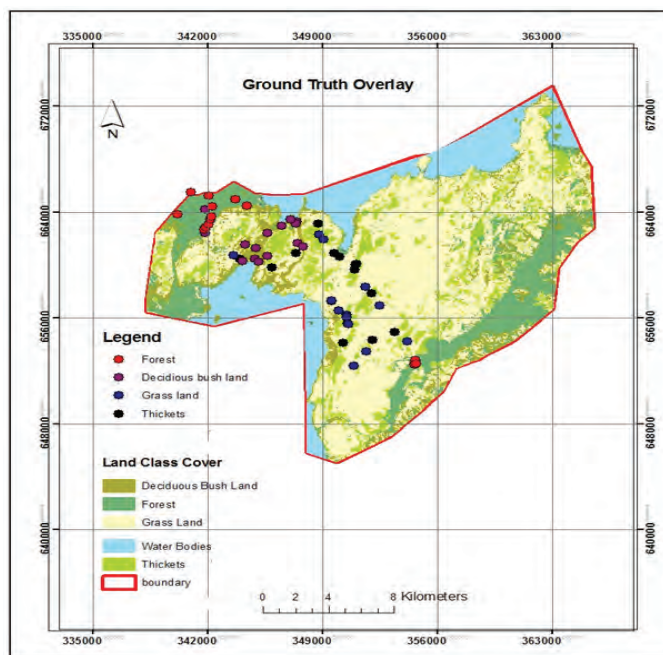


Fig. 8: Ground truth collected from field survey overlay with land class cover map

research work that was conducted on the park prior to this project the total areas of the NNP was written as 514 Sq.km (Fetene *et al.*, 2011). But the finding of this project deviated by 26 Sq.km and according to the finding of this project the total area of NNP is 488 Sq.km (Table 1).

Grass land is the largest habitat of the NNP covering the extent of 237.51 km² which accounts 46.67% of the total area of the plain. The plain of the “Nechisar” (white grass) were almost treeless, but most of the hill and gentler slopes of the plain were covered with deciduous bush land covering the extent of 35.53 km² which accounts 7.28% of the NNP. The forests of NNP

are two types, ground water forest and reverie forest. The ground water forest is located in the northern part of the park which is commonly known as Arbaminch ground water forest while, Kulfo and Sermele river forests are located in the western and eastern part of the park respectively. Forest land of NNP covers 82.99 km² or 17% of NNP land class cover. Thickets are discontinuous bush land located almost in all parts of the NNP and it covers 52.2 km² which accounts 10.69% of NNP vegetation cover. Water bodies are parts of Lake Abaya and Lake Chamo in the north and south respectively and it covers 79.75 km² which accounts 16.98% of NNP land class cover.

Mapping Land Class Cover of Unapproachable Areas

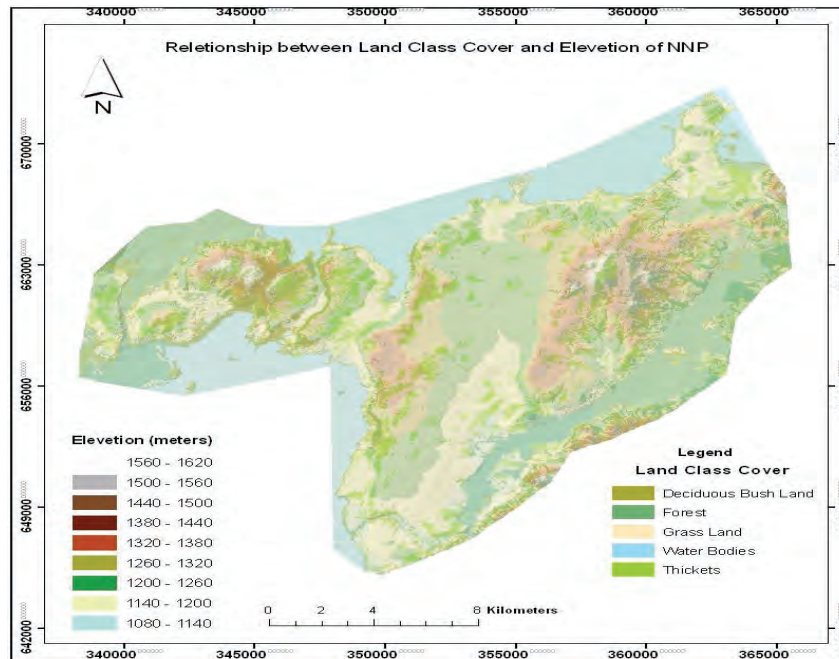


Fig. 9: Map showing relationship between land class cover and elevation of NNP

The grass land, which accounts 47% of the NNP, is found almost in all parts of the parks except in the areas covered by forest but it mainly dominate the altitudinal ranges between 1200-1260. Deciduous bush lands are found relatively in the hillside part of the park dominating the eastern escarpments above 1440 meters. Like grass land, Thickets are found almost in all parts of the park except in the area covered by forest and water bodies.

CONCLUSION

This study was combined remote sensing, ERDAS (9.1) image processing software, GIS and extensive and detailed ground information to map land cover of the NNP. Satellite images data acquisition, digital image processing, training sites selection, digital image classification are the processes involved to map the Land cover of NNP. Image enhancement was applied to increase the contrast of the satellite images using the false color composite image. Using the frequency histograms of the bands and prior general knowledge of the land category together with the first principal image and false color composite image of bands 3, 4 and 5 features existing in the park could be predefined and mapped. This was used to set up a field campaign

to map the training sites for supervised classification. Maximum likelihood classifier was used to obtain the final land cover map of the park. The analyzed result of the study area was composed of five major land cover types; these are: grassland, forest land, deciduous bush land, thickets, and water bodies. The quantitative evidences of land cover presented were also measured from the satellite images coupled by GIS analyses. The NNP is by far dominated by grasses (48.67%). Using well-defined training sites, supervised classification procedures and maximum likelihood classifier prove to be useful in the classification of the satellite images to obtain a reasonable land class cover map of the NNP. Finally based on the finding of this project the following recommendations were made: 1) the low computer literacy levels of end-users are among the problems that should be addressed if GIS mapping is to be fully developed. GIS and RS users must invest considerable enough time to learn complex software packages and become familiar with the large quantities of data used in its applications. Insufficient skilled personnel in GIS field, lack of awareness about the value of GIS and its potential in mappings are also other challenges; 2) The findings of this study demonstrate the potential use and advantages of using GIS and RS techniques in mapping land class cover of inaccessible areas with

particular reference to NNP and establish a baseline to carry out further investigations as in this area there was no digital land cover map information; 3) These findings of this project will also be useful for subsequent applications such as for tourist information map and for Management and monitor of NNP; 4) The investigation of the use of GIS and RS techniques to Map and estimate Land Class Cover of NNP is also still open. Possible improvement and subjects for future studies are: the use of various sets of satellite images covering all seasons and change detection using images of different year's interval are some of them.

AUTHOR CONTRIBUTIONS

L. Tadesse has performed the methodology, literature review, software analysis, result interpretation and validation, formal analysis, and investigation, data collection, writing original draft preparation, funding acquisition, and prepared the manuscript text and agreed to the published version of the manuscript.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

ABBREVIATION

%	Percent
ASTER	Thermal emission and reflection radiometer

CSA	Central statistical agency
DEM	Digital elevation model
EPA	Environmental Protection Agency
ESRI	Environment Systems Research Institute
ESCAP	Economic and Social Commission for Asia and the Pacific
ETM+	Enhanced thematic mapper
EMA	Ethiopian mapping agency
EWCO	Wildlife conservation organization
FCC	False color composite
GCP	Ground control point
GIS	Geographic information system
GPS	Global positioning system
ISODATA	Iterative self-organization data system
km ²	Kilometer square
MLC	Maximum likelihood classifier
NNP	Nechisar national park
RS	Remote sensing
WGS	World geodesic system

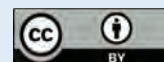
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ORIGINAL RESEARCH PAPER

Effect of green human resource management practices on environmental sustainability

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Structural equation modeling (SEM)

ABSTRACT

In today's world, green human resource management is one of the most important factors in forward-thinking your environment-friendly business. Most of the researchers are of the view that employees must be empowered and environmentally aware of greening while carrying out green human resource management practices. The present study is examining the impact of different Green human resource practices on environmental behavior directly or indirectly via Pro-environmental behavior. The data is collected through questionnaire from the educational institutions in Baltistan region. The sample size is 300 employees of public universities. A Structure Equation Modeling is utilized to obtain the relationships between the variables. The results show that green human resource management practices have a strong direct impact on Environmental sustainability while the indirect relationship between green environmental training and sustainable environment through a mediator "pro-environmental behavior". The results illustrate that Green Performance Management and Appraisal has a positive ($\beta=0.27$), Green Reward and Compensation and environmental sustainability which again shows a positive ($\beta=0.14$) and significant impact of Green Reward and Compensation on environmental sustainability. Green Training and Development also shows a positive ($\beta=0.29$) and Green Training and Development has a positive and significant relationship. The results suggest that the mediator does not sensitize environmental sustainability. The study suggests that Public Sector universities need to train and compensate their employee to reduce environmental degradation and make their contribution to the sustainability of the environment.

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INTRODUCTION

The organizations need to adopt environmental-friendly strategies due to increasing environmental concerns at the global level and the creation of international environmental standards (Ashraf and Anam, 2015). The compliance approach has

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been used by the majority of the companies in the initiative of their Green Management. Though the environmental forces like customer preferences and customer boycotts have to change the basic business approaches to pollution control (Luu, 2018; González-Benito and González-Benito, 2006; Daily et al., 2012; Jabbar and Abid, 2014). High management and technical skills are involved in the implementation

of green management practices. The organization will develop such environmental initiatives among the employees which have a substantial impact on the firms' competitive sustainability (Sudin, 2011; Boselie et al., 2001). Previously the success of the organization as determined by the economic value but today they need to consider environmental and social factors. The execution of different techniques like employment selection, recruitment process, training, reward and appraisal system design to boost employee's environmental awareness and expansion of management and technical skills have great importance in fostering environmental sustainability (Jackson et al., 2011). For environmental management proactive approach is required around the world (Ashraf et al., 2015). The level of pollution in the environment is increasing due to rapid industrialization. For this purpose, to reduce the destruction of the non-renewable resources various policies, rules and regulations are implementing by the government and by the private sector. An environmental management system is improved and enhanced by the corporate segment. As a result of which new strategic movement is emerged called green management. Green management is the approach in which the organization shapes the management of environmental strategies to protect the environmental aspects (Sudin, 2011). Therefore, there must be a balance between industrial growth and environmental sustainability. Therefore, researches are emphasizing to the adoption of GHR practices as the main objective of a firm. So there is need to identify the ways that how green human resource management can successfully be implemented in the educational institute of Gilgit-Baltistan to reduce the environmental degradation, therefore the main purpose of the research is to explore and review previous literature that how Green Human Resource practices can effectively and successfully implement the policies which will help to reduce the environmental degradation and improved the environmental sustainability. The changing market environment requires all managers to adopt a green strategy in order to remain competitive. Over the years there has been a shift in organizational goals from profit-making only to the need for environmental and social goal accomplishment. Economic and financial success need to be accompanied by the minimization of

ecological footprints and increased attention to social aspects. Having two Public sector federal chartered universities with several sub-campus in different districts, there is great potential to promote sustainability both through education and practice. The need for general attitude change from reactive to proactive is required in ensuring the Green human resource management (GHRM) strategy is implemented. The need to have a sustainable environment is a collective responsibility of all employees in any organization since human resource function has the overall responsibility of recruitment and employee welfare, there is a need to educate and advocate for the green environment in the organization. Employees must, therefore, be equipped with the necessary knowledge as to how to maintain and sustain a conducive environment free from pollution and disposal. Therefore, this study is aimed to investigate; what is the impact of Green HRM practices in stimulating environmental sustainability through the pro-environmental behaviors of the public sector universities of GB? Following the given problem of statement, the objective of the study is to investigate the effect of Green HRM practices in stimulating environmental sustainability through the pro-environmental behaviors of the public sector universities of GB. Fig. 1, theoretical framework shows the relationship between different green HR practices on environmental sustainability with the mediating role of pro-environmental behavior. The aim of the study is to investigate the impact of different green HR practices on environmental sustainability in different educational institutions of Gilgit-Baltistan. This study has been carried out in BachaKhan University, Charsadda, Pakistan in 2019.

