International Journal of Scientific & Engineering Research Volume 10, Issue 7, July-2019 1581
ISSN 2229-5518

Land Change Modeler for Characterizing the Spatial Trend of Land Use Land Cover Change: Case study Kilombero District-Tanzania

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ABSTRACT

Investigating the spatial trend of LULC change is vital in taking a broad view about the spatial pattern anthropogenic activities while portraying the hotspots and spatial direction of LULC degradation. Thus, this research study took a broad view about the pattern of LULC change from 1985 to 2018 using classified Landsat image in Kilombero district. The overall objective was to determine the transition of forest and agriculture using Landsat image of in year 1985 to 2018 using LCM of Idris Selva software. The specific objectives were to establish three transitions of forest which are forest to agriculture, impervious and all LULC categories from year 1985 to 2018. While second specific objective was to investigate the transition of agriculture to all LULC categories and impervious land cover from year 1985 to 2018. A pair wise comparison of classified images of year 1985 and 2018 was carried in LCM of Idris Selva software were used for developing the maps of the spatial trend of LULC change for the epoch of 1985 – 2018. The spatial trend of change from agriculture to all LULC categories was more intense in the wards found in the eastern part of Kilombero district with value of 0.22 to 016. While the spatial trend changes of agriculture to impervious in period of 1985- 2018 were more intense with values 0.023 to 0.015 in the North-East of Kilombero district. While the lowest value of 0.000 to -0.017 were recorded in the South-West of Kilombero district. The transitions from forest to impervious were more intense with 0.026 to -0.010 in the direction of East to South-West while the lower values of -0.023 up to -0.046 were observed North-West part of Kilombero district. The spatial trend change forest to and all LULC in period of 1985- 2018 which shows that, the transition from forest to and all LULC were more intense in the South –West towards the East part of Kilombero district. The higher values (0.38– 0.28) were observed at the Masagati, Mlimba and Mchombe wards found in South West of Kilombero district. While the value 0.23—0.01 covered parts of Namwawala, Mbingu, Idete, Lumemo, Kibaoni, Ifakara, Kidatu ward. The research findings have revealed the presence of spatial pattern of LULC change in year 1985 to 2018 in Kilombero district. soilless plant culture, agro forestry farming, Sustainable Land Management (SLM) practices, CSA technology in form of agro forestry farming, restructure the policies, bylaws and regulation on settlement development and climate change are highly recommended.

Key words: trends of LULC; spatial determination of LULC and spatial analysis of LULC

1.0 INTRODUCTION

Land cover is the bio-physical layer covering the Earth surface, while land use represents the human utilization of the land cover (Megahed et al. 2015). Land cover includes Earth's land surface distribution of vegetation, water, desert and ice, as well as the biota, soil, topography etc. in the immediate subsurface, and it also includes human activity areas, such as settlements and mine exposure (Lambin et al. 2003). Whilst land use is attributed to how humans exploit the land cover to serve their own purposes and includes features such as residential zones, agricultural farms, logging areas (Lambin, Geist, and Lepers 2003). Then, LULC dynamics describes the differences in the area occupied by LULC types through time and it's comprised of losses and gains (Behera et al., 2012). Therefore, the term LULC change is used to describe the modification and conversion of major LULC categories over time and entail both natural (e.g. weather, flooding, earthquake etc.) and anthropogenic causes.

Tanzania is not exempted from LULC change following the abundance and rapid expansion of of anthropoid activities particularly at district levels. In Kilombero district more than 80% of the population is involved in agriculture (Sophia and Emmanuel 2017) which is also considered as major source of income and food in Kilombero district. Rapid expansion of agriculture and other anthropogenic activities have resulted change LULC which have resulted to environmental degradation such as the loss of forest and wetland resources in Kilombero district. On the other hand, the reliance of the 80% of the population on forest and wetland resources for construction purpose, charcoal and firewood harvesting also have aggravated the speed of the emerging impacts of LULC dynamics in Kilombero district. Despite of the prevailing situation in Kilombero district, updated information on the spatial trend of change of LULC change are still missing. Conventional methods for understanding the spatial trend of Land Use Land Cover (LULC) change in landscapes dominated by anthropogenic activities are complex and challenging. As results, planners, environmentalist, decision makers, researchers and other stakeholders are challenged in proposing mitigation of the emerging impacts of LULC dynamics.

