COULD LOCAL PERCEPTIONS OF WATER STRESS BE EXPLAINED BY LULCC?

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ABSTRACT

Mapping land use/land cover changes (LULCC) is essen al for a wide range land use planning and adapta on mechanisms to global warming/climate change, impacts of natural hazard and socio-economic dynamics on the local to global scales. In this study, we seek to inves gate whether water stress in the induced savanna of Southwestern, Nigeria as perceived by the various communi es can be explained by LULC changes in the region. LULCC was conducted using orthorec ed Landsat mul -temporal imageries for 1970/1972, 1986/1987, 2000/2001 and 2006 using maximum likelihood classi ca on and change detec on techniques in ENVI 4.4 so ware. The results showed a decrease in the forest area and an increase in built-up and cul va on/others (open space, bare land, grassland etc.) areas. Between 1972 and 2006, forest had reduced by about 50% while built-up almost increased by about 300% of its size in 34years ago. Forest loss was found to be higher in the Northeast part of forest – savanna fringe and in areas where built-up used to be sparse in the past. The matrix analysis of change detec on between 1972 and 1987, 1987 and 2002, and between 2002 and 2006 depicted -20,963.53km^2 (48.96%), -4,551.08km^2 (20.82%), and -1,156.33km^2 (6.68%) image di erence in forest landcover with almost 60% loss to cul va on/others class. Notably, however, in areas where forest lost prevailed, increased fetch to the storage water (surface earth dams). Between 1987 and 2006, ve dams were constructed in the area which is suspected to have reduced rivers and streams input to the area. *Ab ini o,* the communities' perception generated from social survey indicate that changes in clima c condi on e.g. decreasing rainfall, con nuous forest degenera on in the last 30years, and diversion of rivers and streams into surface storages (earth dams and reservoirs) are the major factors responsible for water stress and scarcity in most rural communi es in the region. In conclusion, this study provides an opportunity to be er understand the usefulness of LULCC in explaining local percep on to water stress and the expected implica ons.

INTRODUCTION

Recent works suggest that the environmental changes over the last several centuries are evidence from signi cant popula on increase, intensi ed migra on, urbaniza on, deforesta on, overgrazing, irriga ons, damming rivers to create man-made lakes and reservoirs, land- lling of swamps and marshlands, as well as accelerated socio-economic ac vi es (Lim *et al.,* 2005; Hale *et al.,* 2008; Jiunn-Der *et al.,* 2008; Stone, 2009; Mahmood *et al.,* 2010). These ac vi es not only a ect the climate and landscape processes on scales ranging from the micro-scale to the macro-scale but could as well intensify water shortage/stress (Davey and Pielke, 2005). LULCC studies also provide valuable informa on for large-scale vegeta on biomass and forest cover assessments that are key components to not only the carbon cycle but also water balance (Pielke *et al.,* 2002).

It is not erroneous to a rm that LULCC is linked to climate and ecosystems pathways in complex ways. For instance, causes of forest degenera on in tropical regions of the world has been linked mainly with LULCC and climate change. This is coupled with growing demand for food due to popula on growth and changing consump on pa erns in emerging economies as well as increased use of biomass for bioenergy. Strategies to prevent the loss of forests have failed mostly as a result, its degrada on con nuing not only at regional scales but globally. Forests provide a range of ecosystem services (e.g. conserving watershed) but virtually underes mated. The services can be essen al for sustainable adapta on mechanisms to climate change and water stress e ects via proper forest management (Pielke and Avissar, 1990; Adegoke and Carleton, 2000).

The parameters in uencing water stress are complex and interlinked with respect to environmental changes and in uences men oned above (Zhang and Wei, 2012). Nevertheless, water stress/shortage and land use pa erns are intrinsically linked, and require an integrated understanding of the changing in land use around the catchment (RICS Research 2011). At a catchment level, changes in forest cover and agricultural cul va on have signi cant impacts on the water behavior and a ect availability of domes c water for rural-urban use. At the urban scale, changes to land use increases impermeable areas which limit groundwater recharge or the cul va on of unsustainable urban landscape (parks and lawns) can have a signi cant e ect on water resources. Water stress issues may arise out of reduc ons in the watershed forest and increases evapora on from land use conversion par cularly forest to built-up and/or cul va on/bare land/open space. In recogni on, the study non-parametrically relates water stress to LULCC through evaluation of communities' perception to water stress and used of remotely sensed data of Landsat MSS, TM, and ETM (Pekkarinen *et al.,* 2009).