Green HRM practices

It is now worldwide largely recognizing that by adopting pro-environmental practices, employees in any organization can improve environmental sustainability (Lülfes and Hahn, 2013). Pro-environmental initiatives in organizations are increasing day by day due to the alarming situation because the climate is changing irreversibly, destruction of the environment and the scarcity of resources (Zibarras and Coan, 2015). Environment protection is now an emerging trend all around the world. Many organizations are forced to implement

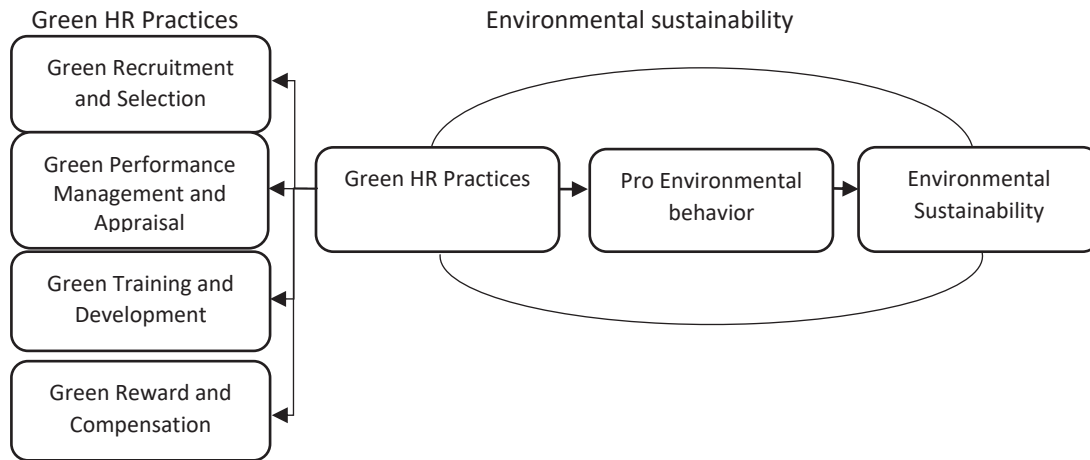


Fig. 1: Conceptual framework of the study

environmental protection policies as their concern of every society (Mcguire and Germain, 2015). GHR practices are when an organization adopts different techniques, methods, policies, and plans for the sustainability of the environment (Dutta, 2012). It's the responsibility and role of HR to provide training and awareness to the employees regarding environmental sustainability. There are several methods by which HR policies and practices can be combined which result in better involvement of employees, minimization of cost and greater efficiencies in performances (Mathapati, 2013).

Green performance management and appraisals (GPMA)

The process when the activities of employees are evaluated during the course of environmental management is recognized as Green performance management and appraisal (Jabbour and Santos, 2008). Most of the research shows specific features such as sending feedback in the process of green performance management (Jackson et al., 2011). Likewise, most of the studies show that some of these methods are not effective because some organizations have different resources and structural attributes also there is no standard and uniform policies (Jasch, 2000). Organizations need to adopt a common standard for the implementations of green performance management and clearly identify its indicators for the members such as reducing carbon

emissions, collaborating and implementing policies regarding environmental concerns.

H1 = GPMA effect directly the Environmental Sustainability
H1a =GPMA effect the Environmental Sustainability through Pro-Environmental Behavior

Green reward and compensations (GRC)

Green Reward and compensation are strategies to attract and motivate the employees by giving them monetary and nonmonetary rewards in achieving environmental goals (Zibarras and Coan, 2015) (Jackson et al., 2011). It has been claimed that employees feel more motivated when they are provided by a nonmonetary reward such as acknowledging and praising (Jabbour and Santos, 2008). For aligning performances of employee's incentives are more powerful tools in achieving the firm goals. Nonfinancial rewards should be provided along with financial rewards such as green tax, green recognition and green travel benefits. Green tax rewards comprise of exemptions to endorse the use of less polluting vehicles. Green travel incentives include transport and travel reward for the employees, these financial incentives have major impact on the willingness of employees towards the sustainability of the environment (Cheema and Javed, 2017). Green recognition involves nonmonetary rewards such as gifts, certificates of appreciation, praising. Employees feel motivated, pride in the organization,

and start working effectively for the protection of the environment (Sudin, 2011).

H2 = GRC effect the Environmental Sustainability directly
H2a = GRC effect the Pro-Environmental Behavior

Green training and development (GTD)

Green Training and development is systematic actions and events which encourage employees to learn and adapt skills to protect the environment and take conscious steps regarding environmental issues (Jabbour, 2011). Employee's information, skills, awareness, and skills regarding environmental activities can boost and enhances by providing them adequate training to them (Jabbour, 2013). The provision of green training is not only associated with environmental departments, but it should be part of the educational program of all organizations. Green training increases employee's responsiveness regarding pro-environmental behavior in the organization. It helps the employees to recognize the importance of the ecosystem, which eventually makes them more conscious about environmental protection, detecting sources of pollution and the process of prevention methods. Saeed et al., (2018) explore that the implementation of GHR practices such as preservation of natural resources, training, and skills, allowed them to use abilities and efficiency to work for the sustainability of the environment through pro-environmental behaviors (Dias-Sardinha and Reijnders, 2001). Environmental activities are also carried out by providing knowledge management to the employees. Through proper training, evaluation and reward system employees can be engaged in pro-environmental activities (Jabbour, 2013). A report exposed that knowledge and familiarities about the environment in China are the main factors and reasons about environmental activities. Employees get extensive training and skills through knowledge management.

H3 = GTD directly affect the environmental sustainability
H3a = GTD effect the Pro-Environmental behavior directly

Green recruitment and selection (GRS)

Organizations can select applicants who will oblige to environmental problems (Chaudhary, 2019). Green recruitment and selection are considered an important part of green HRM practices (Saeed et al.,

2018). (Jabbour, 2013) categorize green recruitment and selection by three characteristics of candidates. The first one is green awareness, which involves personality features like consciousness about the environment, and sociability (Dutta, 2012). The study shows that employees who have a concern about the environment actively participate in the operational process and boost environmental knowledge, which in turn improves the environmental performances of the organization. The second is green employer branding which discusses the reputation of the organization. It is related to environmental management and can be shaped with the help of green HRM practices. The employees feel pride working for the institutions having good environmental reputations (Jackson et al., 2011). The employees should have recruited based on green criteria. The firm may select those employees who perform better in these three categories (Saeed et al., 2018).

H4 = GRS effect the Environmental Sustainability directly.
H4a = GRS effect the Pro-Environmental Behavior directly.

Ability, Motivation and Opportunity theory (AMO Theory)

Different theories from the field of human relations and organization have affected the previously mentioned ideas of Green HRM. By investigating them in detail a more prominent comprehension of Green HRM can be developed (Arulrajah and Opatha, 2016). The theory claims that HRM may play a positive role by attracting, selecting, training, developing and properly compensating their skillful, able, and competent workforce, which in result enhances their level of motivation and productivity. It also makes them more effective and efficient in terms of higher profit, maximum profit, and better quality. (Chaudhary, 2019). This systematic assessment examines the core components of Green Human Resource Management GHRM in turn. Recruiting, training and developing an able and competent workforce is a major challenge in this competitive environment where every organization is striving to employee skillful workforce to take competitive advantage. Nowadays different organizations worldwide are adopting GHRM practices as a form of employer branding as it is also considered the main source of taking competitive advantage by providing awareness to the youth about the environment and

environmentally friendly practices in the organization (Han and Kim, 2010). Various recent developments intended to involve workforce in different pro-environmental behaviors like using recycled paper, teleconferencing or video conferencing, sharing of car among employees or using a common van for employees pick and drop, help different firms to become more environmentally friendly (Arulrajah and Opatha, 2016). Both the Public sector federal chartered universities working in Gilgit and Baltistan region can apply AMO theory because there is great potential to promote sustainability and Green behavior both through education and practice.

H5 = Pro-Environmental Behavior has Significant direct impact on Environmental Sustainability

Environmental sustainability (ES)

Employee commitment, training and authorization for the pro-environmental activities are directly related to the sustainability of the environment and perform the role of mediator (Luu, 2018). According to the definition of the World Commission on Environment and Development sustainable development means to fulfill the present need without sacrificing the needs of the future generation (Dias-Sardinha and Reijnders, 2001). Sustainable environments improved environmental quality and accountability to avoid depletion and destruction of the environment. It consists of three stages; in the first stage, the organization responds to environmental regulations and policies to influence its framework. In the second stage, the organization put concentrations to protect the environment by reducing pollution and by taking other related measures. In the third phase, environmental sustainability is ensured by taking voluntary proactive activities (Jabbour and Santos, 2008).

Pro- Environmental Behavior (PEB)

Pro-environmental behavior is the readiness of employees to involve in pro-environmental activities. These activities consist of turning off light after office hours, avoiding wastage of resources, using public transport or bicycle, taking new initiatives to promote environmental sustainability. This Pro-environmental behavior of employees significantly contributes to the sustainability of the environment (Saeed et al., 2018). Pro-environmental behavior

artwork is a type of pro-social behavior; it is not obligatory; it relates with a genuine concern for the Planet; it can only be displayed when an individual thinks of future generations, nature, and humankind (Paillé and Boiral, 2013; Scherbaum et al., 2008). Pro-environmental behavior is a multifaceted behavior because it contains pro-social dimension of work, and it is very tough for managers to influence or encourage an employee to display such behavior through traditional leadership styles or approaches (Paillé and Boiral, 2013). Probably the most effective way to initiate pro-environmental behavior is arousing sense of deeper meaning in life, sense of community, care for the nature and planet, and convincing them that what they do today has a long-term consequence on the society and the coming generations. To become a responsible, environmentally friendly and effective organization it is an attractive strategy to use Pro-environmental behavior to combat environmental issues (Saeed et al., 2018).

H6 = Green HRM practices effect the Environmental Sustainability via Pro-Environmental Behavior.

MATERIALS AND METHODS

Sample and sampling method

The study will opt proportionate stratified random sampling technique to select the sample from the population. The stratified random sampling identifies heterogeneous stratum within a study population that may expect to vary in parameters and assign a specific proportion to each stratum and select sample accordingly. As in our study, the population consists of two subgroups i.e. members of the KIU Gilgit and UOBs Skardu, and the study expect these two groups vary in parameters. Hence the adoption of this stratified random sampling technique will minimize sampling bias as it offers equal opportunity to each element of a given population to be sampled.

Population of the study and Sample size

The population of this study consists of employees from the public sector universities of Gilgit-Baltistan.

The sample of this study will be consist of 300 employees of public sector universities of GB. 150 employees will have sampled from The Karakoram International University Gilgit and the remaining 150 will be selected from the Baltistan University.

Research design

The study is casual in nature. The researcher wants to assess the relationship between the Green HR functions (independent variable) and Environmental Sustainability.

Data collecting method and questioner

To carry out the empirical investigation of relationships between the Green HR functions and environmental sustainability specified by the above mentioned theoretical model, the study has adopted a questionnaire of (Saeed et al., 2018). The questionnaire has used a 5 point Likert scale containing responses from strongly agree to strongly disagree. This questionnaire will be distributed among the selected pool of employees from the public sector universities of both the Gilgit and Baltistan region.

