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Research Article

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Could Local Perceptions of Water Stress be Explained by LULCC?

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Abstract

Mapping land use/land cover changes (LULCC) is essential for a wide range land use planning and adaptation 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 investigate whether water stress in the induced savanna of Southwestern, Nigeria as perceived by the various communities can be explained by LULC changes in the region. LULCC was conducted using orthorectified Landsat multi-temporal imageries for 1970/1972, 1986/1987, 2000/2001 and 2006 using maximum likelihood classification and change detection techniques in ENVI 4.4 software. The results showed a decrease in the forest area and an increase in built-up and cultivation/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 detection between 1972 and 1987, 1987 and 2002, and between 2002 and 2006 depicted -20,963.53 km^2 (48.96%), -4,551.08 km^2 (20.82%), and -1,156.33 km^2 (6.68%) image difference in forest landcover with almost 60% loss to cultivation/others class. Notably, however, in areas where forest lost prevailed, increased fetch to the storage water (surface earth dams). Between 1987 and 2006, five dams were constructed in the area which is suspected to have reduced rivers and streams input to the area. *Ab initio,* the communities' perception generated from social survey indicate that changes in climatic condition e.g. decreasing rainfall, continuous forest degeneration 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 communities in the region. In conclusion, this study provides an opportunity to better understand the usefulness of LULCC in explaining local perception to water stress and the expected implications.

Keywords

Local; Perceptions; Water stress; LULCC; Derived savanna; SW-Nigeria

Introduction

Recent works suggest that the environmental changes over the last several centuries are evidence from significant population increase, intensified migration, urbanization, deforestation, overgrazing, irrigations, damming rivers to create man-made lakes and reservoirs, land-filling of swamps and marshlands, as well as accelerated socio-economic activities [1-5]. These activities not only affect the climate and landscape processes on scales ranging from the micro-scale to the macro-scale but could as well intensify water shortage/stress [6]. LULCC studies also provide valuable information for large-scale vegetation biomass and forest cover assessments that are key components to not only the carbon cycle but also water balance [7].

It is not erroneous to affirm that LULCC is linked to climate and ecosystems pathways in complex ways. For instance, causes of forest degeneration in tropical regions of the world have been linked mainly with LULCC and climate change [8-10]. This is coupled with growing demand for food due to population growth and changing consumption patterns in emerging economies as well as increased use of biomass for bioenergy. Measures to mitigate further degradation of forest have been inadequate in the study region and this appears to be a global trend. Forests provide a range of ecosystem services (e.g. conserving watershed) but virtually underestimated. The services can be essential for sustainable adaptation mechanisms to climate change and water stress effects via proper forest management [11,12].

The parameters influencing water stress are complex and interlinked with respect to environmental changes and influences mentioned above [13]. Nevertheless, water stress/shortage and land use patterns are intrinsically linked, and require an integrated understanding of the changing in land use around the catchment [14]. At a catchment level, changes in forest cover and agricultural cultivation have significant impacts on the water behavior and affect availability of domestic water for rural-urban use. At the urban scale, changes to land use increases impermeable areas which limit groundwater recharge or the cultivation of unsustainable urban landscape (parks and lawns) can have a significant effect on water resources. Water stress issues may arise out of reductions in the watershed forest and increases evaporation [15] from land use conversion particularly forest to built-up and/or cultivation/bare land/open space. The study has employed non-parametric methods [16} to understand the relationships between LULCC derived from remotely sensed data and the communities' perception of land use change and water stress in the induced savanna landscape.

Study Area

The Nigeria induced derived savanna vegetation lies between latitude 7^{0}10' & 8^{0}30'N. For representative study, part of this vast area (between longitude 3^{0}20^1 and 6^{0}00^{1}E, and latitude 7^{0}10^1 and 8^{0}40^{1}N) was used as case study for this research work. The area cuts across seven states (Ekiti, Kogi, Kwara, Ogun, Ondo, Osun, Oyo,) in the southwest corridor of River Niger (Figure 1).

Methodology

Image preprocessing and classification

The analysis was based on spatio-temporal image data sets, freely available at the Global land facility (GLF) [17]. The scenes consist of global datasets created from the primary Landsat sensor of: the Multispectral Scanner (MSS) in the 1970s, the Thematic Mapper

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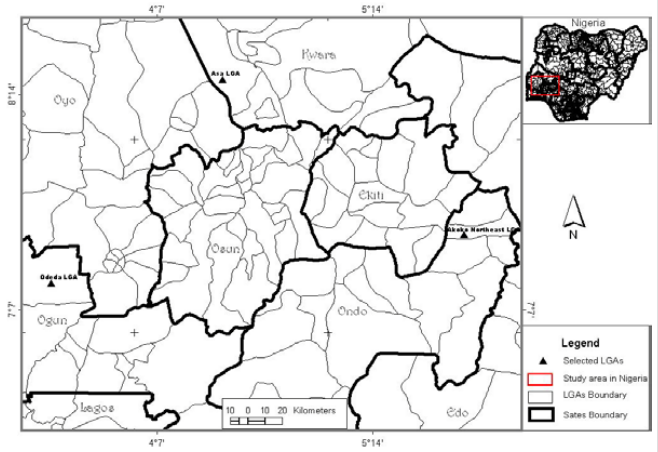

Figure 1: Study Area.

