DYNAMICS OF SPATIAL INTERACTION AND SOCIO-ECONOMIC TRANSFORMATIONS AROUND CHUKA UNIVERSITY MAIN CAMPUS BASED ON REMOTE SENSING AND GIS TECHNIQUES

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ABSTRACT
Universities are physical entities exemplifying complex human-land interaction and diverse processes. Their expansion into towns and rural areas drives urbanization, social transformations and economic development. However, with widespread human activities, surrounding ecological conditions change. The present study analyzed the implications of the changing landscape and land use/land cover around Chuka University from 2003 to 2013. Land Use and Land Cover (LULC) change was identified as a key factor driving transformations. The study used GIS and remote sensing to evaluate the dynamics of interactions which have produced the present and historical scenarios. Remote sensing provided multi-temporal data on the patterns and processes of human activities, while GIS mapped and analyzed LULC changes. Results revealed increasing growth of built-up areas, decreasing land under vegetation cover, open spaces and increase in peri-urban agriculture. Ndagani is an upcoming peri-urban center, undergoing rapid growth and expansion through physical factors, demographic changes, land subdivision and sale, accessibility and proximity to motorized roads. The rate of socio-economic transformation taking place in this area could be assessed more effectively if Public Participatory GIS (PPGIS) and biophysical factors were integrated to enhance holistic understanding and decision making for monitoring current changes and forecasting future sustainable development, information exchange and spatial interactions.
Keywords: PPGIS, spatial interactions, LULC, Remote Sensing, GIS

INTRODUCTION
Institutions of higher learning as they establish campuses in towns and rural areas are driving urbanisation and urban growth in Kenya. Urbanization and urban growth is considered an essential indicator of economic growth and development (Sharma and Joshi, 2013).Through attracting human population, infrastructural

development and economic activities in the concerned areas, universities are promoting urban expansion. Urbanisation has brought significant changes in landscape patterns and land cover around the concerned areas. Changes occurring in these universities are a starting point for large scale urbanisation processes within the adjoining areas. It has been acknowledged widely that urbanisation is a widespread anthropogenic cause of landscape change (Lopez, Bocco, Mendoza, and Duhau, 2001). Decentralization of higher education into counties is attracting unprecedented urbanisation which is leaving a trail of notable effects on both natural and human ecosystems (Turner, 1994).). In case of land use patterns around universities, loss of natural vegetation and arable land is becoming more pronounced. For instance, rapid urbanization has resulted to the transformation of rural areas into developed areas, with estimated more than 809 km^2 of agricultural land being converted to cities, roads and infrastructure annually (Barnsley and Barr, 1996). In Kenya, Universities are burgeoning urban centers with human activities strongly driving the dynamics of the ecological conditions around these micro-urban environments (Yeh and Li, 1999). Land use and cover(LULC) changes associated with human activities are more prevalent in developing countries than in the developed world(World Bank, 2007).This is attributed to increasing population witnessed in the developing urban centers (Holdgate,1993). Ndagani is not an exceptional market being close to chuka university main campus, which is an upcoming commercial and residential hub of Chuka town. The ongoing and current studies on LULC are directed towards monitoring land use and land cover change in urban environments (Stow and Chen, 2002). However, these studies do not consider the contributions of higher learning institutions in the process of urbanisation and urban growth especially at a location-specific scale. The study will analyse spatial and temporal LULC patterns as key driving forces behind the changing spatial interactions and socio-economic transformations around Chuka University. Understanding the factors driving these changes is essential for policy planning and effective management of physical, educational and social facilities within these institutions. For development of effective policies governing the holistic life of students, place-based assessments and experiential knowledge will provide university administration and decision-makers with geographic data important for rational planning and decision making(Brown, 2012; Hall, Moore, Knight, and Hankey,2009;Kahila and Kyttä,2009).