Alternatively, the Land Change Modeler (LCM) incorporated in Idris Selva software has ability to map the spatial trend of LULC change by pair wise comparison of classified images. The LCM is endeavor to represent the overall distribution of properties throughout space whiles sketching the spatial trend of distribution as a simplified surfaces. A spatial trend surface model relies on the principle of regression function which estimates the property value Pi at any location, based on the Xi,Yi coordinates of this location. Equation **(1)** is the general the function for computing

$Pi = f(xi, yi)$ ……………………………………………………………………Equation 1

Where the Pi=property values at location i; xi, yi=coordinate value at location i and regression. In LCM, the spatial trends of LULC change panel provide ability to map trends with a best fit polynomial trend surface to the pattern of change. Using LCM, to recognize the spatial trend of LULC change in Kilombero district facilitates taking a broad view about the pattern of LULC change while portraying the hotspots and spatial direction of LULC degradation. Hence, this research was conducted to determine the spatial trend of LULC Change in Kilombero district.

2.0 METHODOLOGY

2.1 Description and geographical locations and of study area

Kilombero district is one of five districts in Morogoro region; other districts are Morogoro, Ulanga, Mvomero, Morogoro urban and Kilosa. The district is located between 08° 00′ – 16° South and 36° 04′ - 36° 41′ East with elevation ranging from 262 to about 2111 m (Augustino et al., 2013)(Augustino et al., 2013) and covering an area of about 1,424,000 hectares (Ha).The district is situated in a floodplain of Kilombero river been in the South-East and the Udzungwa-Mountains been in the North-West. Most of the areas of Kilombero district are still predominantly rural with the semi-urban district headquarters Ifakara as major settlement. In the Eastern side it is bordered with Kilosa district while North-East it's bordered with Morogoro rural. In the North and West side the district borders to Mufindi and Njombe districts of Iringa and Njombe region, respectively. While in the South and South-East it shares the border with Songea district of Ruvuma region and Ulanga district, respectively.

In Kilombero district, the rainfall pattern is bi-model rains (usually occur in two seasons) which supports production of several crops including rice, maize, bananas, vegetables and cassava and average annual rainfall is in the region of 1200-1400 mm (Connors, 2015).While the topography is characterized by flat in lowlands clay, loam, sand and some cotton black soil in flooded areas while in uplands topography is undulating hills with red soil (Laswai, 2011). More than 80% of the population is involved in agriculture and agriculture sector considered as major source of income and food in Kilombero district. Besides, in Kilombero district about 80% of the population depends on forest for several products including timber for construction purpose, charcoal and firewood harvesting for domestic and commercial cooking purpose. Other economic activities include bee keeping and fishing which also rely on the availability of health forest and wetlands of Kilombero district.

