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The local experts' perception of environmental change and its impacts on surface water in Southwestern Nigeria

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ABSTRACT

In this study, we investigated whether environmental changes (climatic conditions, deforestation and surface water) in the woodland savanna and rain forest zones of Southwestern Nigeria, as observed by the rural communities' local experts', can be used to evaluate Land cover change (LCC) in the region. LCC was conducted using orthorectified Landsat multi-temporal imagery for 1970/1972, 1986/1987, 2000/2001 and 2006 using maximum likelihood classification and change detection techniques. The results showed a decrease in the forest area and an increase in built-up and cultivation/others (open space, bare land, grassland) areas. Between 1972 and 2006, forest reduced by about 50% while built-up areas increased by about 300%. A Participatory Learning Approach (PLA) involving experienced elderly local experts above 65 years old was conducted to assess their observations in the region on (i) LCC and (ii) the causes of water shortage, and (iii) the associated risk and adaptation/recommendation. The communities' local experts reported that changes in climatic condition, deforestation in the last 30 years and constructions of surface storages (reservoirs) are the major factors responsible for declining surface water in the region. There is thus, a good corroboration between the results of remotely sensed data of LCC assessment and the communities' local experts' observations of land cover changes and changes in surface water resources in the region. The study therefore inferred that LCC map products-information could be used in a participatory approach involving the communities to assess the impact of environmental change on an important service of forest ecosystems such as fresh water resources.

1. Introduction

The vast changes in land cover and land use in tropical environments are negatively impacting on their ability to provide essential services to the human community, thus threatening food, water, and energy security (Hulme et al., 2001; Challinor et al., 2007; Shemsanga et al., 2010). This could be exacerbated by climate change i.e., increasing frequency and severity of extreme climatic events and long-term shifts in temperature, rainfall patterns and water availability, in the aggravating context of rapid population growth and fast-paced urbanization (IPCC, 2012; Ren et al., 2012). This will increase the risk of

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leaving many of the vulnerable rural communities in a fragile economic situation for some time to come (Adeniji-Oloukoi et al., 2013).

An important question is whether inhabitants of tropical biomes in Africa are aware of the changes occurring to the environment and the consequences thereof. Published research results seldom trickle down to the general population and let alone to the uneducated masses. This makes it particularly challenging for rural populations to craft common adaptation and mitigation measures to land cover change (LCC, and associated land use), and climate change (Mapfumo et al., 2013; Fasona et al., 2013). The question arises whether local perceptions of LCC can be corroborated with quantitative and objective assessment of LCC using remote sensing data and whether inhabitants of tropical environments see these and climate change as the causes of resource depletion, more specifically fresh water. Several studies have argued that people's perceptions and attitudes towards depletion of natural resources are instrumental to wise use and management of natural resources (Mogome-Ntsatsi and Adeola, 1995; Pavlikakis and Tsihrintzis, 2003; Kerr and Cihlar, 2005, Fasona et al., 2013; Ayeni and Olorunfemi, 2014). Ayeni et al. (2013) assessed the relationships between LULCC derived from remotely sensed data and the communities' perception of land use change and water stress using three LGAs to represent the region. It was found that change detection analysis and the choice of nine communities from three LGAs over the region are subjective, and therefore could not give detailed interpretation of people's perception on changes in surface water, land-cover and climate relatively to what obtained from remotely sensed data. In addition, the complexity of human-environmental influences can be addressed not through only scientific protocols but also through active participation of community based indigenous knowledge and informal science education that involves indigenes' attitudinal and behavioral mechanisms. This has not be explored in environmental change research in the region

These therefore create the lacuna that this present study intends to fill. This is very important in the process of finding solutions to the problems affecting local communities in Africa.

The aims of this study are to: (i) assess local experts' perception of land cover change (LCC) and climate change in the woodland and secondary rainforest areas in Southwest Nigeria, (ii) assess local experts' perception of the causes of water stress in the region, and (iii) investigate whether information from the local experts' perceptions of environmental change (LC and climate changes) corroborate LCC information derived from remote sensing data.