Geographic Information is a specialised kind of information which provide spatial understanding of facts, dynamics, connections and interdependencies of individuals (Pfeiffer, Baud, Denis, and Sydenstricker-Neto, 2010; Yeager and Steiger, 2013). The multiple and diverse geo-information needed to understand the dynamics of man-environment interactions within a University set up, require a tool for understanding geography and help make informed decision through spatial visualization and analysis. GIS is chosen as a technological tool with ability to map, explore and as an integrating technology which can leverage geographic and non-spatial databases for effective decision-making. Public Participatory GIS (PPGIS) has been used in the acquisition of more informative base maps resulting to increased involvement of local communities in the planning process (Dunn, 2007; Gonzalez, 2002; Van Herzele, 2004). Ndagani market, particularly Chuka University has registered enormous structural and infrastructural developments in the recent years resulting to increased built up areas, localized rural-urban migrations and modifications of the existing areal geomorphology. The on going process of urbanisation has brought observable changes in population distribution, socio-economic life, landscape and land cover patterns. Limited literature exists about the dynamics of LULC changes that have shaped the genesis, growth and expansion of the current Main campus of Chuka University especially on a spatial and temporal dimension. This is attributed to lack of geospatial data or access to update quantitative information on existing land use patterns in Ndagani location. The existing land use patterns within Chuka municipality are based on the proposed master plan which is largely developed from census records and ground observations. It is against this background the empirical study sets out to understand the dynamic interactions between different aspects of the historical and the current built-up area and social spaces which are perceived to be expanding within rapidly.

The objective of this study was to analyse LULC change as a key force driving the current expanding urban space and social identity within Chuka University by use of remotely sensed data and Geographic Information Systems (GIS). Specifically, the objectives of the study were three fold: (1) Evaluate the LULC

changes around the Main campus for the period from 2003 to 2013; (2) Explore the types and number of social spaces and how they have transformed within these ten years period; (3) Analyze factors causing the current expansion of the University neighbourhood. Geographic Information Systems (GIS) and Remote Sensing (RS) were chosen because they are powerful geospatial tools to use for assessing the spatial and temporal dynamics of LULC changes (Hathout, 2002; Mundia and Aniya, 2005; Lambin et al., 2003; Serra et al., 2008)

Study Area

Chuka university is located approximately $0^0 19' 13''$ S and $37^0 39' 30''$ E and on an altitude of about 1400m. The area has volcanic foot ridge fertile soils with annual rainfall of between 1250-1500mm and temperature ranges of between 20.6^0c to 18.2^0c on average (Jaetzold.R et al., 2006). This area has potential for coffee, tea, horticulture and dairy farming. Ndagani is one of the fast growing part of chuka town ship given the high rate of infrastructural developments, land use and land cover changes and population increase. Chuka University is the ninth chartered public university in Kenya, the first university in Eastern province only starting as a campus, later a university college and then full pledged university (http://www.cu.ac.ke). It is the only institution of higher learning in Tharaka-Nithi County. The Chuka University is projected to be fast expanding in terms of infrastructure, spatial coverage and population. Because of its existence and proximity to chuka town, the demography, land use, economy and infrastructure of this area are transforming into a true cosmopolitan urban set up. For example the ongoing upgrading of roads in Chuka town, increasing construction activities, entry of local supermarkets and growing urban population have force the county planning office to develop a new master plan for the expanding township (Figure 1).

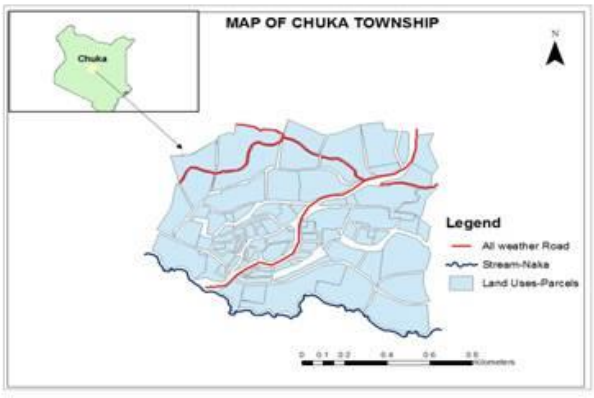

Figure 1: Proposed new township boundary
(Source: Chuka town Master Plan 2013; Digitization by the Author)