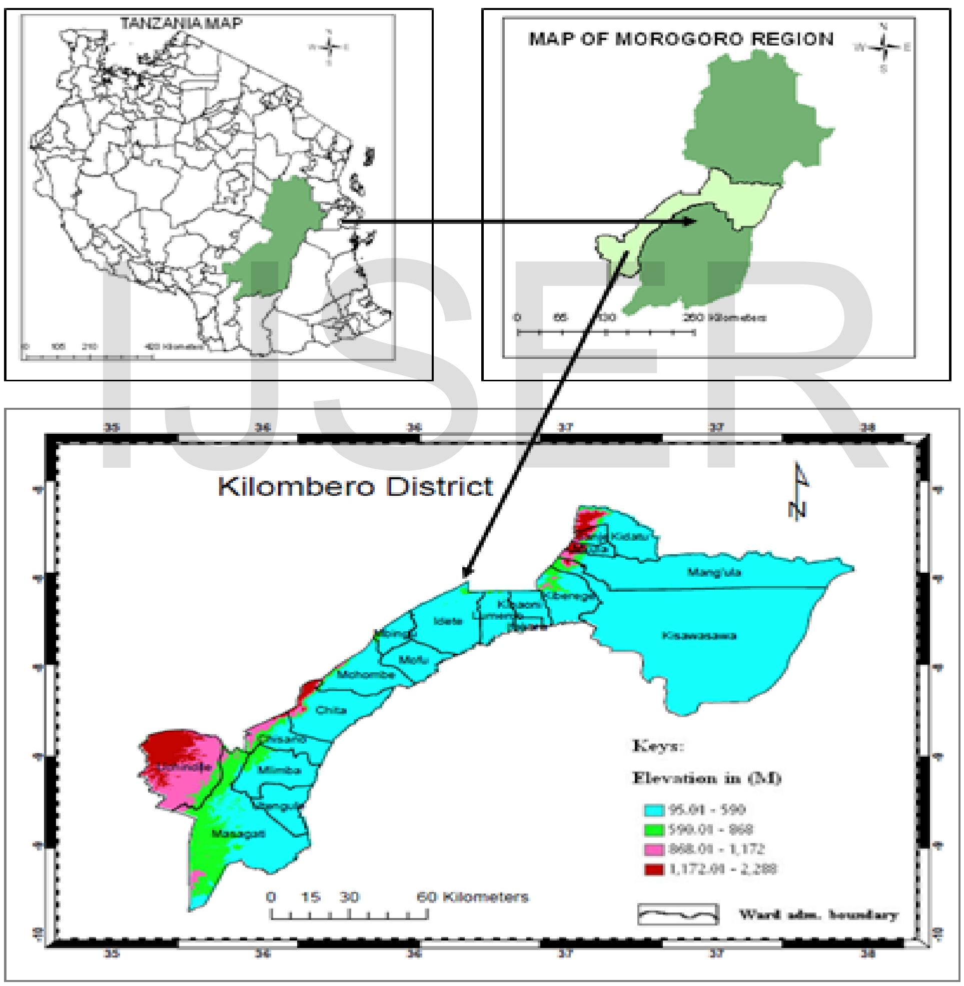

Figure 1: Geographical location of the study area

2.2 Data collection and analysis

Landsat data collection: The Level 1 Terrain (Corrected) Product (L1TP) of Landsat 5 TM of year 1985, 1996, 2007 and 2018 was downloaded from United State Geological Survey (USGS) official web site (http://www.earthexplore.usgs.gov.com). To accommodate the study area three images captured at path and row of 167065, 167066 and 168066, were downloaded. The Landsat data sets were subjected to visual assessment of the percentage cloud cover d and images of cloud cover of less or equal to 20% were found appropriate and were downloaded for the purpose of this research study. Table 1 presents the Landsat dataset collected for this study.

Table 1: Landsat dataset collected for this study

Dataset	Path and row	Date acquired
Landsat 5 TM	P167r65	1985-04-17
	P167r68	1985-06-14
	P168r66	1985-04-17
	P167r65	1996-12-27
Landsat 5 TM	P167r67	1996-12-27
	P168r66	1996-10-15
Landsat 5 TM	P167r65	2007-01-24
	P167r68	2007-01-24
	P168r66	2007-04-05
Landsat 8	P167r65	2018-05-30
	P167r68	2018-05-30
	P168r66	2018-05-30

Source : (United State Geological Survey Website).

Image classification and accuracy assessment: The ERDAS Imagine software was used for classification of Landsat dataset for year 1985, 1996, 2007 and 2018 covering the Kilombero district. Maximum Likelihood Classification (MLC) algorithm was used to develop classified images of year 1985, 1996, 2007 and 2018 using the signature files of Landsat image of year 1985, 1996, 2007 and 2018, respectively. The classified images of year 1985, 1996, 2007 and 2018 were subjected to accuracy assessment using ERDAS Imagine software.