STUDY AREA

The Nigeria induced derived savanna vegeta on lies between la tude $7^{0}10'$ & $8^{0}30'$N. For representa ve study, part of this vast area (between longitude $3^{0}20^{1}$ and $6^{0}00^{1}$E, and la tude $7^{0}10^{1}$ and $8^{0}40^{1}$N) is used as case study for this research work. The area cuts across seven states (Eki , Kogi, Kwara, Ogun, Ondo, Osun, Oyo,) in the southwest corridor of River Niger (Fig. 1).

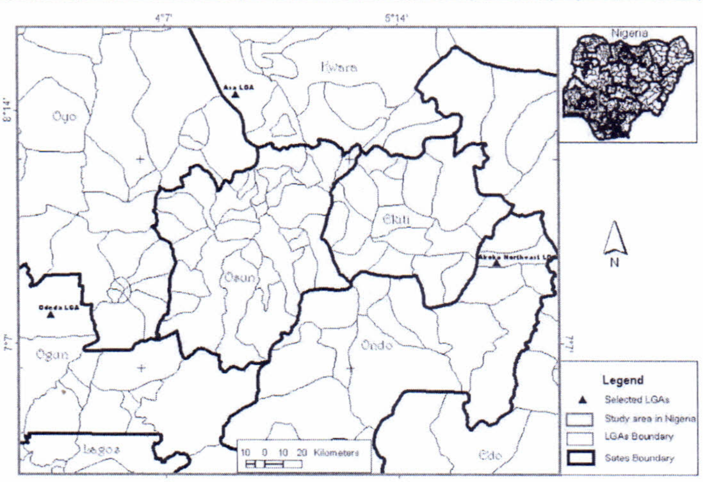

Fig. 2: Study Area

METHODOLOGY

Image preprocessing and classi ca on

The analysis was based on spa o-temporal image data sets, freely available at the Global Land Survey (GLS) h p://glovis.usgs.gov/. The scenes consist of global datasets created from the primary Landsat sensor of: the Mul spectral Scanner (MSS) in the 1970s, the Thema c Mapper (TM) in 1990, the Enhanced Thema c Mapper Plus (ETM+) in 2000 and 2006. Hence, the study data sets consist of Landsat of years 1972; 1986/1987; 2000/2002 and 2006/2007. Both data sets had already been orthorec ed by the providers according to their standards. The reported root mean square (RMS) errors for the posi onal accuracy were less than 50m. The datasets used were subsequently corrected geometrically and radiometrically, according to the standard opera onal procedures of SLATS (NRW, 2008; Pringle *et al.,* 2009). Geometric correc on was based on the method of Armston *et al.,* (2002) as part of resampled the images. Radiometric correc on was based on the de Vries *et al.,* (2007) local calibra ons. Atmospheric correc on was done using LandSat calibra on tools embedded in ENVI so ware (Chander *et al.,* 2009). This was followed by band interpola on - four re ectance bands for MSS images and six re ectance bands for TM & ETM images. The two ETM+ thermal bands were not considered for interpola on.

Based on the study objec ve, we iden ed 4 major landuse: Built up, forest, cul va on/others and water-bodies. Five (5) ROIs were selected per each iden ed class using ROI tool. The resul ng classes generated from ROI were used to map the LULCC and followed by change detec on analysis.

Social survey of people's perception of water stress

Social survey technique was used to generate informa on on rural communi es' varying percep ons about water stress and LULCC. The informa on includes observa on of surface water and LULC changing trend, changing rate, and rst me the change was observed. Three communi es were sampled from each of the three Local Government Areas represen ng the three dominant sub vegetal zones of induced derived savanna of SW Nigeria. In each community, twenty 20 social survey instrument were randomly distributed among the elderly people (Between 50 and 75yeras old) who could recall at least 40years back experience about the observed changes in their environment.