MATERIALS AND METHODS

Satellite images used in this study were acquired from Google Earth for the years 2003 and 2013 respectively. Year 2003 was chosen because the university was not established yet but existing on the area was the then Ndagani Youth Polytechnic on the northwestern edge (Fig. 2). The year 2013 present a period of successive historical transformations from a campus, University College and then a full- pledged University (fig.3). The 10 year period (2003-2013) represent a decade of both spatial and temporal LULC changes in the study area. Images for the months of February (2003) and September (2013) were used because they had no cloud cover. Google Earth uses Geo-Eye satellites which collect relatively moderate resolution images and that such images can be zoomed, panned and saved at any resolution makes then preferred in this case. Google Earth produces true colour composite images therefore reducing the need to create a composite image from individual bands as is the case with other satellite images. The area of interest was subsetted from the whole image using ENVI 4.8 Software to come up with the study area (Figures 2 and 3).

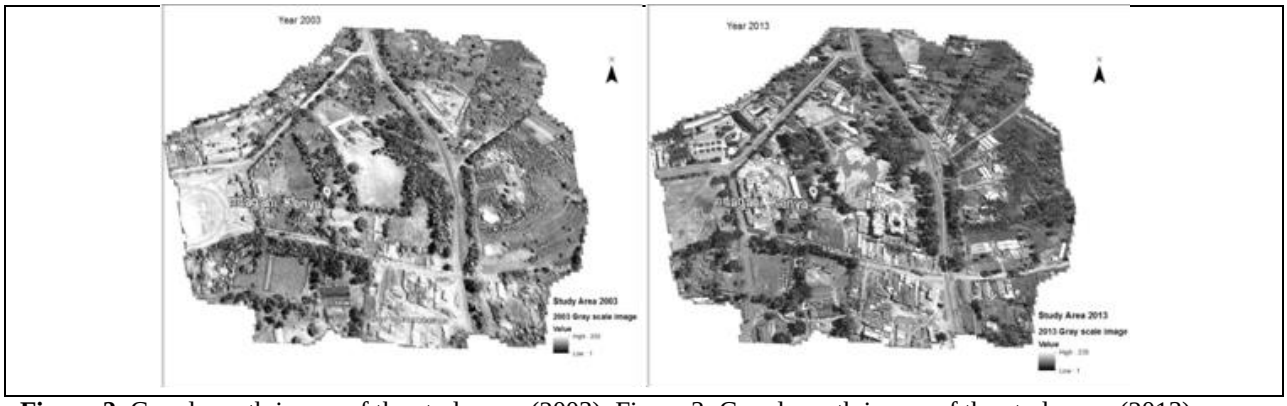

Figure 2: Google earth image of the study area (2003). Figure 3: Google earth image of the study area (2013)

Geometric correction was then carried out on the two multi temporal images (2003 and 2013) using a geo-referenced land sat TM image of year 2000. Six Ground control points evenly distributed were used to register the year 2003 and 2013 images to WGS_1984_UTM_Zone 37S. Nearest neighbour resampling (NNR) method was used to resample the images to the 30m pixel output in order to match that of land sat TM reference image. Nearest neigbour resample was used because the Pixel's Digital Numbers (DNs) were integers associated with the reflectance values of the ground features (Land cover). A polynomial surface was computed using a linear mapping function based on the 6 control points (Table 1)

Table 1: Linear polynomial function used for geometric correction (image resampling)

Coefficient	X	Y
b0	-94.9538292524142089	-17.7236138707425224
b1	1.0559069952396529	0.0315823783732287
b2	0.1892297283571491	1.0051606438088057