Developing maps of the spatial trend of LULC categories for year 1985 – 2018: The LCM of Idris Selva software was used to create the spatial trend of LULC categories for year 1985 – 2018. A pair wise comparison of classified images of year 1985 and 2018 were used for developing the maps of the spatial trend of LULC change for the epoch of 1985 – 2018. In principle the LCM uses the 3rd order of polynomial to create maps of the spatial trend of LULC change for the epoch of 1985 – 2018. The maps of spatial trend of change of LULC category was used in interpreting complex pattern of landscape change with regard to anthropogenic by human intervention. Hence, maps of spatial trend provided a means of generalizing the pattern of LULC change for the period of study of year 1985 to 2018 in Kilombero district.

3.0 RESULTS AND DISCUSSION

3.1 Spatial trend change from agriculture to all LULC categories in 1985 to 2018

The spatial trend of change of selected LULC categories in this research study provided the scale of LULC change along with the direction. The purpose of the spatial trend of change procedure in this research study was to generate and provide a means of generalizing the pattern of LULC change. Thus, the output of spatial trend was used in identifying the critical zone in Kilombero district where the LULC changes have occurred mostly during the study period of year of 1985 to 2018.

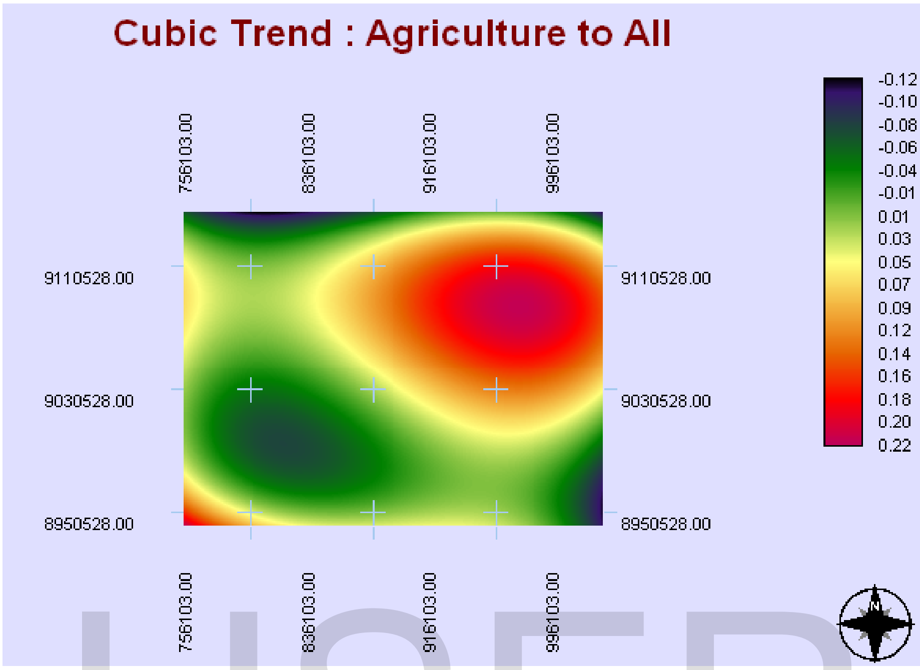

Figure 2: Spatial trend change of agriculture to all LULC categories in 1985- 2018

Using Figure 2, the spatial trend of change from agriculture to all LULC categories was more intense in the wards found in the eastern part of Kilombero district with value of 0.22 to 016. Thus, Kidatu, Sanje, Kisawasawa and Mang'ula wards found in the eastern part of the district have experienced intensive conversion of agricultural lands into other LULC categories. While the wards in the South West of the district have experience have experience little conversion of agricultural lands into other LULC categories with values of 0.05 to -01.2. Thus, the Masagati, Mchombe and Mlimba wards have experienced intensive conversion of agricultural lands into other LULC categories. In the wards found in the Eastern part of Kilombero district, creating awareness and promoting soilless plant culture reduce competition of agricultural lands. Soil less plant culture is a method of growing plants without soil. The application of soilless plant culture is highly recommended due to rapid urbanization, industrialization and in addressing the environmental threats imposed by climate change and its related adverse effect. The soilless plant culture production system helps in facing the challenges of climate change and efficient utilization of natural resources and mitigating malnutrition.