Econometric techniques

The following statistical tools used after assessing the assumptions of tests regarding the data:

1. Cronbach alpha for reliability test
2. Factor analysis for validity
3. Heterotrait- Monotrait Ratio (HTMT)
4. Discriminant Validity
5. Structural Equation Modelling

RESULTS AND DISCUSSION

Demographics

Table 1 shows the demographic characteristics of individuals. The Table 1, illustrates that male respondents are 70% while the rest 30% are female respondents. 20.7% of the individual respondents are faculty members while the rest 79.3% respondents belong to non-teaching staff members. The study have 55.3% respondents from rural areas and 44.7 belongs to the urban areas. The data is mainly collected from the Gilgt Baltistan (GB) so 98.7% respondents are from GB, 0.7% from Khyber Pukhtoon Khwa (KPK) 0.3% from Sindh and 0.3% are from Balochistan province. The current designation of the respondents is also reported in demographics. A major junk (85%) are of the respondents are students while others are involved in teaching and administrator jobs. The author also reported the experience in the same university. Those respondents who spend less than 5 years in the university are 97%. The individuals who have greater than 5 years' experience are 3%.

Construct reliability and validity

The very first step to analyze the model is to check the relationship between variables and its indicator to examine that the constructs reflective nature in the model (Diamantopoulos and Siguaw, 2006;

Table 1: Demographic statistics

Demographics	Frequency	Percent
Gender		
Male	211	70.3
Female	89	29.7
Type of Staff		
Teaching Staff	62	20.7
Non-Teaching staff	238	79.3
Family Home		
Rural	167	55.3
Urban	133	44.7
Province		
KPK	2	0.7
Sindh	1	0.3
GB	296	98.7
Balochistan	1	0.3
Current Designation		
Student	255	85.0
Teaching	40	13.3
Administrator	5	1.7
For how long have you worked with this University		
less than 5 years	291	97.0
5-10 years	7	2.3
10-15 years	1	0.3
15-20 years	1	0.3

Gudergan *et al.*, 2008; Hair *et al.*, 2014; Klarner *et al.*, 2013). The most important reason for conducting the reliability and validity checks is to examine whether the indicators are representing the constructs or not. To validate this statement, constructs reliability tests are applied to the data. The Cronbach's Alpha in Table 2 shows that the constructs are ranging from 0.67 to 0.85 which means that all the constructs are reliable. The AVE values are mostly higher than 0.4 and the construct reliability are mostly greater than 0.7 threshold (Hair *et al.*, 2014).

Discriminant validity

Discriminant validity is the level to which each LV is different in the model for other constructs (Hair *et al.*, 2014). To construct discriminant validity, the AVE's square root should be greater for each construct than all the inter correlations among the constructs in the model for Fornell–Larcker criterion (Chin 2010; Hair *et al.*, 2014). Furthermore, the heterotrait–monotrait (HTMT) ratio has newly

been recognized as a better criterion related to the additional conventional valuation approaches, for instance the Fornell–Larcker criterion (Henseler *et al.*, 2015). Earlier literature has recommended construct thresholds of 0.85 and 0.90 for HTMT to construct discriminant validity (Henseler *et al.*, 2015). The present study utilizes more restricted HTMT 0.85 to measure discriminant validity. Tables 3 and 4 show the outcomes of the discriminant validity valuation of the measurement model via the Fornell–Larcker criterion and the HTMT 0.85 ratio and showed that models own a satisfactory discriminant validity.

Valuation of the structural model

The Structural equation modeling (SEM) for environmental sustainability were then analyzed. To analyze the structural model, R2 value of the internal constructs was measured as being representative of the model's explanatory power (Hair *et al.*, 2014). The R2 values were 0.52 for Environmental and 0.66 for Green Performance Management and Appraisal,

Table 2. Construct reliability and validity

Constructs	Cronbach's Alpha	rho_A	CR	AVE
Environmental Sustainability	0.771	0.798	0.775	0.417
Green Performance Management and Appraisal	0.829	0.829	0.829	0.547
Green Recruitment and Selection	0.853	0.860	0.847	0.530
Green Reward and Compensation	0.805	0.812	0.805	0.510
Green Training and Development	0.833	0.842	0.832	0.556
Pro Environmental behavior	0.675	0.701	0.594	0.260

*Rh= Reliability measure, CR = Composite Reliability; AVE** = Average Variance Extracted

Table 3: Discriminant Validity

	ES	GPMA	GRS	GRC	GTD	PEB
Environmental Sustainability	0.645					
Green Performance Management and Appraisal	0.691	0.740				
Green Recruitment and Selection	0.525	0.817	0.732			
Green Reward and Compensation	0.615	0.818	0.751	0.687		
Green Training and Development	0.693	0.893	0.732	0.847	0.681	
Pro Environmental behavior	0.253	0.231	0.144	0.022	0.134	0.516

Table 4: Heterotrait-Monotrait ratio (HTMT)

	ES	GMPA	GRS	GRC	GTD	PEB
ES						
GPMA	0.689					
GRS	0.506	0.811				
GRC	0.609	0.812	0.741			
GTD	0.690	0.898	0.742	0.864		
PEB	0.287	0.213	0.161	0.178	0.166	

0.56 for Green Recruitment and Selection, 0.79 for Green Training and Development and 0.13 for Pro-Environmental Behavior respectively. The behavioral research standards propose that the R^2 value of 0.2 is relatively great and satisfactory (Hair *et al.*, 2014). Furthermore, SRMR value in PLS-SEM is considered for the as model fit (Ray *et al.*, 2016) were estimated. The value for SRMT which is lower than 0.08 is acceptable for PLS-SEM (Ray *et al.*, 2016). The results shown SRMR model fit values of 0.065 and 0.08 for Saturated and Estimated model respectively. Table 5 shows the analyzation of SEM using non-parametric analysis (Henseler *et al.*, 2009). It is reflected as conventional PLS-SEM technique for the analyzing of the path co-efficient. Hypothesis 1 is concern with the relationship between GPMA and ES, the PLS results shows that GPMA has a significant ($t=2.87$) and positive ($\beta=0.23$) impact on ES. Therefore, hypothesis 1 is supported. H1a Hypothesis illustrate that GPMA has a positive ($\beta=0.27$) and significant ($t=2.15$) impact on Pro-environmental behavior (PEB). H2 is focused on the relationship between GRC and ES which again shows a positive ($\beta=0.14$) and significant ($t=1.70$) impact of GRC on ES. H2a assumed that there is direct and significant relationship with PEB but the data did not support the hypothesis and showed a non-positive

but significant impact on PEB. The study support hypothesis 2 accordingly. GTD also shows a positive ($\beta=0.29$) and highly significant ($t=3.44$) impact on ES, hypothesis 3 is also supported. H3a has stated that GTD has a positive and significant relationship but this hypothesis is rejected due to non-significant ($t=0.10$) behavior. The study formulates a positive and significant impact of GRS on ES which is not supported by the data. Hence, the study reject 4th hypothesis of the study. In H4a hypothesis, it is assumed that GRS has direct impact on PEB but the data has not supported the hypothesis.

Indirect effect

In Table 6 examine the indirect effect by putting Pro-Environmental behavior as a mediating variable. The author is expecting the relationships to be mediated through PEB. The author calculated the indirect specific through the process of bootstrapping by SmartPLS by including a single mediator. The results in Table 5 showed that all the relationship mediated insignificantly. GPMA>PEB>ES has path co-efficient ($\beta=0.04$) with ($P=0.15$). GRS>PEB>ES has ($\beta=0.00$) and insignificant ($P=0.66$) relationship. GRC>PEB>ES has negative ($\beta=-0.02$) and insignificant ($P=0.18$) indirect effect. GTD>PEB>ES has ($\beta=0.00$) mediations and insignificant (0.93) indirect effect.

Table 5: Direct effect

Hypothesis	Relationships	Std β	T -Stat	Significance level	
				5%	95%
H1	GPMA>ES	0.23***	2.87	0.09	0.368
H1a	GPMA>PEB	0.27**	2.15	0.07	0.453
H2	GRC>ES	0.14*	1.7	0	0.279
H2a	GRC>PEB	-0.21*	1.79	-0.39	-0.013
H3	GTD>ES	0.29***	3.44	0.16	0.43
H3a	GTD>PEB	0.02	0.1	-0.15	0.19
H4	GRS>ES	-0.01	0.15	-0.12	0.101
H4a	GRS>PEB	0.04	0.49	-0.13	0.213
H5	PEB>ES	0.13**	1.96	1.95	0.02

*= $p<0.10$, **= $p<0.05$, ***= $p<0.001$

Table 6: Indirect effect

Relationship	Std β	T Stat	P Values
GPMA>PEB>ES	0.04	1.42	0.15
GRS>PEB>ES	0.00	0.44	0.66
GRC>PEB>ES	-0.02	1.33	0.18
GTD>PEB>ES	0.00	0.09	0.93

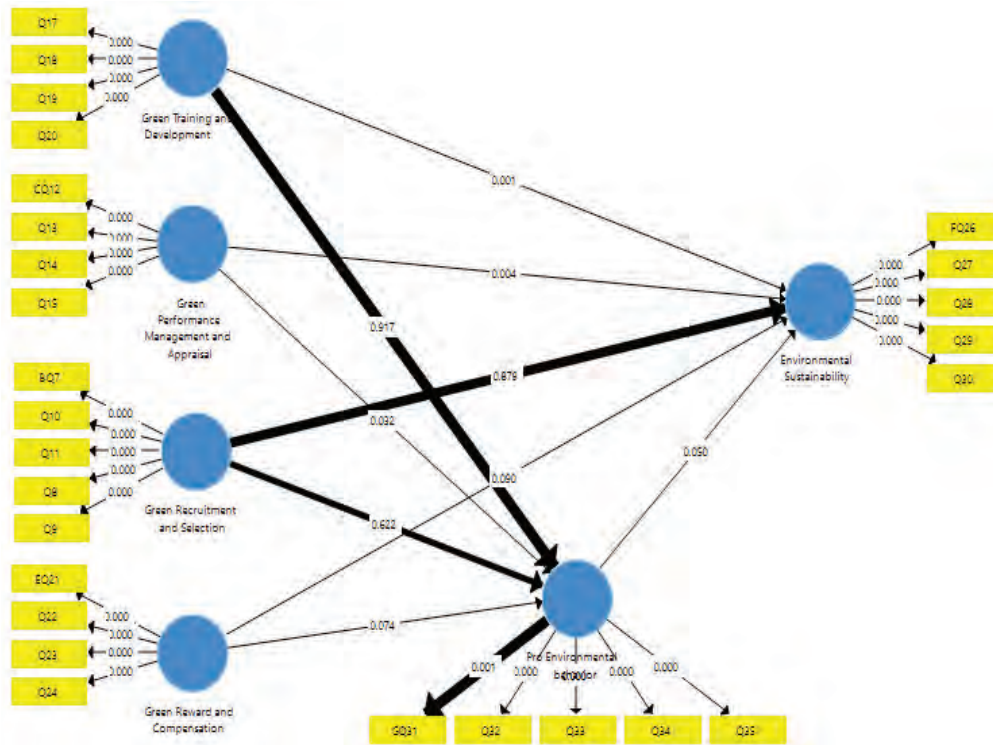


Fig. 2: Structural Equation Modeling (Bootstrapping)