2. Study area

The study area lies between longitude 3°2' and 6°0'E, and latitude 6°5' and 8°20'N, in the Southwest corridor of the Niger River (Fig. 1).

The mean annual temperature ranges from 29 °C in the northern part to 27 °C in the southern part. The annual rainfall ranges from 1000 mm in the northern part to 1800 mm in the southern part depending on the vegetation zones. The geology is characterized by undifferentiated igneous and metamorphic rocks, mostly granite, mischist, gneisses, and

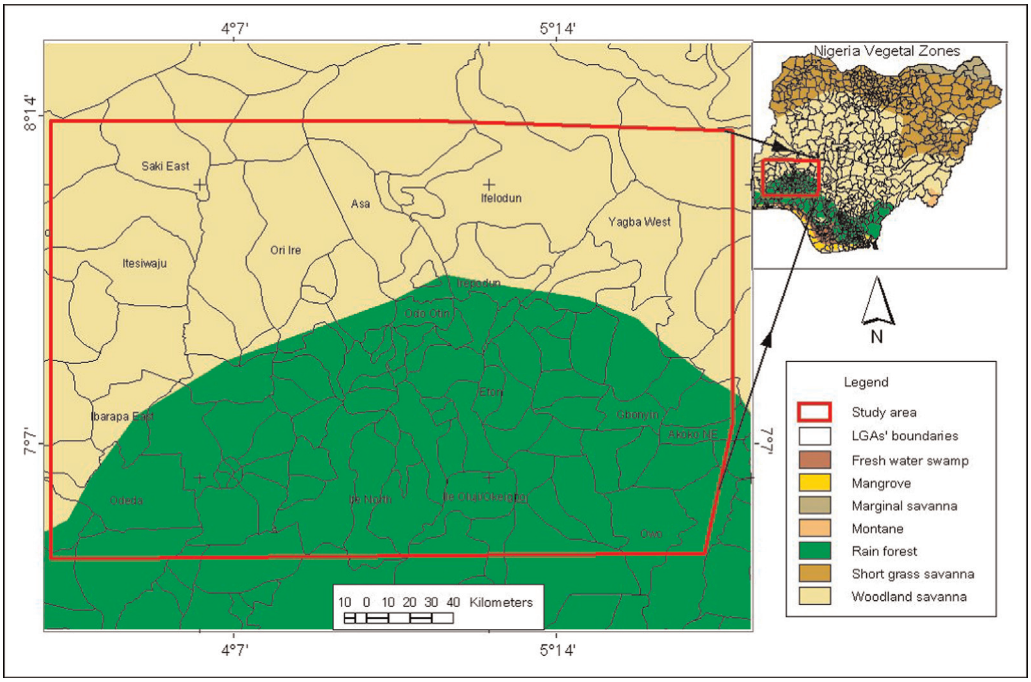

Fig. 1. Location of study area in the southwest corridor of the River Niger.

Table 1
Landsat images information.

Year	1972				1986/1987				2001/2002				2006/2007			
Paths	204	204	205	205	190	190	191	191	190	190	191	191	190	190	191	191
Rows	054	055	054	055	054	055	054	055	054	055	054	055	054	055	054	055
Year	1972	1972	1972	1972	1986	1986	1987	1987	2001	2002	2002	2002	2006	2007	2006	2006
Month	Nov	Nov	Nov	Nov	Nov	Dec	Dec	Dec	Nov	Jan	Feb	Feb	Nov	Jan	Nov	Dec
Day	07	07	08	08	15	17	21	21	13	03	06	06	14	01	18	07

metasediment (Barbour et al., 1982; Adekunle et al., 2007; Ayeni, 2012). These rocks are impervious with limited storage capacity, and as a result, the rural population relies on surface and shallow ground water sources, mostly ponds, wells and streams for water supply (Adekunle et al., 2007; Ayeni, 2012). The study area is characterized with woodland and secondary rainforest vegetation mostly in the north and south respectively. The original rain forests have been destroyed and replaced with remnants of re-growth secondary forest made of heterogeneous mixes of trees, luxuriant grasses, fern and bush. Subsistence farming is the major economic activity. Mainly rain-fed crops like maize and tubers are grown in the region (Fasona et al., 2007; Alo et al., 2008).