(TM) in 1990, the Enhanced Thematic 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 orthorectified by the providers according to their standards. The reported root mean square (RMS) errors for the positional accuracy were less than 50m. The datasets used were subsequently corrected geometrically and radiometrically, according to the standard operational procedures of SLATS [18,19]. Geometric correction was based on the method of Armston et al. [20] as part of resampled the images. Radiometric correction was based on the de Vries et al. [21] local calibrations. Atmospheric correction was done using LandSat calibration tools embedded in ENVI software [22]. This was followed by band interpolation - four reflectance bands for MSS images and six reflectance bands for TM & ETM images. The two ETM+ thermal bands were not considered for interpolation.

Based on the study objective, we identified 4 major landuse: Built up, forest, cultivation/others and water-bodies. Five regions of interest (ROIs) were selected per each identified class using ROI tool. The resulting classes generated from ROI were used to map the LULCC and followed by change detection analysis.

Social survey of people's perception of water stress

Social survey technique was used to generate information on rural communities' varying perceptions about water stress and LULCC. The information includes observation of surface water and LULC changing trend, changing rate, and first time the change was observed. Three communities were sampled from each of the three Local Government Areas representing 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 Figure 2 and Table 2 revealed that in 1972, forest covered almost 42,800 km² (76%) out of the total area of 56,100 km². This was followed by Cultivation/others which occupied an area of 13,100 km² (23%) while built-up and water-bodies together represent only 110 km² i.e. 0.20% of the total area (Table 1 and Figure 2).

In 1986/87, forest had reduced to almost half of its initial size in 1971/72 (i.e. from 76% to 39%). On the other hand built-up and cultivation/others nearly triple their initial sizes in 1971/72 i.e. they rose from 0.2% and 23% to 0.6% and 60% respectively. There was also increase in water-bodies (from 0.05% to 0.13%) resulting from two surface earth dam (surface water storage) constructed between 1976 and 1985. The 2000/02 classified image revealed a massive increase in built-up, cultivation/others, and water-bodies as forest landcover

Table 1: Study area LULC values from classified 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
Cultivations & 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

Table 2: Change detection matrix between 1972 and 1986/87. **Table 2**: Change detection matrix between 1972 and 1986/87.

		1972									
		Built-up		Forest		Cultivations & others		Water bodies		Class Total	
		km²	%	km²	%	km²	%	km²	%	km²	%
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
	Cultivations & 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 Difference	224.2	271.5	-20,963.5	49.0	20,694.5	157.5	44.8	167.6		