3.2 The spatial trend change of agriculture to impervious in period of 1985- 2018

Figure 14 presents the spatial trend change of agriculture to impervious in period of 1985- 2018 which shows that, the transition from agricultural lands to impervious were more intense with values 0.023 to 0.015 in the North-East of Kilombero district. While the lowest value of 0.000 to -0.017 were recorded in the South-West of Kilombero district.

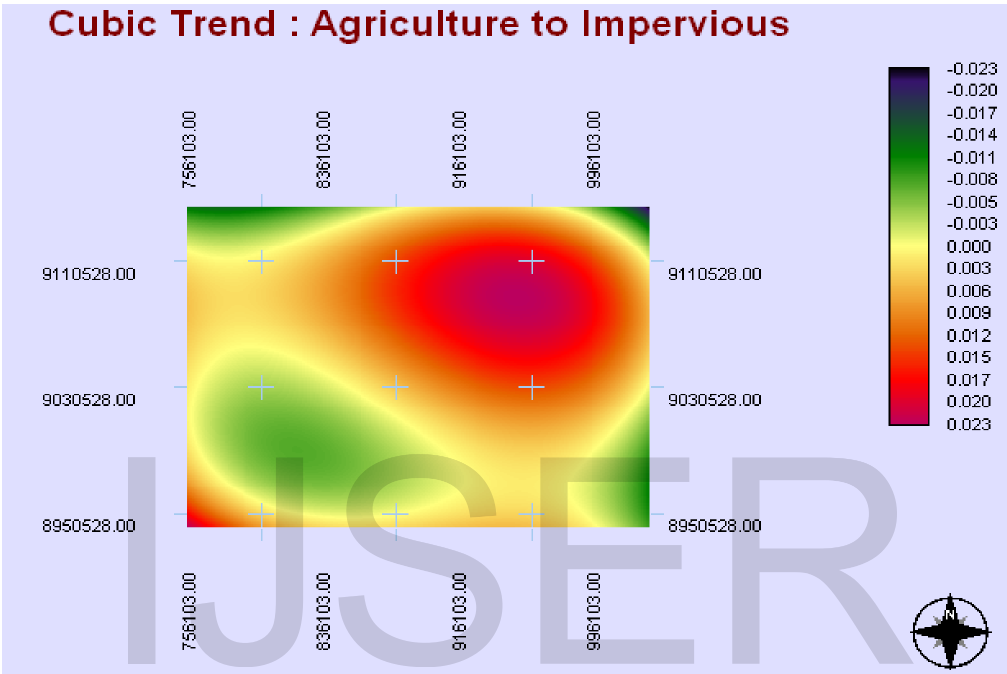

Figure 3: Spatial trend change of agriculture to impervious in period of 1985- 2018

The environmental impacts associated with transition of agricultural areas to impervious class include land degradation, pollution, uncontrolled urban growth and fluctuations of hydrological). In attempt to balance the land development in Kilombero district, there is need to restructure the policies, bylaws and regulation on settlement development, urbanization and climate change.supply downstream (Sophia & Emmanuel, 2017).

3.3 Spatial trend change of forest to impervious in year 1985 to 2018

The transitions from forest to impervious were more intense with 0.026 to -0.010 in the direction of East to South-West while the lower values of -0.023 up to -0.046 were observed North-West part of Kilombero district. Figure 15 presents the spatial trend change of forest to impervious in period of 1985-2018. The transitions from forest to impervious were more intense with 0.026 to -0.010 in the direction of East to South-West while the lower values of -0.023 up to -0.046 were observed North-West part of Kilombero district. The environmental implication of such LULC dynamics will include increase in surface temperature, soil erosion and sediments, rainfall and ground water level change in Kilombero district.