3. Materials and methods

3.1. Image acquisition and preprocessing

Four Landsat scenes freely available at the Global Land Survey (GLS) (http://glovis.usgs.gov/) were required to cover the study area (Table 1).

The scenes were acquired by three Landsat sensors: the Multispectral Scanner (MSS) in the 1970s, the Thematic Mapper (TM) in the 1990s, and the Enhanced Thematic Mapper Plus (ETM+) in 2000 and 2006. We targeted images captured between November and February when the region is at the dry season. During this season the images are cloud free and the spectral contrast between investigated classes is high, reducing the possibilities of classification errors. In addition, the images provide information at the most water shortage period, for example when the extent of the water bodies is the smallest. All data sets had already been orthorectified by the providers with a reported root mean square (RMS) errors for positional accuracy of less than 50 m (Tucker et al., 2004). However, further geometric correction was performed based on the method of Armston et al. (2002). Radiometric correction was based on the de Vries et al. (2007) local calibrations using Landsat calibration tools embedded in the ENVI software (Chander et al., 2009). Four reflectance bands for MSS images (Bands 1=blue, 0.45–0.52 nm; 2=green, 0.53–0.61 nm; 3=red, 0.63–0.69 nm; 4=near infrared – NIR, 0.76-0.90 nm) and six reflectance bands for TM & ETM images (Bands 1=blue, 0.45–0.52 nm; 2=green, 0.53–0.61 nm; 3=red, 0.63–0.69 nm; 4=NIR, 0.76–0.90 nm; 5=medium infrared – MIR, 1.55–1.75 nm, and 6=medium infrared, 2.08–2.35 nm) were used for the classification. The thermal bands of TM and ETM+ were not considered. The images for each time period were mosaic prior to the classification.

3.2. Land cover classification

Based on the objective of the study, we identified four major land cover types: built-up, forest, cultivation/others (mostly bare ground: open space, bare land, rocky outcrop, road networks), and water bodies. Field data were used to train the

Table 2
Reference points for accuracy validation.

S/n	*Northing*	*Easting*	*Location*	*Landmark descriptions*	*Land use*
1	7.84969	3.93225	Oyo	Central area of Oyo town, Oyo State	Built-up
2	7.52536	5.75628	Ikare	Central area of Ikare town, Ondo State	Built-up
3	8.49487	4.54199	Ilorin City	Along University of road, Ilorin, Kwara State	Built-up
4	7.43571	4.92039	Ikeji area, Osun State	Disturbed rain forest with patches of cocoa farms, Osun State	Forest
5	8.254406	3.833742	Old Oyo National Park	Undisturbed reserved forest, Oyo State	Forest
6	7.41075	4.23138	Ikire/Ife Rd	Disturbed rain forest along and around Ife – Ikire axis, Osun State	Forest
7	7.61373	4.77112	Ilesha	Subsistence farming area, patches of shrubs, and open land, Osun State	Cultivation
8	8.31313	4.39366	Budo Egba/Ogbomosho Rd	Large subsistence crop farming area and patches of shrubs, grass, and open lands, Oyo State	Cultivation
9	8.28804	5.65059	Ejiba Area	Fadama farm land along Ilorin – Egbe rd, Kogi State	Cultivation
10	7.36244	4.13477	Asejire Dam Area	Asejire dam by Coka Cola plant along Ikire – Ibadan rd, Oyo State	Waterbody
11	8.43953	4.54450	Asa Dam Area	At the southeastern part of Ilorin town for urban water supply, Kwara State	Waterbody
12	8.20650	5.63862	Ejiba Dam	Dams constructed for Ejiba FADAMA activities, Kogi State	Waterbody