RESULTS AND DISCUSSION

LULC result

LULC analysis as shown in g. 2 and table 2 revealed that in 1972, forest covered almost 42,800km^2 (76%) out of the area total LULC of 56,100 km^2. This was followed by Cul va on/others which occupied an area of 13,100 km^2 (23%) while built-up and water-bodies together represent only 110 km^2 i.e. 0.20% of the total area (Table 1 & Fig. 2).

Table 1: Study area LULC values from classi ed images (between 1971/72 and 2006/2007)

	1972		1986/87		2000/02		2006/07	
	Km2	%	Km2	%	Km2	%	Km2	%
Built-up	82.6	0.2	307	0.6	803.3	1.4	1,133.5	2.0
Forest	42,819.3	76.4	21,855.7	39.0	17,304.6	30.9	16,148.3	28.8
Cul va ons & others	13,143.7	23.4	33,838.2	60.4	37,801.9	67.4	38,616.6	68.9
Water-bodies	26.7	0.05	71.5	0.13	162.3	0.3	173.8	0.3

Total	56,072.3	100	56,072.3	100	56,072.1	100	56072.1	100

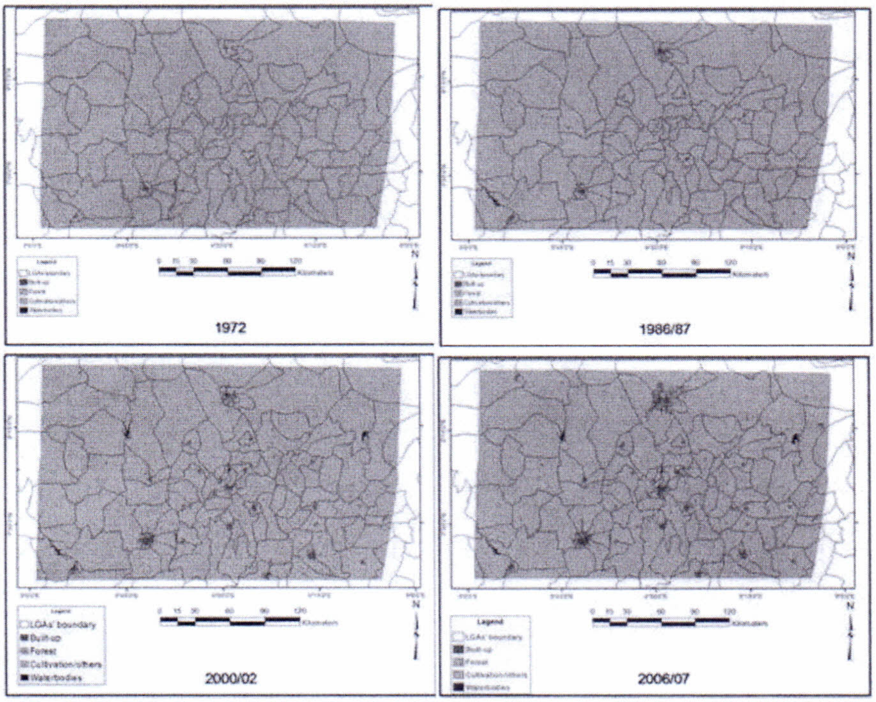

Fig. 2: The study area LULC classi ed images (between 1972 and 2006/2007)

In 1986/87, forest had reduced to almost half of its ini al size in 1971/72 (i.e. from 76% to 39%). On the other hand built-up and cul va on/others nearly triple their ini al sizes in 1971/72 i.e. they rose from 0.2% and 23% to 0.6% and 60% respec vely. There was also increase in water-bodies (from 0.05% to 0.13%) resul ng from two surface earth dam (surface water storage) constructed between 1976 and 1985. The 2000/02 classi ed image revealed a massive increase in built-up, cul va on/others, and water-bodies as forest landcover con nue to decrease in spa al extent. As shown in table 1 and fig. 2, built-up, cul va on/others, and water-bodies increased to 803.3km^2 (1.4%), 38,81km^2 (67.4%), and 162.3km^2 (0.3%) respec vely. The increase in area extent of water-bodies was also a ributed to addi onal surface water supply dams constructed between 1987 and 2000. Between 2000/02 and 2006/07, there were no conspicuous changes as forest loss only 2.1% while built-up, cul va on/other, and water-bodies increased by 0.6%, 1.45%, and 0.02% respec vely.