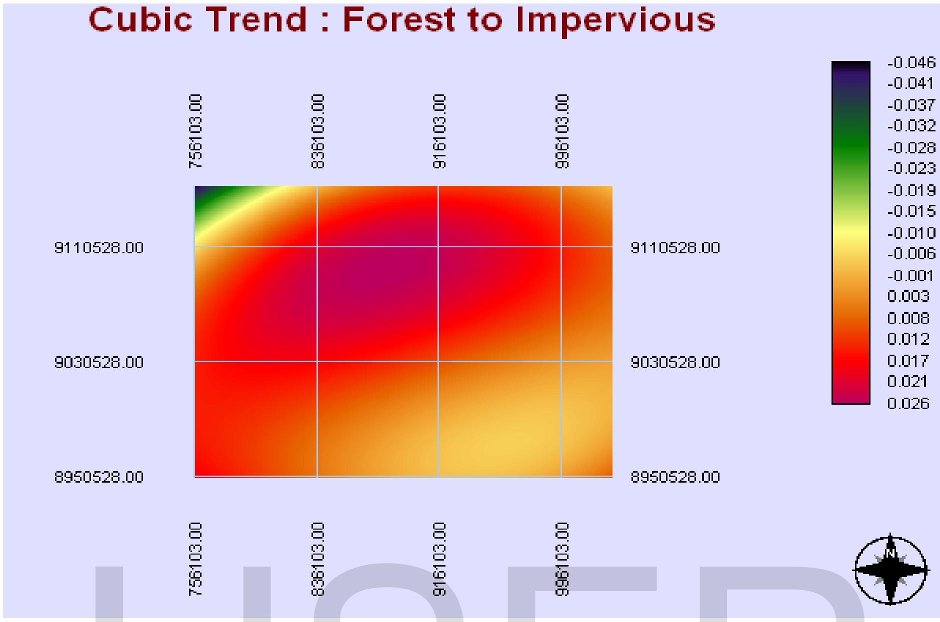

Figure 4: Spatial trend change of forest to impervious in year 1985 to 2018

In attempt to restoring the environmental systems while enhancing food diversity, nutrition and security in Kilombero district, campaigning for promotion Climate Smart Agriculture (CSA) and Sustainable Land Management (SLM) practices are required in Kilombero district.

3.4 The spatial trend change of forest to agriculture in year 1985 - 2018

Figure 16 presents the spatial trend change from forest to agriculture in period of 1985- 2018. The transition of forest to agriculture was more intense in wards located in the South-West with values of 0.17 to 0.01. The low value of -0.01 to -0.20 were recorded in the North-West and South-East in which the land is under protection as reserved lands. In the North- East towards the South-West the transition from forest to agriculture was moderate with values of 0.07 to -0.040. In the wards located in the South-West of Kilombero district, the conversion of forest to agriculture will have environmental implication in form increased pollution due to heavy application of inorganic fertilizers, herbicides and insecticides for pest control. Such impacts of agriculture will the consequences on aquatic ecosystems water quality and aquatic food web structure (Tilman, 1999). On the other hand, flooded agricultural farms creates anaerobic conditions a few millimeters beneath the soil surface and leads to the production of methane (CH4), a major greenhouse gas (Roger & Joulian, 1997).