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classifier, and assess the classification accuracy. A total of 28 sites were identified using the Landsat color composites and based on information from sixteen local experts. The 16 local experts provided information on the historical land cover or land use patterns in the region. The site consisted of sites that have changed over the study timeframe e.g. settlements and water bodies, conserved landscape such as national parks. The sites were visited and verified in November 2011. A total of 16 sites (four per class) were used as training data. The remaining twelve (12) field sites together with the Landsat color composites, and the visual interpretation of Google Earth historical imagery (November 2007) were used to assess the classification accuracy. These validation sites were revisited between 18 and 22 June 2012. In each place, geo-reference point was recorded with qualitative description of the area (Table 2). Local experts were further consulted on areas where land use activities were observed during the period if the generated maps and/or classifications correlated with land cover pattern of the area. Both results (although qualitative measurements) are assessment for accuracy.

3.3. Post-classification change comparison

This study used the post-classification change matrix technique to quantify and compare class loss and gain between 1972 and 2007. It separately classifies multi-temporal images into thematic maps and subsequently implements comparison of the classified images pixel by pixel (Lu et al., 2004). Post-classification comparison method minimizes the effect of impacts of atmospheric, sensor and environmental differences between multi-temporal images and provides a complete matrix of change information (Lu et al., 2004). The result of confusion matrices for each year also shows that there is correlation between the observed changes and land use pattern of the area based on result of adjusted estimates for all classes at 95% accuracy level at 95% confidence level.

3.4. Analysis of climatic variables

Two historical climatic variables (rainfall and temperature) used for this study were acquired from the Nigerian Meteorological Agency (NIMET) Oshodi, Lagos. The data which spanned from 1970–2010 were originally generated on a daily basis from the eight synoptic stations (Abeokuta, Akure, Ibadan, Ilorin, Ijebu Ode, Iseyin, Ondo, and Oshogbo) covering the region. Monthly averages were computed for the purpose of the study. The mean annual rainfall and temperature were also computed from the monthly data.