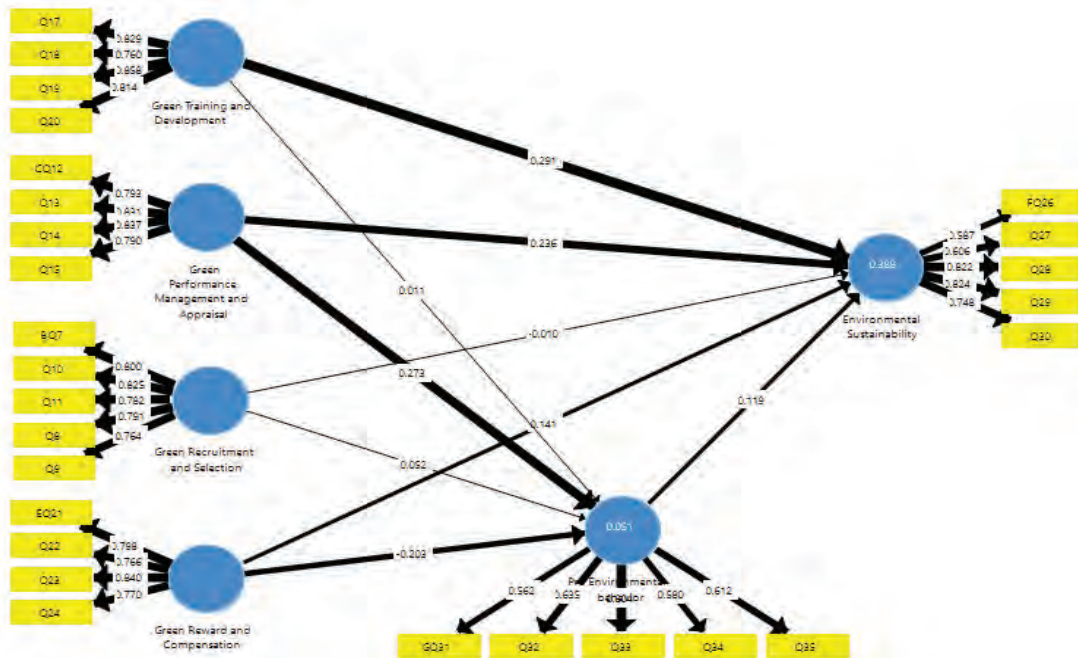


Fig. 3: Structural equation model (Path analysis)

CONCLUSION

The study explores the relationship of Green Performance Management and Appraisal, Green Recruitment and Selection, Green Reward and Compensation, and Green Training and Development with the Environmental Sustainability via Pro Environmental behavior. Primary data has been used to extract the results. The study utilized Structural Equation modeling to evaluate the relationship between green environmental practices and sustainable environment. The behavior of a mediator “Pro-Environmental Behavior” between green practices and environmental sustainability is analyzed. According to the results green performance management appraisal shows a significantly positive impact with the environmental sustainability. This results reveals that increasing the assessments of employ during the course of environmental management positively affect the environmental sustainability. GPMA has a positive and highly significant relationship with the pro environmental behavior as well. It reveals that increasing the management of green performance appraisal, pro environmental behavior will be increase. Likewise, green recruitment compensation also affects the environmental sustainability. It means that by giving the monetary and non-monetary compensation the environmental sustainability can be achieved. Due to this compensation the employee feels more energetic and support to sustain the green environment. According to the results GRC has a negative relationship with the pro-environmental behavior. Another factor that effect the environmental sustainability is Green Recruitment and Selection. The results show that GRS has direct and positive but insignificant impact on sustainable environment. Green Training and Development shows a highly significant and direct relationship with both pro-environmental behavior and sustainable environment. By increasing training and development of the employee regarding green environment, sustainable development of green environment will also be increased. Same is the case with the pro-environmental behavior, more skillful and developed the employee more pro-environmental behavior will exist. GTD has an insignificant relationship with the pro-environmental behavior. The study analyzed the indirect relationship between green environmental training and sustainable environment through a

mediator “pro-environmental behavior”. The results suggest that the mediator do not sensitize the environmental sustainability. The green HR practice has an insignificant relationship with environmental sustainability via pro-environmental behavior. The study assess that public sector university need to train and compensate their employee to reduce the environmental degradation and make their contribution in sustainability of the environment. The limitation of the study is that the data is collected from a single region i.e. Baltistan. Further research can be done by expanding the data and apply a new technique to get more accurate results.

AUTHOR CONTRIBUTIONS

Y. Jehan performed conceptualization, methodology, software, and literature review and manuscript preparation. M. Batool performed data correction, writing original draft preparation, writing reviewing and editing references. M. Imran helped in the visualization, investigation, software validation.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

AMO	Ability, motivation and opportunity
ES	Environmental sustainability
GHRM	Green human resource management
GRS	Green recruitment and selection
GPMA	Green performance management and appraisal

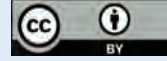
GTD	Green training and development
GRC	Green reward and compensation
HRM	Human resource management
KIU	Karakoram International University
SEM	Structural equation modelling
UOB	University of Baltistan

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ORIGINAL RESEARCH PAPER

Effect of family structure on urban areas modal split by using the life cycle concept

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ABSTRACT

The modal split model is one of the steps of the classical four-step travel demand planning. Predictive, descriptive, and prescriptive modal split models are essential to make a balance between travel demand and supply. To calibrate these models, it is necessary to detect and employ influential independent variables that are related to characteristics of travel modes, individual and family attributes, zones land use, etc. In previous studies, researchers used the household size, the number of children, and the number of employees as independent variables to show the role of family structure on the modal split. These variables cannot discriminate between different families with different structures. This paper uses the life cycle concept to categorize families based on their structures, and the effectiveness of these new variables on modal split models is examined. For this purpose, five types of family structures are considered that differences between them are based on the age of the family's children. The Multinomial Logit model is used for mode choice modeling for different trip aims. The mode choice model has been calibrated using the origin-destination data of Qazvin-Iran. Results show the critical role of life cycle dummies in the mode choice models compared to household size, for work, educational, personal, and social- recreational trip aims. Life cycle variables are more active on the work trips mode choice model by estimating 14 significant coefficients, in a 90 percent level of significance. The number of life cycle significant coefficients is decreased to 3 for the shopping trips model.

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INTRODUCTION

A considerable increase in urban trips, especially those with personal vehicles, is one of the main factors that cause traffic congestion, and related problems such as air pollution, noise pollution, energy loss, and safety decrease (Batur *et al.*, 2019). On the other

hand, the welfare of humans is increasing along with the improvement of lives quality, and for this reason, increasing the use of personal vehicles is expectable (Gilhooly and Low, 2005; Vijayalakshmi and Raj, 2019). Due to this high volume of vehicles, the urban structure will be changed as well as the streets and roads must be widened (Edrisi and Askari, 2019). The development of infrastructures is one of the tasks which are used for solving traffic congestion. Still, in

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most cases, this is not a logical instruction or solution for solving this problem. Additionally, the high costs of construction and limitation of resources lead to finding a better solution (Provotorov *et al.*, 2018). Therefore, more efficient and right policies and plans, as well as infrastructure development, can respond to the future demand for transportation (Wijaya and Imran, 2019). One of the most significant results of the transportation planning process is to determine the modal share. There are various models with different concepts and data for determining modal share (Mitra, 2013; Ton *et al.*, 2019; Calastri *et al.*, 2019; Shen *et al.*, 2020). The main goal of mode choice models is to discriminate the share of modes among the traffic flow. The first application of these models was dual selection among the personal vehicle and public transport (Train and McFadden, 1978). With the development of mode choice models, determining the share of each mode was generalized after the step of trip distribution (Vrtic *et al.*, 2007). These models are called as trip interchange models (Othayoth and Katti, 2017). The common ones are Probit (Van Can, 2013), Logit (Liang *et al.*, 2018), nested logit (Ma *et al.*, 2020), and mixed logit (Guo *et al.*, 2020). There are other models for determining the share of modes before the trip distribution step. These models are called trip end (for example, product models) (Blainey, 2010). Determining the influential factors in choosing each mode is one of the essential parts of modeling. In the current study paper, the role of factors related to the family structure is studied. The independent variables associated with the individual attributes are used in many studies (Johansson *et al.*, 2006). Other critical independent variables in the mode choice models are related to the family structure (Chang *et al.*, 2014; Kuo *et al.*, 2012; Boellis *et al.*, 2016). Several studies consider some variables such as the number of family members and children to study the effect of family structure on the mode choice (Rubin *et al.*, 2014; Mehdizadeh *et al.*, 2018). For instance, Li *et al.*, (2014) consider some variables such as the number of employed members and the number of children as independent variables in order to capture the effect of the family structure in the mode choice models. In another study, Yun *et al.*, (2014) for studying the impact of family structure on mode choice use household size and the number of children as independent variables. The most crucial point is the inability of these variables to distinguish

between families with the same attributes but different structures. In Yun *et al.*'s study, a family with four members, including two children, ages more than 18 years, and the other family consists of two children, age of children are less than 7 years, were considered have the same structure. The structure of these two families is different, as well as their transportation decisions. How to define the effect of family structure on transportation decisions is considered in some studies (Kitamura and Kostyniuk, 1986; Kitamura, 2009; Huntsinger and Roupali, 2012; Susilo *et al.*, 2019). In this paper, the idea which was proposed by Rasaizadi and Kermanshah (2018) was used to capture the effect of family structure on the modal split.

In this study, life cycle dummy variables are defined as follows:

- Life cycle 1 (LC1): The age of the oldest child is less than 6 years;
- Life cycle 2 (LC2): The age of the oldest child is between 6 and 12 years;
- Life cycle 3 (LC3): The age of the oldest child is between 12 and 18 years;
- Life cycle 4 (LC4): The age of the youngest child is under 18 years, and the age of one of the children [at least one child] is more than 18 years; and
- Life cycle 5 (LC5): Other families.

LC1, LC2, and LC3 only depend on the age of the oldest child. Usually, the trips of children under 6 years old are completely dependent on family trips. Children between 6 and 12 years old that are students of elementary school need to have educational trips with the family escort. Children between 12 and 18 years old that are students of high school can have their independent educational trips. LC4 includes families that have at least one child who can drive a car and at least one young child under 18 years old. Other families are placed in LC5. Kermanshah (1997), in another study, used these variables in order to study the effect of family structure on the trip generation model. In the current study, the impact of these variables on the mode choice models is investigated, for different trip aims, separately. Trip aims include work, educational, shopping, personal and recreational trips. The estimated coefficients of these variables are compared, and the statistical significance of them is examined. According to

the author's knowledge, it is the first time that the life cycle concept is used for modal split by using the multinomial logit model. The remainder of the paper is as follows. In the next section, the proposed model is introduced. After that, the data description is provided. Results and interpretations are presented in the result and discussion section. In the final section, the conclusion is presented. The current study has been carried out in Tehran, Iran, in 2019.

MATERIALS AND METHODS

Methodology

The multinomial logit model is used for modeling the mode choice. Assume that "q" is the index of a person, "i" is the index of each mode, and "h_{qi}" is the utility of "i" mode for the individual "q" (Eq. 1) (Ben-Akiva et al., 1985). Therefore:

$$h_{qi} = \beta x_{qi} + \varepsilon_{qi} \quad (1)$$

In which; x_{qi} is the vector of independent variables, β is the coefficient vector that must be estimated, and ε_{qi} is the error term of the utility function. Assume that ε_{qi} follows the iid extreme value, with location parameter equal to 0 and scale parameter equal to 1. Based on the utility theory, "q" chooses the mode "i" in a case as its utility is more than other ones. In other words, it can be said that the utility of "i" is more than the maximum utility of other modes for individual "q". This term can be written as Eq. 2:

$$h_{qi} > \max_{j \neq i} h_{qj} \quad (2)$$

r_{qi} is a dummy variable that is equal to 1 and 0. It is equal to 1, if the mode "i" is chosen by "q"; otherwise, it is equal to 0. Also, v_{qi} is defined as Eq. 3:

$$v_{qi} = \{\max_{j \neq i} h_{qj}\} - \varepsilon_{qi} \quad (3)$$

By combining Eq. 1 and Eq. 2:

$$\beta x_{qi} + \varepsilon_{qi} > \max_{j \neq i} h_{qj} \quad (4)$$

The Eq. 4 is rewritten as follows:

$$\beta x_{qi} > \max_{j \neq i} h_{qj} - \varepsilon_{qi} \quad (5)$$

And by substiting v_{qi} from Eq. 3 into Eq. 5:

$$\beta x_{qi} > v_{qi} \quad (6)$$

So, r_{qi} = 1 if and only if βx_{qi} > v_{qi}.