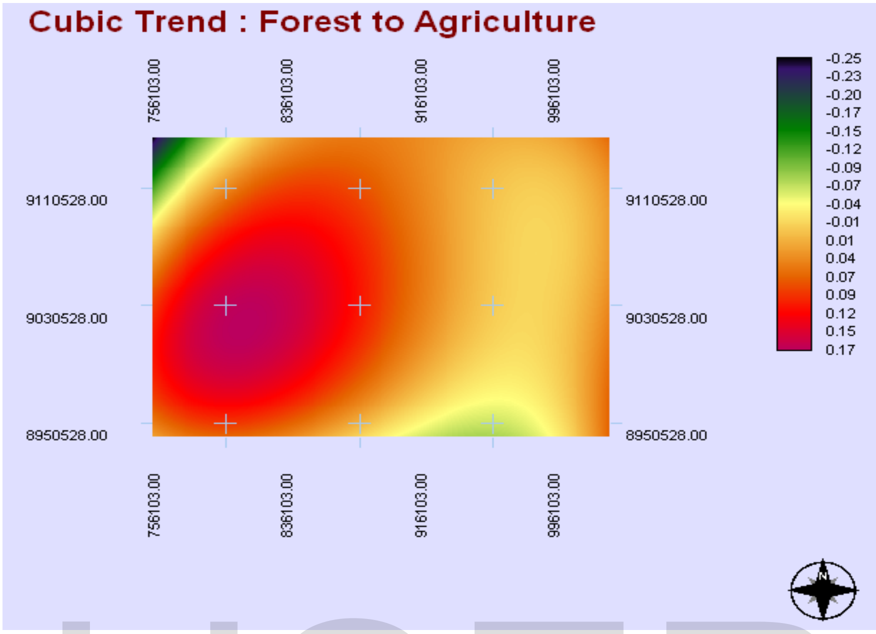

Figure 5: Spatial trend change of forest to agriculture in year 1985 to 2018

Besides, the expansion of flooded rice farms in the wards located in South-West also favors the propagation of aquatic invertebrates that are vectors of human and animal diseases, mostly mosquitoes and snails which are important vector-borne diseases for malaria, and schistosomiasis (Roger & Joulian, 1997). In attempt to restoring the environmental systems while enhancing food diversity, nutrition and security, creating awareness, campaigning for promotion Climate Smart Agriculture (CSA) and Sustainable Land Management (SLM) practices are required in Kilombero district.

The transition of forest to agriculture was more intense in wards located in the South-West with values of 0.17 to 0.01. The low value of -0.01 to -0.20 were recorded in the North-West and South-East in which the land is under protection as reserved lands.

3.5 Spatial trend change of forest to and all LULC categories for year 1985 to 2018

Figure 17 presents the spatial trend change forest to and all LULC in period of 1985- 2018 which shows that, the transition from forest to and all LULC were more intense in the South –West towards the East part of Kilombero district. The higher values (0.38– 0.28) were observed at the Masagati, Mlimba and Mchombe wards found in South West of Kilombero district. While the value 0.23—0.01 covered parts of Namwawala, Mbingu, Idete, Lumemo, Kibaoni, Ifakara, Kidatu ward. In the reserved mountains and forest were found to have the values of -0.5 to 0.39. Thus, deforestation has occurred from the South-West towards the North-East of Kilombero district. The consequences following this deforestation will include disturbances in forest hydrological cycle, erosion and sediment yield and forest nutrient cycle. In the context of forest hydrological cycle, the evergreen broadleaved forest serves as roof for preserving the soil structure during rain seasons (Bruijnzeell, 1996). Thus, the deforestation has resulted into changes in soil infiltration and water holding capacity in Kilombero district. Such changes in soil properties also will speed up the rate of soil erosion, as reported by Flinn et al., (2005) disturbed forest usually has high erosion rates than undisturbed or natural forest. Deforestation also interrupts the soil nutrient cycles as undisturbed forest produces biomass containing the nutrient taken by forest system (mainly in rain, dust and aerosols). Forest clearing in Kilombero district will have adverse effect on soil nutrient cycle of Kilombero district. On the other hand, larger amounts of greenhouse gases will be entering the atmosphere of Kilombero district as forest play a critical role in absorbing the greenhouse gases which is fuel global warming. Promoting Smart Climate Agriculture (CSA) technologies and Sustainable Land Management (SLM) practices in the district are the best approach for addressing the observed deforestation. CSA technology in form of agro forestry farming is one of viable approach for ecological restoration of forest in Kilombero district.