LULC Change detec on analysis

As shown in table 2, between 1972 and 1986/87 built-up loss 11.2km^2 (13.6 %.) of its total 82.6km^2 to other classes - forest (0.5%), cul va on/others (12.8%), and water-bodies (0.3%).

Table 2: Change detec on matrix between 1972 and 1986/87

		1972									
		Built-up		Forest		Cul va ons & others		Water bodies		Class Total	
		Km^2	%	Km^2	%	Km^2	%	Km^2	%	Km^2	%
1986/87	Built-up	71.4	86.4	74.7	0.2	160.6	1.2	0.2	0.7	306.8	100
	Forest	0.4	0.5	19,284.3	45.0	2,567.4	19.5	3.5	13.2	21,855.7	100
	Cul va ons & others	10.3	12.8	23,411.6	54.7	10,400.3	79.1	15.8	59.1	33,838.2	100
	Water-bodies	0.3	0.3	48.7	0.1	15.4	0.1	7.2	27.0	71.5	100

	Class Total	82.6	100	42,819.2	100	13,143.7	100	26.7	100		
	Class Changes	11.2	13.6	23,534.9	55.0	2,743.3	20.9	19.5	73.0		
	Image Di erence	224.2	271.5	-20,963.5	49.0	20,694.5	157.5	44.8	167.6		

There was massive reduc on in forest class with 23,534.9km^2 (56.0%) of its ini al area extent (42,819.3km^2) in 1972 changed to other classes. About 2,743.3km^2 (20.9%) cul va on/others total class of 13,143.7km^2 changed to built-up, forest, and water-bodies. Of the 26.7km^2 of water-bodies class total, 19.5km^2 acquired by built-up, forest, and cul va on/others during the same period (Table 2 and g. 2). The change detec on image for the period shown that forest class losses -20,963.5km^2 (-49.0%) while built-up, cul va on/others, and water-bodies correspondingly gained 224.2km^2 (271.5%), 20,700.2km^2 (157.5%), and 44.8km^2 (167.6%) respec vely.

Table 3 revealed more interes ng result on detected changes between 1986/87 and 2000/02 as rate of changes becomes more dynamic and drama c. A total of 219.9km^2 (71.7%) of built-up remain unchanged while only 28.3% changed to other classes. Forest retained almost half (49.9%) of it 1986/87 size and loss almost the remaining half (49.7%) to cul va on/others.

Table 3: Change detec on matrix between 1986/87 and 2000/02

		1986/87									
		Built-up		Forest		Cul va ons & others		Water bodies		Class Total	
		Km^2	%	Km^2	%	Km^2	%	Km^2	%	Km^2	%
2000/02	Built-up	219.9	71.7	27.8	0.1	5,55.3	1.6	0.3	0.4	803.3	100
	Forest	7.9	2.58	10,915.2	49.9	6,368.3	18.8	13.2	18.5	17,304.6	100
	Cul va ons & others	78.5	25.6	10,869.3	49.7	26,845.5	79.3	8.5	11.9	37,801.9	100
	Water-bodies	0.3	0.1	43.4	0.2	69.1	0.2	49.5	69.2	162.3	100
	Class Total	306.8	100	21,855.7	100	33,838.2	100	71.5	100		
	Class Changes	86.8	28.3	10,940.5	50.1	6,992.7	20.7	22.0	30.8		
	Image Di erence	496.5	161.8	-4,551.1	20.8	3,963.7	11.7	90.8	126.9		

Of the 33,838.22km^2 cul va on/others 1986/87 area extent, 79.3% remain unchanged in 2000/02. Forest reclaimed 18.8% while lost the remaining 20.7% to built-up (1.6%) and water bodies 0.2%. The period also observed a nega ve image di erence of 20.82% for forest class and high posi ve image di erence of 163.8% and 126.9% in built-up and water-bodies classes respec vely. Cul va on/others had a low posi ve image di erence of 11.7% (Table 3).