Extensive field work was carried out in the study area on early February and mid September 2013 to collect ground truthing information and identify the existing land cover features. This information was used to select training areas for the supervised classification. On screen digitization of the sample land cover training sites was done in IDRISI Kilimanjaro where five classes were developed based on collected field information and Anderson Classification system (Anderson et al, 1976). The five land use and land cover class types were: Built Up areas, Agriculture and Fallow, Wood lot and Vegetation, Open land, Roads and pavement. The training samples comprised of more than eighty sites with pixels ranging between 41614 and 294744 for all the five classes. These pixels were used in the development of spectral signatures for statistical characterization of the five information land cover classes. The resulting signature file was used to train each image where Minimum Distance classifier for supervised classification was applied to each image to come up with land cover map for year 2003 and 2013(Figures 4 and5). Signature development and classification was done in IDRISI Kilimanjaro Software.

For assessing the accuracy of the generated LULC change maps, a set of sites to be visited for verification of the existing land cover types during ground truthing were produced from stratified random sampling using SAMPLE module in IDRISI. Fifteen sample locations were used for verifying the land cover features from the fifty generated ones. The fifteen sample locations (n) were gotten using the algorithm proposed by Ronald. J.E, 2003; $n=z^2pq/e^2$. Where: n is the size of sample to use in accuracy assessment. *z* is the level of confidence. *e* is the desired confidence interval.

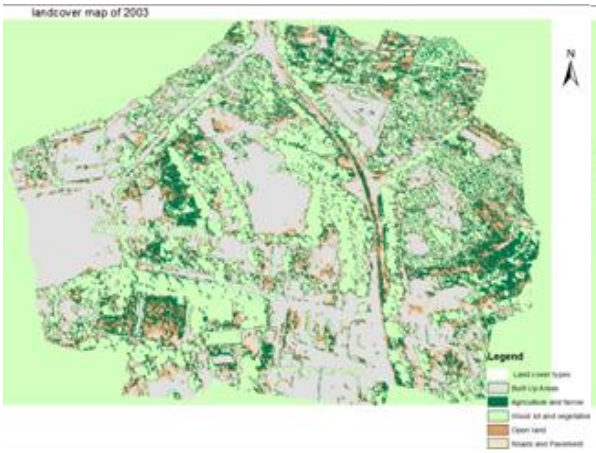

Figure 4: Land cover map of 2003

Figure 5: Land cover map of 2013

p is the estimated proportional error and *q*=1–p. After carrying out accuracy assessment, overall accuracies of 65%, 61% with corresponding Kappa index of 0.180 and 0.24 for the two land cover maps of 2003 and 2013 were gotten .The low accuracies could be attributed to the large number of mixed pixels and the low resolution of the images used in this study (Haack, 1987; Yang and Lo, 2002; Dewan, A.M. and Yamaguchi.Y, 2009). Finally post classification change detection analysis was done to understand where the change occurred, what changed and how much change occurred. Post classification technique of change detection analysis was used because it has been widely applied in LULC change studies (Dewan, A.M. and Yamaguchi.Y, 2009; Hardin et al., 2007). Image differencing was used to obtain spatial changes that occurred within the period of the ten years (2003-2013) being evaluated. To determine the change, cross tabulation was done and a map showing the conversions 'from which' land use/cover 'to which' was produced in ARCGIS 10.1 as shown in figure 6.