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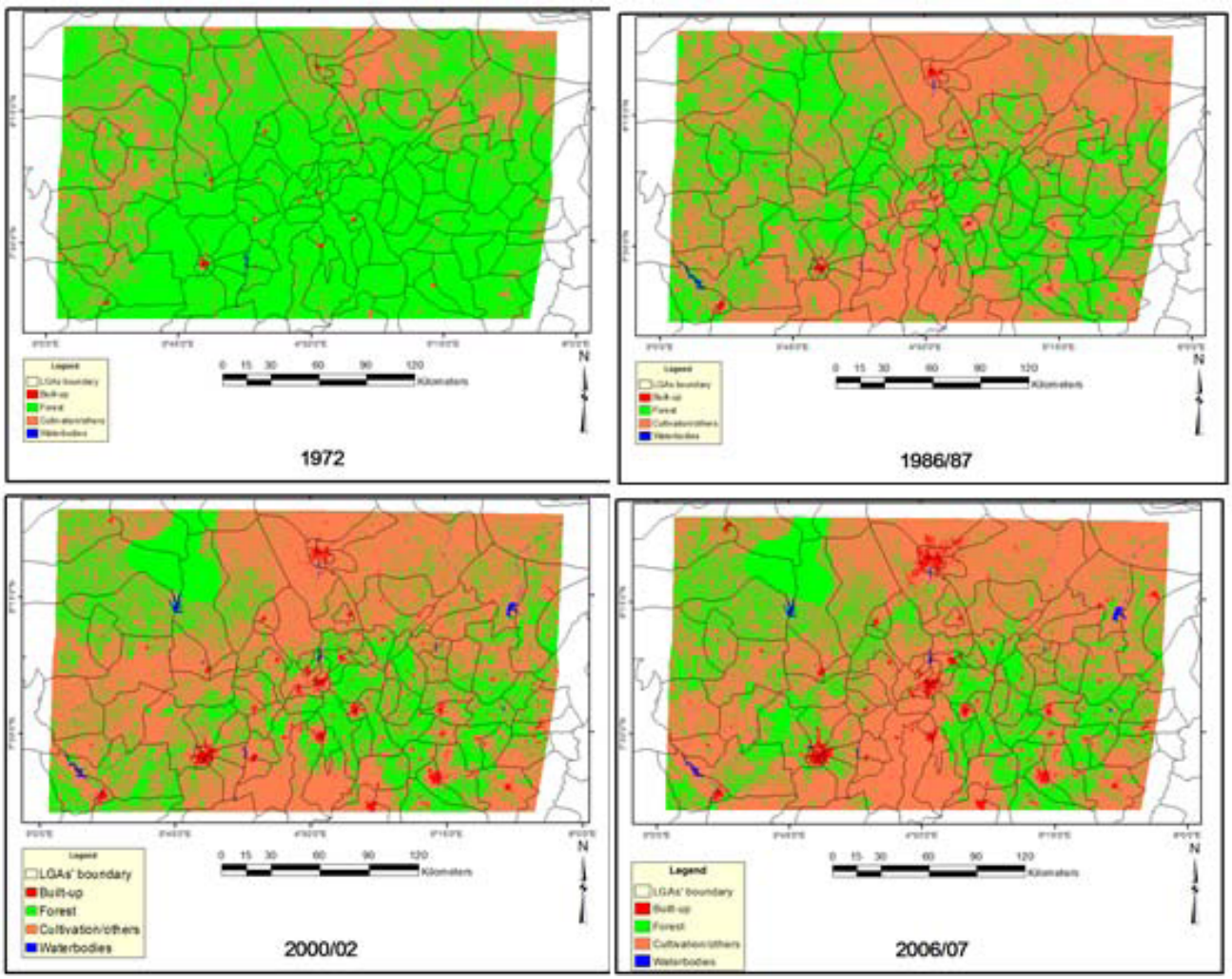

Figure 2: The study area LULC classified images (between 1972 and 2006/2007)

continue to decrease in spatial extent. As shown in Table 1 and Figure 2, built-up, cultivation/others, and water-bodies increased to 803.3 km² (1.4%), 38,81 km² (67.4%), and 162.3 km² (0.3%) respectively. The increase in area extent of water-bodies was also attributed to additional surface water supply dams constructed between 1987 and 2000. Between 2000/02 and 2006/07, there were no conspicuous changes as forest area decreased by only 2.1% while built-up, cultivation/other, and water-bodies increased by 0.6%, 1.45%, and 0.02% respectively.

LULC change detection analysis

As shown in Table 2, between 1972 and 1986/87 built-up decreased by 11.2 km² (13.6 %.) of its total 82.6 km² to other classes - forest (0.5%), cultivation/others (12.8%), and water-bodies (0.3%).

There was massive reduction in forest class with 23,534.9 km² (55.0%) of its initial area extent (42,819.3 km²) in 1972 changed to other classes. About 2,743.3 km² (20.9%) cultivation/others total class of 13,143.7 km² changed to built-up, forest, and water-bodies. Of the 26.7 km² of water-bodies class total, 19.5 km² acquired by built-up, forest, and cultivation/others during the same period (Table 2 and Figure 2). The change detection image for the period showed that forest decreased by -20,963.5 km² (-49.0%) while built-up, cultivation/others, and water-bodies correspondingly gained 224.2 km² (271.5%), 20,700.2 km² (157.5%), and 44.8 km² (167.6%) respectively.

Table 3 revealed more interesting result on detected changes between 1986/87 and 2000/02 as rate of changes becomes more dynamic and dramatic. A total of 219.9 km² (71.7%) of built-up remain unchanged while only 28.3% changed to other classes. Forest retained almost half (49.9%) of its initial area in 1986/87 while almost the remaining half (49.7%) changed to cultivation/others.

Of the 33,838.22 km2 cultivation/others 1986/87 area extent, 79.3% remain unchanged in 2000/02 while 18.8%, 1.6%, and 0.2% changed to forest, built-up, and water bodies respectively. The period also observed a negative image difference of 20.82% for forest class and high positive image difference of 163.8% and 126.9% in built-up and water-bodies classes respectively. Cultivation/others had a low positive image difference of 11.7% (Table 3).