Change detec on analysis revealed that much change did not occur between 2000/02 and 2006/07 in the area. The LULC changes distribu on shows that 12.4km^2 (0.1%), 5,019.9km^2 (29.0%), and 19.5km^2 (0.1%) of forest changed to built-up, cul va on/others, and water-bodies (Table 4).

Table 4: Change detec on matrix between 2000/02 and 2006/07

		2000/01									
		Built-up		Forest		Cul va ons & others		Water bodies		Class Total	
		Km^2	%	Km^2	%	Km^2	%	Km^2	%	Km^2	%
2006/07	Built-up	677.8	84.4	12.3	0.1	442.9	1.2	0.4	0.26	1,133.4	100
	Forest	17.5	2.2	12,252.9	70.8	3,872.2	10.2	5.7	3.51	16,148.3	100
	Cul va ons & others	107.8	13.4	5,019.9	29.0	33,466.9	88.5	22.1	13.60	38,616.6	100
	Water bodies	0.2	0.1	19.5	0.1	19.9	0.1	134.1	82.63	173.8	100
	Class Total	803.3	100	17,304.6	100	37,801.9	100	162.3	100		
	Class Changes	125.5	15.6	5,051.7	29.2	4,335.0	11.5	28.2	17.37		
	Image Di erence	330.2	41.1	-1,156.3	6.7	814.7	2.2	11.5	7.07		

During the period, forest class experienced nega ve image di erence of -1,156.33km^2 (6.7%) while built-up, cul va on/others, and water-bodies had posi ve image di erences of 330.2km^2 (41.1%), 814.7km^2 (2.2%), and 11.5km^2 (7.1%) respec vely

The general pa ern shown in this analysis is the increasing nega ve change in the forest landcover to the other classes mainly cul va on/others. The con nuous nega ve changes in forest class revealed that forest reduc on was intensive between 1972 and 2000/02 with less change between 2000/02 and 2006/07. Nevertheless, within 35years more than 60% of forest land cover changed into other land uses. The rate at which the changing is taking place is so phenomenal and requiring urgent plan of ac on on forest protec on. The observed pa ern of change have much economic, social, environmental and management implica ons on ecological biodiversity, sustainable forest resources management, and livelihoods of communi es in the area.

Communi es' perception on Water Stress and LULCC

Majority of the rural communi es are directly sensi ve to water stress and will likely produce a range of impacts based on their percep ons of LULCC. They also a ributed the impacts of LULCC on water stress to changing in surface water using for domestic purposes and climate.

The respondents in the rural communi es re ect their percep on to changing in surface water between 1971 and 2011 (Table 5). It was observed that on the average, 86.1% of rural indigenes agreed that there were changes within the period.

Table 5: Communities' perception on change in surface water

		Akoko NE LGA		Odeda LGA		Asa LGA		Total	
		Freq	%	Freq	%	Freq	%	Freq	%
Observa on of changing in surface water	Yes	50	83.3	46	76.7	59	98.3	155	86.1
	No	10	16.7	14	23.3	1	1.7	25	13.9
	Total	60	100	60	100	60	100	180	100
Changing magnitude	Decreasing	16	26.7	13	21.7	12	20.0	41	22.8
	Increasing	31	51.7	19	31.7	32	53.3	82	45.6
	Fluctua ng	3	5.0	14	23.3	15	25.0	32	17.8
	Indi erent	10	16.7	14	23.3	1	1.7	25	13.9
	Total	60	100	60	100	60	100	180	100
Time start observing the changes in surface water	Over 30years	13	21.7	14	23.3	10	16.7	37	20.6
	Between 30 and 15years ago	33	55.0	15	25.0	35	58.3	83	46.1
	Less than 15years now	4	6.7	17	28.3	14	23.3	35	19.4
	Indi erent	10	16.7	14	23.3	1	1.7	25	13.9
	Total	60	100	60	100	60	100	180	100

Their opinion on changing magnitude varies from one region to another. On the average, 22.8%, 45.6%, and 17.8% observed decrease, increase, and uctua on respec vely in the volume of surface water within/around their communi es. Based on the respondent percep on of their immediate environment, the study revealed that 20.6% of the respondents start observing the changing some 30years ago. Between 30years and 15years ago, 46.1% started observa on about the changes while 19.4% explicit that the changing started in the last 15years. In addi on, 13.9% were indi erent in their opinion. Notably amongst them, the changing put the rural communi es at risk of climate change e ects than urban communi es.