FINDINGS AND DISCUSSION

Land Use and Land Cover change for the period from 2003 to 2013

In the year 2003 the dominant land uses in Ndagani area were agriculture and fallow, woodlot and vegetation as well as open land (Fig. 2). Built up areas included Ndagani market, St. Lucie hospital, Ndagani secondary school, Ndagani youth poly technique and Ndagani primary school. Open and bare lands were prevalent in the area due to low population and limited commercial activities. Historical records from the district lands office show that land sale was not so prevalent and as a result subdivision was minimal which explains the rural agricultural lifestyles common in this area at the time. The conversion of Ndagani Polytechnique to Egerton University Eastern Campus in 2004, later to a University College in 2007 and then elevation to a full University in 2013 introduced major changes in the patterns of Land Use and Land Cover in Ndagani Area. The rate of urbanisation increased as the university began infrastructural developments, increasing students enrollments and recruiting more staff. Fieldwork study observed that the area under cultivation began declining as the demand for housing, residential plots and land speculation pushed the land prices high. Many households within the periphery areas of the university sold their land or converted their homes into hostels and residential while others developed their properties.

Analysis of the LULC change around Chuka University Main Campus at Ndagani using GIS indicate that open and bare land decreased by 9.4%, Agriculture and Fallow increased by 2.3%, Woodlot and vegetation areas decreased by 7.6% while built up areas increased by 6.6% and the area under roads and pavement increased by about 8% as shown in table 2.

Table 2: Land use/cover types, area for each class, changed areas for images of 2003, 2013, 2003-2013

Land use/cover class	Area (ha) 2003	%	Area (ha) 2013	%	Area changed (ha) 2003-2013
Open and Bare land	17.03	26.3	12.73	16.9	-4.25
Agriculture and Fallow	10.07	15.6	13.57	17.9	+3.50
Wood lot and Vegetation	34.15	52.7	34.09	45.1	-0.06
Built Up areas	0.86	1.3	6.01	7.9	+5.15
Roads and Pavement	2.63	4.1	9.18	12.1	+6.55

Increase in land under agriculture and fallow, built up areas, roads and pavement is an indication of new urbanisation trend in the study area and attributed to increase in population and economic activities (Li, Sato, and Zhu, 2003). Establishment of Chuka University at Ndagani has promoted notable infrastructural developments such as roads, hotels, hostels, residential as well as commercial buildings. All these have contributed to the current rate of geomorphic changes, urban growth and land conversion being witnessed in the area (Fig. 6)

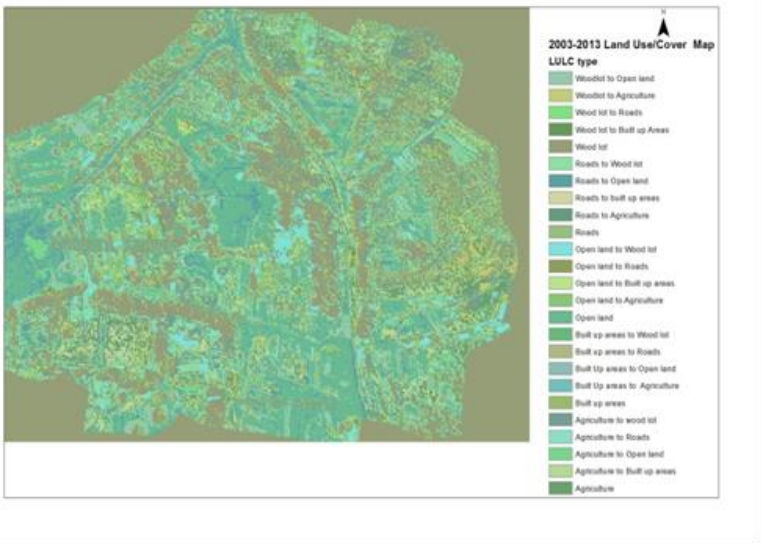

Figure 6: Land use/cover changes that occurred from between 2003 to 2013

Types, number, transformations and the influence of Social Spaces on spatial-interactions