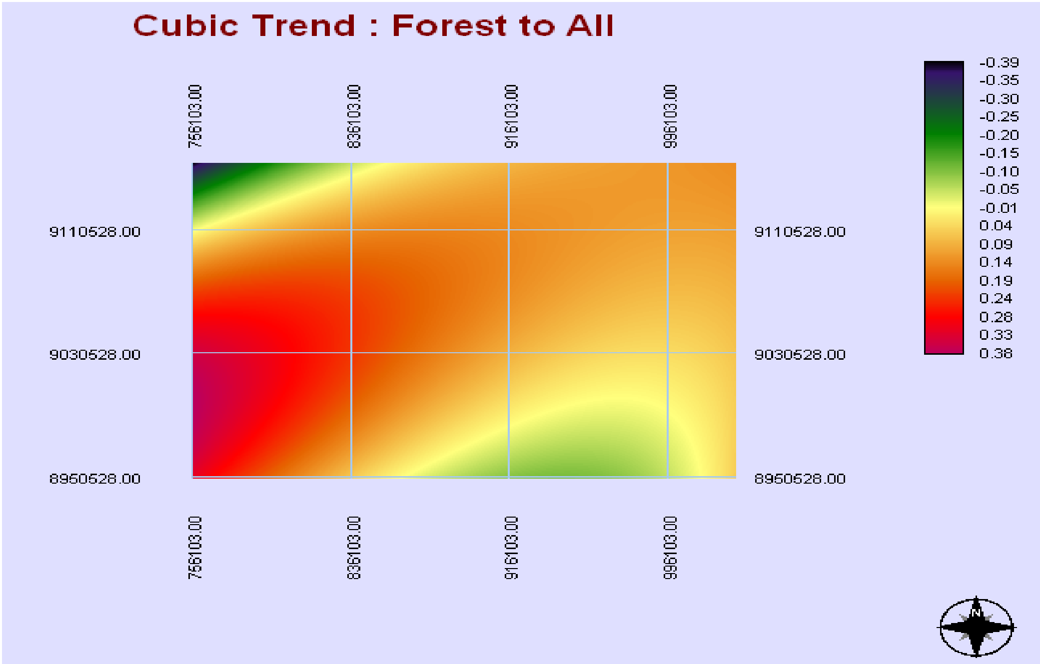

Figure 6: Spatial trend change of forest to all LULC categories in year 1985 to 2018

Agro forestry practices are intentional combinations of trees with crops and/or livestock which involve intensive management of the interactions between the components as an integrated agro-ecosystem. These four key characteristics - intentional, intensive, interactive and integrated - are the essence of agro-forestry and are what distinguish it from other farming or forestry practices.

4.0 CONCLUSION AND RECOMMENDATION

4.1 CONCLUSION

The research findings have revealed the presence of spatial pattern of LULC change in year 1985 to 2018 in Kilombero district. The transition of forest to agriculture, impervious and all LULC categories were mapped. The transition of forest to agriculture was more intense with values of 0.17 to 0.01 in wards located in the South-West while low value of -0.01 to -0.20 were recorded in the North-West and South-East in which the land is under protection as reserved lands. The transitions from forest to impervious were more intense with 0.026 to -0.010 in the East to South-West while the lower values of -0.023 up to -0.046 were observed North-West part of Kilombero district. The transition from forest to and all LULC were more intense with values (0.38– 0.28) in the South –West towards the East part while the value 0.23—0.01 were recorded in the wards located in central zone of Kilombero district. The transitions from agricultural lands to impervious were more intense with values 0.023 to 0.015 in the North-East of Kilombero district. While the lowest value of 0.000 to -0.017 were recorded in the South-West of Kilombero district. The spatial trend of change from agriculture to all LULC categories was more intense in the wards found in the eastern part of Kilombero district with value of 0.22 to 016. While the wards in the South West of the district have experience have experience little conversion of agricultural lands into other LULC categories with values of 0.05 to -01.2.

4.2 RECOMMENDATION

- The promotion of soilless plant culture is highly recommended to reverse the heavy land degradation for land following expansion of agriculture in Kilombero district. Besides, the soilless plant culture production system helps in facing the challenges of climate change and efficient utilization of natural resources and mitigating malnutrition.

- In attempt to balance the land development in Kilombero district, there is need to restructure the policies, bylaws and regulation on settlement development, urbanization and climate change.
- In attempt to restoring the environmental systems while enhancing food diversity, nutrition and security in Kilombero district, campaigning for promotion Climate Smart Agriculture (CSA) and Sustainable Land Management (SLM) practices are required in Kilombero district. CSA technology in form of agro forestry farming is one of viable approach for ecological restoration of forest in Kilombero district.

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