Respondents explained water stress using their perceptions on LULCC between 1971 and 2011. On the average, the percep ons results revealed that 81.1% of 180 respondents were aware of LULCC. The result varies from one LGA to another with 83.3%, 73.3%, and 86.7% for Akoko Northeast, Odeda, and Asa LGAs respec vely. The percep ons on change magnitude are observed for fast, slow or gradual. The respondents that observed fast, slow, and gradual accounted for 48.3%, 24.4%, and 15.0% respec vely while 18.9% explicit indi erent about LULCC. On the average, the study revealed that 31.7% of the respondents start observing the changing some 30years ago; 33.9% (between 30years and 15years ago), and 17.8% (less than 15years). From their observa on, the changes have con nuously exacerba ng forest degrada on through un-control logging, bush burning, intensive cul va on around catchment, and urbaniza on. These are assumed to have caused reduc on in the volume of available rivers, streams, ponds etc. As a result rural communi es are at risk of water stress e ects than urban communi es. According to their percep on, majority observed LULC change between the last 15 and 30years (i.e. between 1982 and 1998). The nding is however, consistent with the result generated on LULCC between 1986 and 2000 (see also table 4).

For instance, in areas where forest lost prevailed, majority of respondent noted consistent decrease in the volume of surface waters (streams, river, spring, and pond). Nevertheless, increase fetched to major storage water (surface earth dams) in the area. Between 1987 and 2006, ve dams were constructed in the area which is suspected to have contributed to low surface water recharge from catchments and subsequently reduced rivers and streams input to the area. The nding revealed that 83.3% of 180 respondents were aware of climate change. The observa ons were explained with decrease in rainfall and increase in temperature pa ern over their environment. Their percep on on rate of change revealed that 44.4%, 22.8%, and 16.1% of respondents argued that the rate of change is fast, gradual, and slow respec vely. On the other hand 16.7% are indi erent in their observa on about rainfall and temperature. Their opinion on me started observing the changes in climate varies from one region to another. On the average, 41.1%, 23.9%, and 18.3% started observing the changes over 30years, between 30years and 15years ago, and in the last 15years.

The majority of respondents argued that changes in clima c condi on (reduc on in rainfall), con nuous forest degenera on in the last 30years, and diversion of rivers and streams into surface storages (earth dams and reservoirs) are the major factors responsible for water stress and scarcity in the most rural communi es of the induced derived savanna of Southwestern Nigeria. In addi on, it has further impacted their physical environment nega vely. Coupled with increase in temperature, the changing is con nuously a ec ng surface water catchment, socio-economic ac vity (farming), access to natural resources, and availability and accessibility of water sources (Hanna, 2007; Tsosie, 2007; Nilsson, 2008; Karl et al., 2009; Lai et al., 2011).

CONCLUSION

The study demonstrated how LULCC is very useful in explaining the local percep on to water stress. The study revealed that LULCC par cularly forest degrada on and urbaniza on could be the contributing factors to water stress and scarcity in the rural area of derived savanna region of Southwestern - Nigeria. Due to the geographically isolated popula ons, poor/low household income, and poor adapta on awareness - emergency response systems to LULCC are o en less e ec ve in rural areas. Therefore, communi es which are predominantly rural may face dispropor onately high risk of water stress that will a ect their livelihoods. Many rural communi es may also face extremely higher levels of climate – LULC changes trigger impacts on socio-economic ac vi es, access to natural resources, future growth, and reduce the availability and accessibility of water sources and food. In Nigeria, many of these rural communi es are currently facing water stress problems and likely to be exacerbated by LULC and climate changes. Since the communi es do not have capacity to respond to threa ng climate change, the problem will be worsening in nearest future.

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