Change detection analysis revealed that much change did not occur between 2000/02 and 2006/07 in the area. The LULC changes

distribution shows that 12.4 km² (0.1%), 5,019.9 km² (29.0%), and 19.5 km² (0.1%) of forest changed to built-up, cultivation/others, and water-bodies (Table 4).

During the period, forest class experienced negative image difference of -1,156.33 km² (6.7%) while built-up, cultivation/others, and water-bodies had positive image differences of 330.2 km² (41.1%), 814.7 km² (2.2%), and 11.5 km² (7.1%) respectively

The general pattern shown in this analysis is the increasing negative change in the forest landcover to the other classes mainly cultivation/others. The continuous negative changes in forest class revealed that forest reduction 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 observed pattern of change have much economic, social, environmental and management implications on ecological biodiversity, sustainable forest resources management, and livelihoods of communities in the area.

Communities' perception on water stress and LULCC

Majority of the rural communities are directly sensitive to water stress and will likely produce a range of impacts based on their perceptions of LULCC. They also attributed the impacts of LULCC on water stress to changes in domestic water consumption and climate change.

The respondents in the rural communities reflect their perception to to changes 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.

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 fluctuation respectively in the volume of surface water within/around their communities. Based on the respondents' perception 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 observation about the changes while 19.4% explicit that the changing started in the last 15years. In addition, 13.9% were indifferent in their opinion. Notably amongst them, the changes put the rural communities at risk of climate change effects than urban communities.

Respondents explained water stress using their perceptions on LULCC between 1971 and 2011. On the average, the perceptions 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 respectively. The perceptions 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% respectively while 18.9% expressed indifference 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). Forest degradation has continued unabated through uncontrolled logging, bush burning, intensive cultivation around catchment, and urbanization. These are assumed to have caused reduction in the volume of available rivers, streams, ponds etc. As a result rural communities are at risk of water stress effects than urban communities. According to their perception, majority observed LULC change between the last 15 and 30years (i.e. between 1982 and 1998). The finding is however, consistent with the result generated on LULCC between 1986 and 2000 (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 storage water (surface earth dams) in the area. Between 1987 and 2006, five 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 finding revealed that 83.3% of 180 respondents were aware of climate change. The observations were explained with decrease in rainfall and increase in temperature pattern over their environment. Their

Table 3: Change detection matrix between 1986/87 and 2000/02.

		1986/87									
		Built-up		Forest		Cultivations & others		Water bodies		Class Total	
		km²	%	km²	%	km²	%	km²	%	km²	%
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
	Cultivations & 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 Difference	496.5	161.8	-4,551.1	20.8	3,963.7	11.7	90.8	126.9		

Table 4: Change detection matrix between 2000/02 and 2006/07.

		2000/01									
		Built-up		Forest		Cultivations & others		Water bodies		Class Total	
		km²	%	km²	%	km²	%	km²	%	km²	%
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
	Cultivations & 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 Difference	330.2	41.1	-1,156.3	6.7	814.7	2.2	11.5	7.07		

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Table 5: Communities' perception on change in surface water.

		Akoko NE LGA		Odeda LGA		Asa LGA		Total	
		Freq	%	Freq	%	Freq	%	Freq	%
Observation 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
	Fluctuating	3	5.0	14	23.3	15	25.0	32	17.8
	Indifferent	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
	Indifferent	10	16.7	14	23.3	1	1.7	25	13.9
	Total	60	100	60	100	60	100	180	100

**LGA (Local Government Area)

perception 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 respectively. On the other hand 16.7% are indifferent in their observation about rainfall and temperature. Their opinion of when climate change was noticed vary 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 climatic condition (reduction in rainfall), continuous forest degeneration 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 communities of the induced derived savanna of Southwestern Nigeria. In addition, it has further impacted their physical environment negatively. Coupled with increase in temperature, the changes is continuously affecting surface water catchment, socio-economic activity (farming), access to natural resources, and availability and accessibility of water sources [23-28].

Conclusion

The study demonstrated how LULCC is very useful in explaining the local perception to water stress. The study revealed that LULCC particularly forest degradation and urbanization 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 populations, poor/low household income, and poor adaptation awareness - emergency response systems to LULCC are often less effective in rural areas. Therefore, communities which are predominantly rural may face disproportionately high risk of water stress that will affect their livelihoods. Many rural communities may also face extremely higher levels of climate – LULC changes trigger impacts on socio-economic activities, access to natural resources, future growth, and reduce the availability and accessibility of water sources and food. In Nigeria, many of these rural communities are currently facing water stress problems and likely to be exacerbated by LULC and climate changes. Since the communities do not have capacity to respond to threating climate change, tthe problem may get worse in the nearest future.

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