Social space in this study is taken to be all places where students, staff and public interact often. Such include; General shops, Salons and barber shops, play grounds, churches, health centers, clubs, Schools, banks and hotels. Important spatial characteristics of these social spaces considered in this study are nature of such entities, their location and the number of hours they operate. These factors are seen as instrumental in dictating the level of man-land interactions taking place. Information collected from goggle map analysis and field visits indicate that the number of such facilities have increased and expanded within Ndagani market, along Meru-Nairobi highway, roads leading to the university and within hostels and residential areas. The major types of the shared social places common in the area are churches (P.C.E.A, S.D.A, A.C.K and others), Hotels and lodges (Muringa inn, Grand Hill and other small ones), Health care centers (St. Lucie, University dispensary, Mutethia clinic, Nithi chemist and others), Salons and barber ships as well as butcheries. Most of these facilities are newly developed with land converted from previously Open lands and woodlots. The built up areas (5.15 ha) and roads (6.55 ha) increased during 2003 to 2013 period due to proximity to the campus, highway and availability of affordable land.

The field study observed that most social spaces except churches operated on daily and routine basis with long business hours extending into late night. The intensity of their activities depended on the number of people visiting them and the competitors within their service area. Interesting to note was how the Ndagani

taxi business has expanded in the same period with proliferation of more cars accelerating movement and spatial interaction within ndagani and other areas. The type and number of social spaces are not uniformly spread throughout the study area but more interactions have been observed in and around the campus compared to other regions due to the concentration of core activities here. Neighbourhood schools (Ndagani Secondary school, Ndagani primary, Njeru junior school and Tumaini academy) have transformed the social perspective of the area as the University students, staff and the community interact either as teachers, parents or workers.

Nature of the expanding University neighbourhood and causing factors

The rate of expansion and growth has not occurred uniformly in this area due to different land ownership types and uses. From close examination of field study statistics, it is clear that the primary driving factors behind the current urban growth and expansion are physical factors (low and flat terrain), Transport routes (good road network), demographic change as well as booming economic activities (Table 3).

Table 3: Nature of LULC change and the driving factors

Major land use/cover type	Nature of change	Driving factors
Open and bare land	Decrease	Physical factors, population growth
Agriculture and fallow	Increase	Land sale, more peri-urban farming activities
Wood lot and vegetation	Decrease	Construction activities, creation of roads
Built up areas	Increase	Economic activities, topography, population growth
Roads and pavement	Increase	Land subdivision, human activities, topography

The eastward and westward expansion of built up areas, peri-urban agriculture, roads and pavements are propelled by low elevation topography and availability of more land. The southern area is sloppy and hilly which explains the minimal built up environment while the terrain in the northern part is flat; expansion has been hampered by agricultural rural land uses. New developments are taking place along roads connecting university to the highway, on the periphery of the university, within and around ndagani market. Population growth has been brought about by the increasing student enrollments, staff recruitments and rural-urban migrations pushed by the construction and economic activities around the university and the nearby market.

CONCLUSIONS

The study revealed rising land use and land cover conversions resulting to the current expansion of the built-up areas and increase in peri-urban agriculture. Establishment of road networks in the area has promoted new developments and growth of more economic activities especially around Ndagani market, along and within the periphery of the University. The on-going urbanisation and expansion is attributed to population growth, low elevation landscape, accessibility and proximity to roads as well as the increasing economic development activities. Expansion and growth in this area show clear spatial and temporal differences in the direction of growth, types and number of social spaces, their locations and operating hours. Spatial interactions have driven the current developments with frequency of these interactions dependent on distance covered, costs associated with movements and availability of attractions. Chuka University and the nearby market have more interactions and large number of social spaces compared to the hinterlands. They form the main attractions. The current rate of development could be assessed effectively if Remote sensing-GIS techniques and socio-economic variables were integrated in the preparation and revision of the township master plan. Public Participatory GIS provides a platform where stakeholders and the public can share geographic data and experiential knowledge. This will assist monitor the rate of physical, environmental and social transformation taking place around Ndagani and Chuka town. This will improve physical planning, enhance decision making and help in forecasting areas of future growth to target new development. For a sustainable future we need increased interactions, sharing and utilization of geographic information for analysis and modeling of present problems.

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