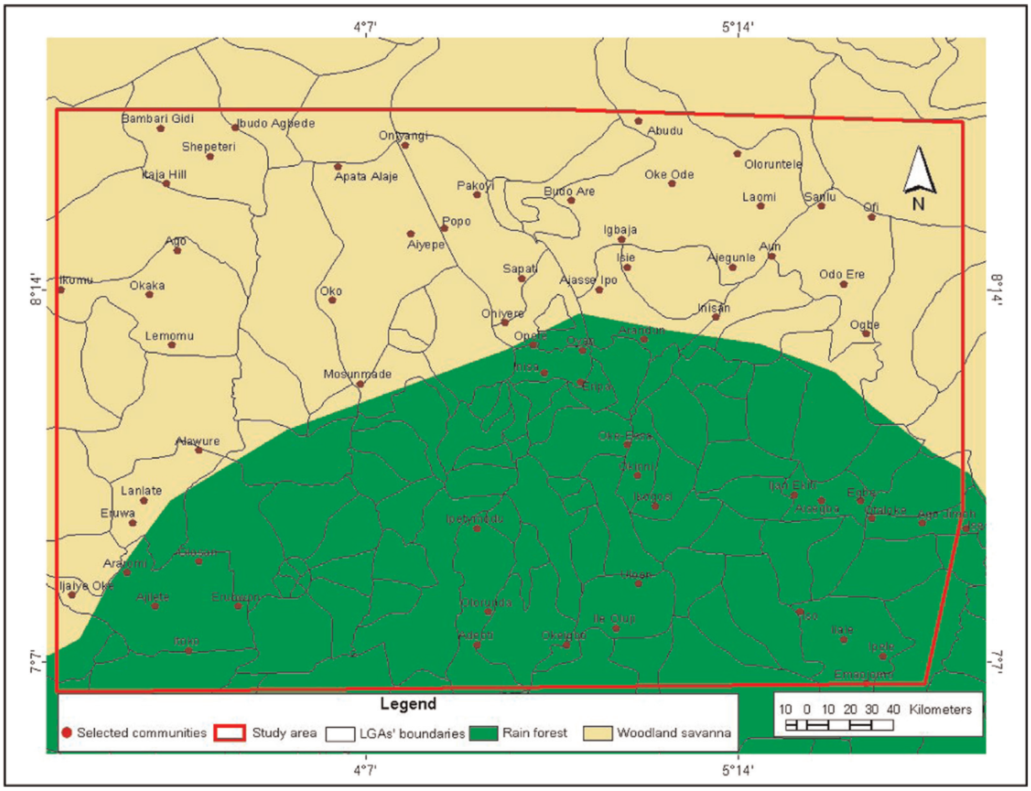

Fig. 2. The selected communities in the southwest Nigeria covered for this study.

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3.5. Acquisition of local experts' knowledge of land cover and climate changes, and surface water footprint

A concept of Participatory Learning Approach (PLA) (Chem and Someth, 2011) involving indigenous elderly experienced experts (local experts) was used in this study, to acquire the perceptions of local experts on environmental change in the region. The focus here is on their perceptions of environmental change as opposed to the use of local experts to identify training and validation data for the LULC classification as previously described. The local experts consisted of community members who use environmental resources for various purposes and include farmers, herbalists/traditional healers, traditional priests (custodians of surface water and forest shrine), loggers/retired forest guides. The local experts for this study were limited to experienced elderly adults of 65 years and above who have the ability to describe and/or narrate the observed changes/situation of at least 50 km radius of his/her environment in the last 45 years (i.e. 1971–2010). Interviews were conducted to obtain information on water resources footprint resulting from environmental changes (climate and land cover) between 1970 and 2010. The information collected through interviews includes perception of surface water and land cover change trends, change rate, and time since the change was observed. Pilot surveys were conducted across the study area with communities' and CDAs' leaders where the experts were identified based on age, activity and experience. They are known for the in-depth knowledge of their immediate environment since their livelihoods were closely linked to natural resources; they spent much of their time in the community and within their local setting, farming and breeding livestock, collecting medicinal plants, protecting sacred forest and water and land cover resources.

For this study, semi structured interviews were conducted with 65 local experts on the perceptions information of change over time. This comprises of 36 experts in the woodland (north) and twenty-nine 29 in the forest (south). In each of the selected LGAs, three to six experts were consulted and interviewed. The interview were designed with a mix of open- and close-ended questions in order to get the relevant information from the respondents, without the use of leading or prompting questions. Three drafts of questions were tested by the researchers to develop the ideal mix of questions. In each Local Government Area (LGA), one expert was visited in the center i.e. a community in the center or close to the center, while others were visited in the suburbs i.e. communities close to the LGA's border (Fig. 2).

The choice of settlements for local experts in the LGA's was based on the locations, proximity and socio-cultural characteristics of each of selected LGAs (Table 3). For example, the minimum distance considered between 2 communities is 10 km. Semi-structured interviews were also conducted with some of the randomly selected Community Development Association Groups (CDAGs)/households' heads to compare their view with those of the local expert on climate and land-cover changes.

4. Results

4.1. Land cover changes

Table 4 indicates the balance between the loss and gain for a specific class e.g. built-up, forest, cultivation/others, and water bodies. The period recorded about 55% loss for the forest class and corresponding gain of 74%, 64%, and 71% for built-up, cultivation/others, and water-bodies (Table 4, Fig. 3a and b). During the same period, about 21% of cultivation/others reverted back to other classes. Of the 27 km^2 of water bodies mapped in 1972, 73% changed to other classes in 1987. This may results partly from the drying up of surface water and over exploitation of the river catchments through extensive logging, dam construction activities, channelization for flood control particularly along the Ogun River.