Based on Eq. 3, v_{qi} has resulted from the differentiation of the utility of the other alternatives and the error term of that mode. As both of them follows the iid extreme value, the random variable of v_{qi} follows the logistic distribution. The marginal distribution of v_{qi} is shown in Eq. 7 as follows:

$$F_i(\beta x_{qi}) = \Pr(v_{qi} < \beta x_{qi}) = \frac{\exp(\beta x_{qi})}{\sum_j \exp(\beta x_{qj})}, j = 1, 2, \dots, J \quad (7)$$

In which, "J" is the number of multinomial logit alternatives.

Assume that 1[0] is a function that its value is changed based on the number of integers and non-integers, one for the integers and zero for the non-integers. In such a case, M_{qik} is defined as Eq. 8.

$$M_{qik} = 1[r_{qi} = 1] \quad (8)$$

If the person "q" chooses mode "i", M_{qik} for that person equals one, and for the other "i_s" equals 0 [1].

The likelihood function of this model is as Eq. 9.

$$\log L = \sum_{q=1}^Q (\sum_{i=1}^J M_{qik} \log [\text{prob}(r_{qi} = 1)]) \quad (9)$$

By maximizing this function, the coefficients of this model can be estimated. R-studio programming is used in order to maximize this function. Numerical methods, including SANN, Nelder-Mead, and BFGS, are used for optimizing the likelihood function (Seyedabrishami and Izadi, 2019).

Data

The used data was collected in the survey of origin-destination trips for Qazvin, a city in Iran in 2010. The number of observations is 8891. The raw data needs data preparation. The age of travelers is continuous in raw data. This paper defines four dummy variables for the age of travelers to explore the effect of each age bracket separately. Also, the job of travelers in raw data is nominal. By defining four dummy variables, job variables become quantitative. Table 1 shows the defined independent variables of this data. The choice set for mode choice model includes personal vehicle, taxi, bus, motorcycle, and other modes.

Fig. 1 shows the location of Qazvin in Iran. The transportation network of this city is divided into 14

The effect of family structure on modal split

Table 1: Variable definition

Characteristics	Variable	Definition
Age	AGE 6-18	1= if the age is between 6 to 18, 0= otherwise
	AGE 19-30	1= if the age is between 19 to 30, 0= otherwise
	AGE 31-41	1= if the age is between 31 to 41, 0= otherwise
	AGE>41	1= if the age is more than 41, 0= otherwise
Sex	SEX	1= if sex is male, 0= otherwise
Job	ADM.JOB	1= if the job is administrative, 0= otherwise
	SERV.JOB	1= if the job is a service job, 0= otherwise
	EDU.JOB	1= if the job is educational, 0= otherwise
	OTHER	1= if the job is another job, 0= otherwise
Driving license	DL	1= if the person has a driving license, 0= otherwise
Number of vehicles	NVEH	Number of vehicles
Household size	HHSZ	Number of family members
Life cycle	LC1	1= if the family placed in life cycle 1, 0= otherwise
	LC2	1= if the family placed in life cycle 2, 0= otherwise
	LC3	1= if the family placed in life cycle 3, 0= otherwise
	LC4	1= if the family placed in life cycle 4, 0= otherwise
	LC5	1= if the family placed in life cycle 5, 0= otherwise

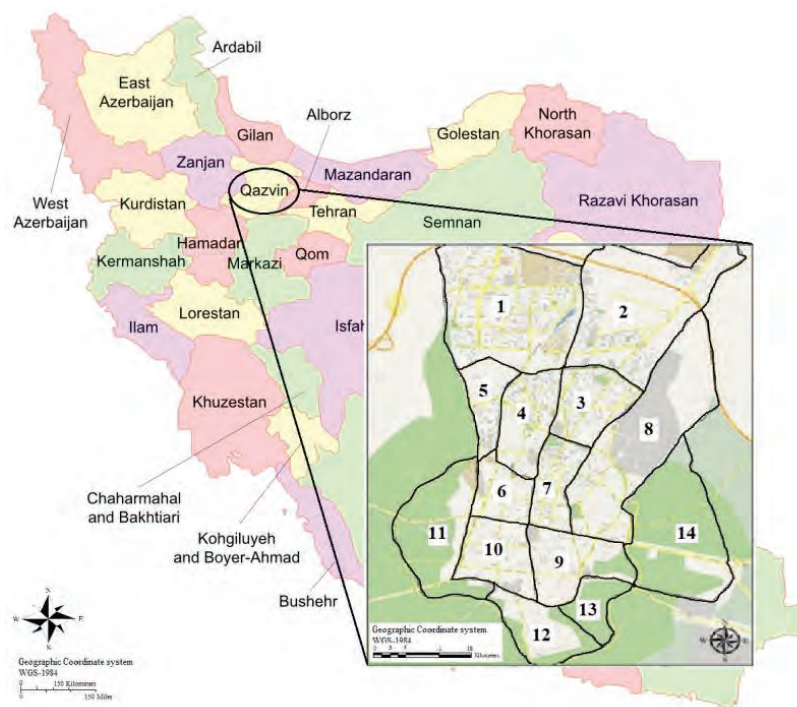


Fig. 1: Location of Qazvin in Iran and its traffic analysis zones

traffic analysis zones. The centroid of each zone is a representative point for all links and nodes of that zone. The origin and destination of trips and location of travelers home are determined based on these 14 traffic analysis zones.

RESULTS AND DISCUSSION

Mode choice models are calibrated for different trip purposes. Work and educational trips include mandatory trips to work and school (also university), respectively. The destination for shopping trips is

shopping centers or stores. Personal trips are related to their aims, such as visiting offices and doctors. Social-recreational trips include trips for visiting friends and family or trips to the parks, etc. to have recreation. Each trip purpose has a different pattern of the modal split, so to depict the effect of family structure on them, it is vital to calibrate separate models based on trip aims. Table 2 shows the mode choice model results for work trips.

For work trips, all life cycle variables and household size are estimated significantly and have a useful role in the mode choice model. LC5 is considered as base variable, and other life cycle variables are estimated related to the base variable. Bus and taxi are a preferable option for individuals that placed in LC5 and motorcycle, and others have more utility for LC1 families. Increasing household size decreases the probability of choosing a personal vehicle. People between 6-30 years old have less tendency to want personal vehicles regarding positive estimated coefficients for the other four modes. For individuals between 31- 40, motorcycle and taxi are a preferable mode and bus has less utility for these persons compared to a personal vehicle and other. The probability of choosing a motorcycle and other is high for men, while bus and taxi have more choosing probability for women. Bus, taxi, and motorcycle are more appropriate modes for individuals with ADM.

jobs and SERV.jobs. Other modes have the highest utility for SERV.jobs and the least utility for EDU.jobs. Also, EDU.jobs have more tendency to choose bus for their work trips. Having a driving license increases the probability of selecting personal vehicles. Table 3 shows the mode choice model results for educational trips.

It can be seen from Table 3 that for educational trips, LC4 can discriminate the taxi from the personal vehicle by its significant coefficient, but for household size, taxi, and personal vehicles considered as base alternatives. It means that families that placed in LC4 have more tendency to choose a taxi rather than families in other families. This result shows the importance of life cycle variables when families can select a taxi for their educational trips. Bus, motorcycle, and other are preferable options for individuals in large families. Bus, motorcycle, and others have the least utility for individuals in LC2, LC3, and LC1, respectively. Also, other coefficients are interpretable. Individuals between 6 to 30 years old have more tendency to use a bus, taxi, and other modes. Taxi has the most utility for individuals between 31-41 years old, and for these individuals, other modes have the least utility. Individuals over 41 years old have less tendency to use taxis and motorcycles. Bus and motorcycle are preferable modes for men rather than women. The probability

Table 2: Mode choice results for work trips

Variables	Personal Vehicle	Bus	Taxi	Motorcycle	Other
constant	--	2.94(***)	2.79(***)	-2.20(***)	-2.14(***)
Individual characteristics					
AGE 6-18	--	0.61(***)	0.89(***)	0.66(***)	0.30(*)
AGE 19-30	--	0.44(***)	0.81(***)	0.70(***)	0.13(*)
AGE 31-41	--	-0.08(*)	0.24(***)	0.32(***)	--
AGE>41	--	--	--	--	--
Sex	--	-0.428(***)	-0.51(***)	2.18(***)	0.49(**)
ADM.JOB	--	1.05(***)	0.77(***)	0.44(***)	--
SERV.JOB	--	0.31(***)	0.55(***)	0.81(***)	0.78(***)
EDU.JOB	--	0.28(**)	--	--	-0.86(**)
OTHER	--	--	--	--	-
DL	--	-2.46(***)	-2.11(***)	-2.38(***)	-1.04(***)
Family characteristics					
NVEH	--	-2.33(***)	2.02(***)	-0.09(*)	-0.98(***)
HHSZ	--	0.19(***)	0.12(***)	0.11(***)	0.27(***)
LC1	--	-0.65(***)	-0.66(***)	0.23(**)	0.83(***)
LC2	--	-0.53(***)	-0.60(***)	-0.20(**)	0.53(***)
LC3	--	-0.26(**)	-0.38(***)	-0.32(***)	0.26(***)
LC4	--	-0.17(**)	-0.28(***)	--	--
LC5	--	--	--	--	--

Stars show level of significance (***)99%, **95% and* 90%)

Table 3: Mode choice results for educational trips

Variables	Personal Vehicle	Bus	Taxi	Motorcycle	Other
constant	--	1.28(***)	2.19(***)	-2.97(***)	-13.91(***)
Individual characteristics					
AGE 6-18	--	1.54(***)	0.48(*)	--	11.84(***)
AGE 19-30	--	2.10(***)	0.46(*)	--	11.20(***)
AGE 31-41	--	1.54(***)	--	--	-5.41 (***)
AGE>41	--	--	-0.74(*)	-1.03(***)	--
Sex	--	2.15(***)	--	2.18(***)	--
ADM.JOB	--	--	--	0.44(***)	-8.03 (***)
SERV.JOB	--	-0.76(**)	-1.67(***)	0.81(***)	--
EDU.JOB	--	--	--	-	--
OTHER	--	--	--	-	--
DL	--	-1.48(***)	-1.21(***)	-2.38(***)	-1.30(**)
Family characteristics					
NVEH	--	-0.93(***)	-0.68(***)	-0.09(*)	-0.51(**)
HHSZ	--	0.05 (***)	--	0.11(***)	0.22(**)
LC1	--	-1.19(***)	--	0.23(**)	-44.12(**)
LC2	--	-1.40(***)	--	-0.20(**)	0.42 (*)
LC3	--	-0.37(***)	--	-0.32(***)	--
LC4	--	--	0.21(***)	--	--
LC5	--	--	--	--	--

Table 4: Mode choice results for shopping trips

Variables	Personal Vehicle	Bus	Taxi	Motorcycle	Other
constant	--	1.11(*)	1.01(*)	-1.49(*)	-19.18(***)
Individual characteristics					
AGE 6-18	--	2.37(**)	2.45(**)	2.50(*)	2.01(*)
AGE 19-30	--	1.87(***)	2.22(***)	1.97(***)	2.75(***)
AGE 31-41	--	0.87(*)	1.09(***)	1.05(*)	1.16 (*)
AGE>41	--	--	--	--	-
Sex	--	--	--	--	16.86 (***)
ADM.JOB	--	1.76(***)	1.29(**)	2.16(**)	0.96 (*)
SERV.JOB	--	--	0.80(**)	2.32(***)	--
EDU.JOB	--	--	--	--	--
OTHER	--	--	--	--	--
DL	--	-3.14(***)	-3.32(***)	-3.07(***)	-1.17(**)
Family characteristics					
NVEH	--	-2.30(***)	-2.22(***)	-0.88(**)	-1.14(**)
HHSZ	--	0.34(***)	0.40(***)	0.29(***)	0.51(***)
LC1	--	--	--	--	--
LC2	--	--	--	--	--
LC3	--	--	-0.55(*)	--	--
LC4	--	--	--	-1.24(**)	-1.49(**)
LC5	--	--	--	--	--

of choosing a motorcycle is higher for ADM.job and SERV.job compared to EDU.job and OTHER. Individuals with ADM.job have less tendency to use other modes. The probability of choosing the bus and taxi is decreased when individuals have SERV.jobs. Peoples that have the driving license are more likely to choose personal vehicles regarding estimated

coefficients for the other four modes. Table 4 shows the mode choice model results for shopping trips.

For shopping trips, household size depicts the family structure better than life cycle variables. This variable appears in all non-base alternatives utilities, but life cycles do not appear in bus utility. Individuals in large families prefer to use a bus, taxi, motorcycle

Table 5: Mode choice results for personal trips

Variables	Personal Vehicle	Bus	Taxi	Motorcycle	Other
constant	--	2.36(***)	2.91(***)	3.47(***)	-2.29(***)
Individual characteristics					
AGE 6-18	--	1.45(***)	--	-1.49(***)	--
AGE 19-30	--	1.14(***)	--	1.80(***)	--
AGE 31-41	--	--	--	--	--
AGE>41	--	--	-0.64(**)	--	--
Sex	--	--	--	6.41(***)	1.78 (**)
ADM.JOB	--	-1.30(***)	--	--	2.28(***)
SERV.JOB	--	--	--	2.26(***)	2.19(***)
EDU.JOB	--	--	0.59(**)	--	--
OTHER	--	--	--	-2.68(***)	--
DL	--	-2.80(***)	-2.57(***)	-2.64(***)	-2.53(***)
Family characteristics					
NVEH	--	-2.01(**)	-1.02(***)	--	--
HHSZ	--	0.11(***)	--	--	--
LC1	--	-0.64(***)	--	--	--
LC2	--	--	-1.11(**)	--	-1.84(**)
LC3	--	--	-0.50(**)	--	--
LC4	--	--	--	--	-0.81(**)
LC5	--	--	--	1.56(**)	--

Table 6: Mode choice results for social-recreational trips

Variables	Personal Vehicle	Bus	Taxi	Motorcycle	Other
constant	--	3.93(***)	1.44(***)	-9.10(***)	-1.60(***)
Individual characteristics					
AGE 6-18	--	--	--	--	--
AGE 19-30	--	--	--	0.72(*)	-2.00(**)
AGE 31-41	--	0.72(*)	0.54(*)	--	-1.09(*)
AGE>41	--	--	--	--	--
Sex	--	--	--	4.41(***)	1.68(***)
ADM.JOB	--	-2.31(***)	--	4.56(***)	-1.59(*)
SERV.JOB	--	-4.06(***)	--	--	-1.19(*)
EDU.JOB	--	--	2.02(**)	--	-0.98(*)
OTHER	--	-0.84(*)	--	--	--
DL	--	-1.79(***)	-1.62(***)	--	--
Family characteristics					
NVEH	--	-1.69(***)	-1.41(***)	--	--
HHSZ	--	--	0.19(*)	--	--
LC1	--	--	--	--	2.25(***)
LC2	--	--	--	-2.98(***)	-1.93 (**)
LC3	--	-0.75(**)	-1.57(***)	--	--
LC4	--	--	-1.05(**)	--	--
LC5	--	--	--	--	1.18 (*)

compared to a personal vehicle. Taxi, motorcycle, and others have the least choosing probability for individuals in LC3, LC4, and LC4, respectively. All individuals, except individuals over 41 years, have more tendency to use a bus, taxi, motorcycle, and others rather than a personal vehicle. The probability of choosing other modes is high for men compared to

women. The personal vehicle has the least utility for individuals with ADM.jobs, and bus and motorcycle are preferable modes for individuals with SERV. jobs. The probability of choosing a personal vehicle is increased when individuals have a driving license. Table 5 shows the mode choice model results for personal trips.

Mode choice model results for personal trips show the critical role of life cycle variables in utility functions. Still, household size cannot consider the effect of family structure on the taxi, motorcycle, and other modes. Individuals in large families are more likely to choose a bus for their trips. Bus, taxi, and others have the least utility for individuals in LC1, LC2, and LC2, respectively. Individuals in LC5 have more tendency to choose the motorcycle. Individuals between 6 to 30 years old have more tendency toward using a bus. The motorcycle is an attractive mode for individuals between 10 to 30 years old, but this mode has a less attractive option for individuals between 6 to 18 years old. Selecting of taxi negatively affected for individuals over 41 years old. The probability of choosing a motorcycle and other is increased for men compared to women. Bus, motorcycle, and other are preferred options for EDU, SERV, and ADM jobs. Having a driving license has a significant positive effect on choosing a personal vehicle. Table 6 shows the mode choice model results for social-recreational trips.

Similar to personal trips, for social-recreational trips, life cycle variables appear in all utility functions by high statistically significant, but household size only appears in taxi utility. Individuals in large families prefer to use a taxi for their social-recreational trips. Bus, taxi, motorcycle, and others have a less choosing probability for individuals in LC3, LC3, LC2, and LC2, respectively. Bus and taxi are the preferred options for individuals between 31 to 41 years old. Individuals between 19- 31 have more tendency to use a motorcycle for their social-recreational trips. Also, other has less utility for persons between 19 to 41 years old. Motorcycle and others are attractive options for men. Persons with EDU.jobs have more tendency to use the bus. Taxi and motorcycle have the highest choosing probability for EDU.jobs and ADM.jobs, respectively. Individuals with OTHER jobs have more tendency to choose other modes for their social-recreational trips. Having a driving license decrease the probability of choosing a bus and taxi.

CONCLUSION

The most important question of this study was; how life cycle as the family structure affects the trip mode choice. Also, there are some variables, such as the number of family members, which shows the family structure. For work trips, the coefficients of all

life cycle variables and the number of family members are estimated and were significant that indicates the mutual effect of these variables for the description of the family structure on mode choice. For the shopping trips, the number of family members is considered in the utility of all modes. However, variables of the life cycle are limited to the utility of two modes. For such trips, the number of family members has an effective role in describing the family structure. For the educational, personal, social, and recreational trips, variables of the life cycle are considered in all alternatives, but, for each aim, the number of family members did not emerge in the utility of two options. This point shows the role of life cycle variables in the description of the family structure. In general, it can be said that the use of life cycle variables is essential for studying the effect of family structure on the modeling of transportation decisions.

AUTHOR CONTRIBUTIONS

A. Rasaizadi commenced the process by conceptualizing and formulating the research idea, followed by data collection and cleaning. A. Rasaizadi and M. Askari calibrated multinomial logit models, reviewing the literature, and preparing the manuscript.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy has been completely observed by authors.

ABBREVIATIONS

LC	Life Cycle
IID	Independently and Identically distributed
ADM.JOB	Administrative job

<i>SERV.JOB</i>	Service job
<i>EDU.JOB</i>	Educational job
<i>HHSZ</i>	Household size
<i>NVEH</i>	Number of vehicles
<i>SANN</i>	Simulated Annealing Algorithm
<i>BFGS</i>	Broyden – Fletcher – Goldfarb – Shanno Algorithm

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REVIEW PAPER

The essence of knowledge management in the air transportation sector

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ABSTRACT

With the modern development and increasing competitiveness of air transport business processes, the management of knowledge is essential most especially for air transport managers. This controls compounded phases of the organization which begins with the fabrication of organisational strategy towards value creation and improving customers` experience. This study was to explore the review on the impact of knowledge management in the Nigerian air transport sector. Knowledge management is the extent to which improved business performance is realizable. The empirical reveals that the importance of knowledge management in the air transport sector is driven by the increasing level of technological change; the changing dynamics of market forces; complex nature, and expansion of air transport sector; information technology which enhances the collection, analysing, recording and transfer or sharing of information, data or facts within the organisation; and the achievement of competitive advantage through cost and schedule leadership. In the situation whereby an organization does not embark on knowledge management practice, and they planned to expand the scope or dimension of the organization, the expansion will be the sinking sand and the hole where the organization will bury all the knowledge resources and organization will be rendered bankrupt.

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INTRODUCTION

In management practice, the classical theorist concentrates on the holistic organization while the scientist concentrates on the efficiency of individual outputs. Knowledge management is embedded classical theory which identifies the improvement of managerial principles. Among the giant authors of the classical theory are Henri Fayol, Max Weber, Mary Parker Follett, Chester I. Barnard (Babcock, 1998). These classical theorists carried out different studies on information flow within the organization

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and emphasized the pertinence associated with the proper perception of how the organization should be operated. This study, therefore, draws clue from the classical theory of management (most especially the definition of management by Mary Parker Follett) to expand the discussion of appreciating knowledge management in the air transport sector. According to Follett (1924) and Follett (1941), management is the art of getting things done by a group of people. Realizing this, manager or an organization of unit of an organization will share the given task with his subordinates to achieve the overall goals (Babcock, 1998). History made it known that air

transport originated on December 17, 1903, when Orville Wright and his brother Wilbur Wright made their historic powered flights in a heavier-than-air machine which occurred at Kitty Hawk, North Carolina. Since the discovery of tactics that made aircraft fly, the developed countries had initiated several management systems to support their aircraft production and development plans as they were, and still are, pioneers in aircraft production, air transport management. Recently, most countries involved in air transport business such as airline and aircraft manufacturing are multinational in nature, they exist through joint venture agreements such as Bilateral Air Service Agreements (BASAs) with other countries to enhance the efficiency of air transport operations. According to [Sangeeta et al., \(2015\)](#), in today's globally competitive environment, acquiring knowledge and managing knowledge is indispensable to realizing organizational efficiency. Knowledge is among the most important resources for needed in a globalized economy ([Davenport and Prusak, 2001](#)), it can be referred to as experience. [Nonaka \(2001\)](#) noted that the management of knowledge is the assiduous efforts, tools and techniques that organization managers adopt for identifying, locating, refining, assigning, reassigning, transferring, and applying available experience in the organizations. Hence, knowledge management (KM) is extensively perceived as a prototype that consists of unified policies and methods in the organizational which enhances knowledge transfer and knowledge sharing within the organizational environment ([Al-Yahya, 2009](#)). In the 1970s, Nigeria established a national carrier which went bankrupt in the early millennium. Among the myriad reasons for the bankruptcy is ineffective or lack of proper management of knowledge. This is not limited to the operation of the defunct Nigerian national carrier, but also the majority of the public institutions. It is pertinent to note that there is evidence of the persistent failure of public organizations (enterprises) in Nigeria; also the returns on huge investments like the national carrier were significantly low and not comparable to the huge amount of resources expended in them ([Jerome, 2008](#); [Ogunsiji and Ogunsiji, 2010](#); [Oghojafor, 2012](#); [Adeniran and Gbadamosi, 2017](#)). The aftermath of the persistent failure results to the policy shift from public ownership and operations of enterprises to

some form of privatizations either at a full scale or partial scale. It is believed that the private management of enterprises are better when it comes to the implementation of management principles and knowledge management. The essence of knowledge and knowledge management enhances competitive benefits ([Nonaka and Takeuchi, 1995](#); [Scarborough et al., 1999](#); [Davenport and Prusak, 1998](#); [Lesser and Prusak, 2002](#)). To achieve a successful implementation of knowledge management within the organization, the components and processes of knowledge management must be effectual ([Bohn, 1994](#)). Hence, the appropriate usage of knowledge within the organization is a necessity for realizing and improving organizational productivity, efficiency and profits. When all these are realized, the sustainability of enterprises into the unforeseeable future will be inevitable ([Al-Hawari, 2004](#)). With the modern development and increasing competitiveness of air transport business processes, the management of knowledge is essential most especially for air transport managers. This controls compounded phases of the organization, beginning with the fabrication of organisational strategy towards value creation and improving customers' experience. This study aims to explore the review on the impact of knowledge management on Nigeria air transport business. The study was carried out in Murtala Muhammed International Airport (MMIA) Lagos, Nigeria, in 2019. The reason for the choice of study location was that MMIA have the record of highest passengers' movement; highest record of aircrafts' movement; highest record of loading and offloading of cargoes; major point of cargo and passenger consolidation for onward movement; frequent aircraft services; and other aviation activities over the years. Also, the airport is the hub for West Africa air travel where facilitates consolidation and fragmentation of flight related. It is pertinent to note that whatsoever that occurs in the airport is a direct replica of happening in other airports within the country and in some West African airports.

Literature review

This review study is targeted as discussing the essentials of knowledge, knowledge management (KM) and air transport business. It also provides the importance of knowledge management in the air transport sector.

Conceptualization

The definition of knowledge management cannot be real without exploring the definition of knowledge, and the principles associated with knowledge. *Boyd et al., (2004)* observed that knowledge has been subjected to philosophical disposition for many years. In the study conducted by *Jashapara (2004)*, the term and the definition of knowledge were realized from Plato and Aristotle. Also, the concept of knowledge management was thoroughly explained in the studies of *Nonaka (1994); Davenport and Prusak (1998)*. According to the *Oxford English Dictionary (OED) (2008)*, knowledge is a structure of information and skills that are acquired through experience or education. Furthermore, it has to do with awareness or familiarity realized by experience over a while. It is the summation of what is acknowledged. According to *Davenport and Prusak (1998)*, knowledge entails both meaning and judgement. A judgement is a conclusion that is rooted in a person’s experience and beliefs. Knowledge is identified to be a powerful resource that enables individuals and organizations to achieve several benefits such as improved decision-making (*Sangeeta et al., 2015*). *Nonaka and Takeuchi (1995)* perceived that knowledge and information are two different constructs whose meanings are similar, but if intertwined they have almost different meanings concerning perspectives, commitments, and actions. The construct of

knowledge has been defined by different authors as shown in *Table 1*.

After critical examination of defining knowledge by various authors, knowledge, in this study can be defined as an experience, skill or understanding that is gathered through individualistic and/or collective dynamic approach from different sources in the form of information that have been critically subjected to hypothetical analysis to avoid errors and indecision during implementation to enhance efficient output that will better the present and future performances of the organization. Furthermore, knowledge is usually evidenced by the following attributes such as hypothesizing, admitting, partaking, contributing, recognizing, sharing, investigating, exploring, pro-activeness, among other attributes. According to *Egbu and Robinson (2005)*, there are three dimensions of knowledge; they are shown in *Table 2*.

It is pertinent to note that regardless of the knowledge dimensions, knowledge can be articulated or transcribed in several dynamics; such as in alphabets, innumerals and can be shared holistically, and scientifically through equations and formulas, specifications, guidelines and manuals. Given the above points on knowledge, the management of knowledge or knowledge management is important. It is the process of planning, organizing, regulating, controlling, sharing and disseminating knowledge most especially in the organization. It is an organized procedure for sharing

Table 1: Definition of knowledge according to different authors

Definition of knowledge	References
Knowledge is the infrastructure of experience, values, and learning that provides a structure for analysing and implementing new experiences and sequences	<i>Davenport et al., 1998</i>
Knowledge is the information that is pertinent and partially gained through experience	<i>Leonard and Sensiper, 1998</i>
Knowledge is a piece of information by which the organization must pay attention to consumers, goods, operations, errors, and success	<i>O’Dell and Grayson, 1998</i>
Knowledge is a set of information with a complete understanding of the reason why it is accurate. It is realized through the accumulation of skill or learning	<i>Klicon, 1999</i>
Knowledge is the information accessible in the right arrangement, at a suitable time, and the appropriate place for efficient decision	<i>Tiwana, 1999</i>
Knowledge is a self-motivating approach for changing the mind of the individual through experiences	<i>McInerney, 2002</i>
Knowledge is the level of understanding of an individual through experience and learning	<i>Awad and Ghaziri , 2004</i>
Knowledge is an approach that enhances decision making based on the action in an individual	<i>Tserng and Lin, 2004</i>
Knowledge is the potential to take actions in critical and uncertain circumstances	<i>Bennet and Bennet, 004</i>
Knowledge is a faith that enhances the capability of an individual to take actions that affect the future dealings of the organization	<i>Nonaka and Takeuchi, 2004</i>
Knowledge is an entity that can be justified, shared, understood, and implemented to attain a set of targets and objectives	<i>Al-Hawari, 2004</i>
Knowledge is the accumulation of skills, such as acknowledging, sharing, recognizing, investigating, pro-activeness and understanding, gained through study, and learning.	<i>Oxford English Dictionary, 2009</i>

Knowledge management in air transport

organizational actions and transferring knowledge by persons and teams towards the realization of organizational objectives (Rastogi, 2000). The construct of knowledge management has been defined by different authors as shown in Table 3.

After critical examination of defining knowledge management by various authors, knowledge management, in this study can be defined as the integrative processes of knowledge identification (resources), knowledge creation, knowledge collection, knowledge planning, knowledge distribution, knowledge transfer, knowledge control, knowledge advancement, knowledge utilization, and knowledge maintenance for the development of the organization. It can be noted that instead of adopting knowledge management, knowledge administration seems to be more presentable as it encapsulate

knowledge identification, knowledge organizing, knowledge creation, knowledge collection, knowledge planning, knowledge distribution, knowledge transfer, knowledge control, knowledge advancement, knowledge utilization, and knowledge maintenance. Knowledge management is a technique that is widely embraced by many large companies and institutions in the world most especially the air transport sectors. Several factors have enhanced the dominance of knowledge management in the sectors including the air transport sector, among are: 1) The increasing level of technological change; 2) The changing dynamics of market forces; 3) Complex nature, and expansion of the air transport sector; 4) Information technology which enhances the collection, analysing, recording and transfer or sharing of information, data or facts within the

Table 2. Dimensions of knowledge and their characteristics

Knowledge dimensions	Characteristics
Technical knowledge dimension	It entails informal personal talent skills and abilities that are often referred to as technical know-how;
Cognitive knowledge dimension	It entails the model of mental magnitude, beliefs, principles, ideas, and values that are deeply embedded within individuals (personal) and which individuals do not easily noticed, or if noticed, they usually take for granted
Explicit knowledge dimension	It is a form of knowledge that is usually codified and can be transmitted in a prescribed and recognised manner through a methodical language, and it is usually cramped in records such as soft and/or hard documents, databases, and in a sequential basis.

Table 3: Definition of knowledge management according to different authors

Definition of knowledge management	References
Knowledge management is the procedure of transferring, establishing, sharing, and the effective utilization of knowledge	Davenport, 1994
Knowledge management is a synergistic mixture of facts and figures, and with its dispensation in terms of the ability of information technologies	Malhotra, 1997
Knowledge management is a plan that turns an organization's logical resources into greater efficiency, new worth and maintained competitiveness	Murray, 1997
Knowledge management is the collection of processes that govern the conception, distribution, and consumption of knowledge	Newman, 1997
Knowledge management is the utilization and growth of the knowledge resources of an enterprise with the tendency to fulfilling the organization's goals	Davenport et al., 1998
Knowledge management is defined in respect to knowledge of consumers, goods, associations, and resources	Skyrme, 1999
Knowledge management is the formation of a surrounding which gives confidence for knowledge to be created, transferred, learned, advanced, planned and utilized for the welfare of the firm and its consumers	BSI, 2003
Knowledge management is lined to unlocking different kinds of knowledge so that it becomes accessible as an organizational resource	Robinson, 2005

Table 4: Approaches for managing knowledge and the indicators

Approaches for managing knowledge	Indicators
Management of technical knowledge	Indicators to be managed are products and services
Management of procedural and regulatory knowledge	Indicators to be managed are organization processes
Identification and management of people	Indicators to be managed are people with specific experiences and skills

organisation; and 5) Achievement of competitive advantage through cost and schedule leadership. All these are crucial as it enhances the greater opportunities for learning from the experiences of businesses, sections, organizations, and people from different parts of the same organisation towards the sustainability of business success in the air transport sector. Egbu and Robinson (2005) identified three major approaches for managing knowledge within an organisation; they are referred to as 3Ps and shown in Table 4.

As a result of these factors, Offsey (1997) pointed out four benefits of knowledge management in any organization without exception to the air transport sector. They are a: 1) Awareness: the stakeholders in air transport are enlightened about where to find the organization's knowledge; 2) Accessibility: all the stakeholders in air transport have access to the organization's knowledge; 3) Availability: all stakeholders in air transport are aware of situations where knowledge is used and wherever it is needed; and 4) Timeliness: knowledge is available to all stakeholders whenever it is needed. According to Palmer and Platt (2005) revealed that the proper management of knowledge cannot be far-fetched from or beyond the following advantages: 1) Competitive advantage; 2) Avoidance of repeated mistakes and reinventing; 3) Reduction of time taken to find information; 4) Enhancement of effective decision-making; 5) Improving client satisfaction, and 6) Improving employee morale and teamwork. All the dynamics of knowledge and the approaches of knowledge management are essential in the air transport sector. The efficiency of the air transport sector is highly dependent on the extent to which knowledge is adequately managed, shared and transferred. Knowledge can be obtained from academic circles and research centres which may be in the form of intellectual knowledge capacity. According to Kamara et al.,

(2002), knowledge management is measured based on realizing the improvement of business performance. According to Marquardt (1996); Liebouritz (1999); Ekaterina et al., (2015), there are four stages of knowledge management, they are: knowledge acquiring; knowledge creation; knowledge transfer and usage; and knowledge storing. Further to the stages of knowledge management, DiBella and Nevis (1998), identified the steps involved in knowledge management which are knowledge acquisition; knowledge dissemination; and knowledge utilisation. In addition, Monk (1998); Alavi and Leidner (2001) differentiate the knowledge management processes which are knowledge creation; knowledge storage; knowledge retrieval; knowledge transfer; and knowledge application. It is pertinent to observe that the stages of knowledge management, steps involved in knowledge management, the processes involved in knowledge management are almost the same. Knowledge management of human capital is driven by the knowledge of employees, employee reward and reward types, motivation dynamics of employee that is most preferred (Kwong and Lee, 2009; Ekaterina et al., (2015).

Historical overview of knowledge management

The beginning of knowledge management was considered in Polanyi's early publications on individual knowledge in the direction of a post-critical philosophy during 1944, 1947 and the tacit domain in 1979 (György, 2015; Polanyi, 1979; Polanyi, 1947; Polanyi, 1944), which later became the basis for the majority of studies carried out on knowledge management especially during the 1990s (Grant, 2007). Another significant development in knowledge management theory was introduced by Nonaka (1991) in 1991 and soon after in 1995. Nonaka (1991), further extended Polanyi's work on individual knowledge through real

case studies from knowledge-creating companies in Japan. Furthermore, Nonaka built up the knowledge model, through which there was a declaration that successful innovations initiate the conversion of organisational tacit knowledge into explicit knowledge and back to tacit knowledge. In the same manner, it was adopted to present the process of knowledge development within the organization. The study of Davenport and Prusak (1998) was also consistent and recognised in the development of knowledge management. Their study on knowledge revealed the difference between data, information and knowledge, and argued for a more holistic analysis of knowledge management from the socio-technical theory (Grant, 2007). According to Claire and Michael (2011), the categorization of knowledge management was one of the more important achievements in the field of knowledge management. The authors acknowledged three main schools of thought surrounding knowledge management: 1) The technocratic school; 2) The economic school; and 3) The behavioural school. The technocratic school is based on information and management technologies that support employees' knowledge in their daily work. The economic school essentially creates profits for the enterprises through the utilization of explicit knowledge, and other ambiguous assets similar to patents and copyrights. The behavioural school is more oriented in the direction of the behavioural aspects of management which requires organizations to be positive in creating, sharing and using knowledge. Gherardi (2006) clearly distinguished between two bodies of knowledge management: 1) The sociology of knowledge, and 2) The history of science. The sociology of knowledge exposes that the conception of knowledge should be analysed concerning the social construction reality; and history of science argues that normal science should not necessarily become institutionalized through a process of accumulating knowledge and reflecting on the knowledge produced but through the mobilization of power resources in the support of claims for its legitimacy and validity (Gherardi, 2006).

Air transportation

Air transportation is a system that consists of different components adopted for facilitating passenger and cargo movement (Wiley, 1986;

Farlex, 2011; Fadare and Adeniran, 2018). The components are distinguished based on three major infrastructures used in air transport operations, they are landside, terminal building and the airside. The terminal building is referred to as airport. It is an enclosure that facilitates fragmentation of passengers and/or cargoes for final distribution; consolidation of passengers and/or cargo for onward movement; and transfer of passengers and/or cargoes from landside to airside or airside to landside with the use of some infrastructures and equipment. The physical and management activities of air transportation take place in the airport. Hence, the airport is indispensable in air transport operations such as aircraft processing, passengers and cargo processing, runway operation, aircraft parking management, control tower operation and signalling, among others (Ashford *et al.*, 1985; Betancor, 1999; Jarach, 2001; Graham, 2003; Jarach, 2004, Jarach, 2005; Almeida, 2011; Serebrisky, 2012). The relevance of knowledge in an organization cannot be far-fetched as it enhances the prediction of market dynamics, amid other rationales. In the air transport sector, particularly the airport, knowledge management is required for analysing demand and supply, competitive intensity, areas of competitive advantage, and other information for making strategic tactical and operational decisions.

The essence of knowledge management in the air transport sector

Knowledge management has been earlier stated by Kamara *et al.* (2003) as to how improved business performance is realizable. It enhances the air transport sector to devise mechanisms that could bring them closer to knowledge communities, thereby generating new knowledge and producing continuous improvement. This interaction enhances the flow of knowledge between internal and external knowledge communities instead of an organisation responding reactively to a knowledge push, the principle of knowledge management can pull that knowledge into itself. Knowledge management establishes the mechanisms by which intangible assets (knowledge) are best exploited to benefit the organization. In the developed countries, air transport (aircraft manufacturing companies, airline companies and airports) have begun to build their long-term strategies upon effective

knowledge management, as knowledge becomes the strategic important resource for enterprise. For instance, British Airways have designed a best practice knowledge sharing database to promote the sharing of practices, knowledge, know-how and lessons learned all over the company. They also developed the Global Information Link (GIL) to manage knowledge; which is a software system that creates a single desktop and operating environment worldwide. However, in developing countries like Nigeria, knowledge management is relatively new. Few studies consulted have revealed the huge importance embedded in the adoption of knowledge management, but none have related them to the air transport sector. This study, therefore, establishes the pertinence of adopting knowledge management in the air transport sector. Significant importance is placed on processes for managing knowledge by the [British Standards Institute \(BSI\) \(2003\)](#) which defines knowledge management as the creation and subsequent management of an environment that encourages knowledge to be created, shared, learnt, enhanced, organised and utilised for the benefit of the organisation and its customers. Regarding the processes that concern the management of knowledge, [Suresh \(2006\)](#); [Egbu and Robinson \(2005\)](#) highlighted the same processes in knowledge management which include: identifying, capturing, codifying, storing, mapping, disseminating, creating, and measuring its impact. [Wiig \(1997\)](#) discusses renewing, organising, transforming, and leveraging knowledge assets; whilst the [BSI \(2003\)](#) refers to creating, sharing, learning, enhancing, organising, and utilizing knowledge. [Kazi and Hannus \(2002\)](#) consider these: identity, collect, organise, share, adapt, use, and create. [Jashapara \(2004\)](#) identifies the processes of discovering, generating, evaluating, sharing, and leveraging knowledge which was contended in a continuous cycle.

Empirical evidence

In the studies of [Alavi and Leidner \(2001\)](#); [Schultze and Ladnere \(2002\)](#); [Clark et al., \(2007\)](#), the emphasis was made that knowledge management is majorly executed through the system of knowledge management which is driven by information technology and networking. The authors identified knowledge management as the most significant resources needed in the organization. In the study of

[Gronau \(2002\)](#), it was pointed out that the knowledge management system enhances information gathering from clients. The process of gathering information begins with the storing of knowledge in a management system which is referred to as "the knowledge care". [Gronau](#) identified knowledge management as a key factor for accomplishments in most organizations in recent times. The study of [Bounchen \(2002\)](#) was conducted to compare the pertinence of knowledge management in the hospitality industry with the pertinence of knowledge management executions in other sectors. In their study, evidence of knowledge management and the dimensions of its analysis were pointed out in the hospitality industry. It was revealed in their findings that knowledge management contributes significantly to the entire performance of the hotel management which helps to improve the quality of service delivery. The study of [Clark et al., \(2007\)](#) recommended knowledge management value as a strategic decision-making process which is usually adopted by the top management board. The study further tinted the pertinence of programs in organization knowledge for supporting the entire process of strategic planning. It was concluded that the idea of knowledge management as a key to achieving successful strategic planning is essential. [Hattendorf \(2002\)](#) conducted a study on knowledge management in the supply chain network. The analytical evaluation revealed that majority of the projects undertaken in knowledge management are devoid of major concepts which undermine the usefulness of a singular factor of information technology but was unable to address other crucial variables which are strategies, structures and processes. The study of [Hattendorf](#) was pertinent to this study because the study emphasized on how this tool was integrated with the projects of knowledge management in the airline sector. [Pan et al., \(2006\)](#) examined the challenges involved in knowledge creation, knowledge definition, and the adoption of knowledge concerning the Chinese outbound market. [Shaw and Williams \(2008\)](#) evaluated a review on knowledge management and knowledge transfer in the tourism industry. Their goal was to explore some of the most common mechanizing practice in knowledge management and means of knowledge transfer in the tourism industry. In doing so, they explored such concepts

as interlocking directorships, communities of practice, learning regions and labour mobility. They emphasize the pertinence of innovations in the tourism sector. According to [Satisbury \(2003\)](#), knowledge management is the deployment of the all-inclusive system that enhances the growth of an organization's knowledge. To expand the knowledge management discipline, knowledge management is defined as the management functions that encompass the knowledge creation, knowledge flow in the forward and backward chain within the organization, and efficient adoption of knowledge for competitive advantage ([Darrock and McNaughton, 2002](#)). [Malhotra \(1997\)](#) made emphasis that knowledge management is an embodiment of organizational processes which combined data processing and information processing based on the capacity of human beings. [Bhatt \(1999\)](#) revealed that knowledge management is the compilation of processes such that administrate the knowledge creation, knowledge dissemination and knowledge utilization. [Ababach \(2008\)](#) studied the effect of knowledge management and learning on the level of achieving innovation in organizations. The study revealed that knowledge management and learning has a strong and positive relationship with innovation attained in the organization. [Sujatha \(2007\)](#) investigated the crucial factors that enhance the successful implementation of knowledge management, including the highlight of the impediments that hinder successful management of knowledge. [Prusak \(2001\)](#) made emphasis that the generation and exploitation of knowledge are well appreciated in the knowledge-based economy which enhances wealth creation. [Sireteanu and Grigorula \(2007\)](#); [Murthy \(2005\)](#) noted that the idea of [Prusak](#) is applicable in the university system. [Drucker \(1993\)](#) made emphasis that organizations should be prepared to discard outdated knowledge and they should endeavour to learn and create new knowledge by continuous improvement and perfection of new applications and incessant innovation. [Cooper \(2006\)](#) made emphasis that information era shifts into the knowledge economy, and that knowledge is a critical resource for achieving competitive advantage. [Clark and Turner \(2004\)](#) made emphasis that knowledge management has to turn into the central point for a discussion on methods that enhances greater competitive

edge of an organization in the emerging economy. [Carlsson \(2001\)](#) cleared the definition of knowledge management as the art of identifying and leveraging collective and individual knowledge to support the firm becoming more competitive. The definition of [Carlsson](#) highlighted the fundamental subsystems of knowledge management in the competitive business environment. In the study of [Churchman \(1971\)](#), it was identified that knowledge does not dwell on the anthology of information and the importance of humans in knowledge conception. In the study of [Earl \(2001\)](#), it was highlighted that the concept of knowledge management is derived from intellectual capacity and technological capacity. [Yun \(2004\)](#) noted that the management practices of knowledge represent the notion which denotes techniques, processes, tools and the users' behaviour to which they share and apply knowledge. [Malhotra \(2001\)](#); [Wick \(2000\)](#) identified knowledge management as an exposition which transitioned from the dominant idea of information value chain to the knowledge value chain. Because of the extent and the connected social responsibility, the organizations in the air transport sector aim at delivering superior services to attain a competitive advantage over their competitors. The air transport sector is an example of a knowledge-based sector with service offerings being provided. Nonetheless, the air transport industry is encountering several challenges when dealing with issues relating to the client's demand for swift and quality air services. The empirical review of knowledge management practices implementation may not have been properly explored by Nigerian researchers most especially in the air transport sector. Therefore, this study is carried out to fill the lacuna.

CONCLUSION

From the extensive literature review, knowledge management is a process by which knowledge is identified, captured, codified, stored, disseminated (shared/transferred), implemented (adapted, transformed, synthesised) for the organizational advantage. Knowledge management is an integrated, systematic process for identifying, collecting, storing, retrieving, and transforming information and knowledge assets (intangible assets) into knowledge that is readily accessible to improve the performance of the organization. For effective

management of knowledge in the air transport sector, there are a need to identify people with specific skills, people with supplying and subcontracting and database management abilities. Also, there is a need for transforming tactical knowledge into explicit forms, such as minutes of meetings, database design for project reviews. Furthermore, storage of valuables in electronic form is needed to avoid repetition of mistakes; the need to train new staff and retaining knowledge of old staff before leaving the organisation. Knowledge management is a process that helps organisations identify, select, organise, disseminate and transfer knowledge. The main focus of creating knowledge was related to researching new ideas and products from external sources. This affirmed the significance of research and development (Rand D) in the air transport sector. To achieve a successful implementation of knowledge management within the air transport sector, the components and processes of knowledge management must remain evident. All these will enhance the improvement of productivity, efficiency and the sustainability of businesses encapsulated in the air transport sector, more especially with the present privatization policy whereby there is high competition. This study points out that instead of knowledge management, knowledge administration seems to be more presentable as it encapsulate it encapsulate knowledge identification, knowledge organizing, knowledge creation, knowledge collection, knowledge planning, knowledge distribution, knowledge transfer, knowledge control, knowledge advancement, knowledge utilization, and knowledge maintenance. It involves the posting, deploying, redeploying and transferring of knowledge resources from one section to another in an organization as the manager deems it fit. In the situation whereby an organization does not embark on knowledge management practice, and they planned to expand the scope or dimension of the organization, the expansion will be the sinking sand and the hole where the organization will bury all the knowledge resources and organization will be rendered bankrupt.

AUTHOR CONTRIBUTIONS

A.O. Adeniran performed the manuscript design and prepared the manuscript text. S.O. Olorunfemi performed the literature review and proofread.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript. Also, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

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