Almost 72% of built-up remain unchanged between 1987 and 2002 (Table 4, Fig. 3b and c). Forest lost a further 50% (10,941 km^2) of its extent in 1987 to other classes in 2002 (Ayeni et al., 2013). Also, about 79% of cultivation/others remained unchanged during the same period, with a gain of 24% and a loss of 21%. These changes resulted in a net decrease of 21% of the forest class, and net increase of 162%, 127%, and 12%, accruing for built-up, water-bodies, cultivation/others, respectively.

Table 3
Physical characteristics of the selected LGAs with respect to vegetation sub classes.

Regions **Locations**	**Woodland** 7°7' and 8°20'N	**Rainforest** 6°5' and 7°7'N
LGAs	Asa, Odo Otin, Orire, Ifelodun, Irepodun, Itesiwaju, Saki East, and Yagba West	Akoko Northeast, Ibarapa East, Ife North, Ileoluji/Okeigbo, Ikole, Ode-da, and Owo
Location	Woodland area of extreme southern part of the woodland and tall grass savanna vegetation	Fringe of wooded savanna and rainforest zones, and extends to extreme south of rain forest vegetal zone
Rainfall	1000–1250 mm	Between 1250 mm and 1500 mm in the fringe, and ranging between 1500–1800 mm in the extreme south of the region
Temperature	Ranges between 26° and 32 °C. The average temperature is about 29 °C with humidity as high as 95%.	Ranging from about 26 °C to 29 °C
Vegetation	Wooded savanna	Secondary rain forest with orchard (orange, mango, cashew etc)

Barbour et al. (1982), Ayeni et al. (2006), NBS (2007), Abdulsalam-Saghir and Oshijo (2009), and Ayeni (2012).

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Table 4
Balance between the loss and gain for a specific class between 1972 and 2007 (km^2).

	Pair of years	Built-up	Forest	Cultivations and others	Water bodies
1972 and 1987	Class total (1972)	83 (100%)	42,819 (100%)	13,144 (100%)	27 (100%)
	Class loss (1987)	12 (15%)	23,535 (55%)	2743 (21%)	20 (73%)
	Unchanged 1987	71 (85%)	19,284 (45%)	10,400 (79%)	7 (27%)
	Class gain (1987)	236 (74%)	2572 (6%)	23,438 (64%)	65 (71%)
	Class total (1987)	307 (100%)	21,856 (100%)	33,838 (100%)	72 (100%)
	Image difference	224 (270%)	−20,964 (49%)	20,695 (158%)	45 (168%)
1987 and 2002	Class total (1987)	307 (100%)	21,856 (100%)	33,838 (100%)	72 (100%)
	Class loss (2002)	87 (28%)	10,941(50%)	6993 (21%)	22 (31%)
	Unchanged (2002)	220 (72%)	10,915 (49.9%)	26,846 (79%)	50 (69%)
	Class gain (2002)	583 (66%)	6390 (22%)	10,956 (24%)	112 (61%)
	Class total (2002)	803 (100%)	17,305 (100%)	37,802 (100%)	162 (100%)
	Image difference	497 (162%)	−4551 (21%)	3964 (12%)	91 (127%)
2002 and 2007	Class total (2002)	803 (100%)	17,305 (100%)	37,802 (100%)	162 (100%)
	Class loss (2007)	126 (16%)	5052 (29%)	4335 (12%)	28 (17%)
	Unchanged 2007	678 (84%)	12,253 (71%)	33,466 (89%)	134 (83%)
	Class gain (2007	456 (36%)	3895 (18%)	5151 (12%)	40 (20%)
	Class total (2007)	1,134 (100%)	16,148 (100%)	38,617 (100%)	174 (100%)
	Image difference	330 (41%)	−1156 (7%)	815 (2%)	12 (7%)

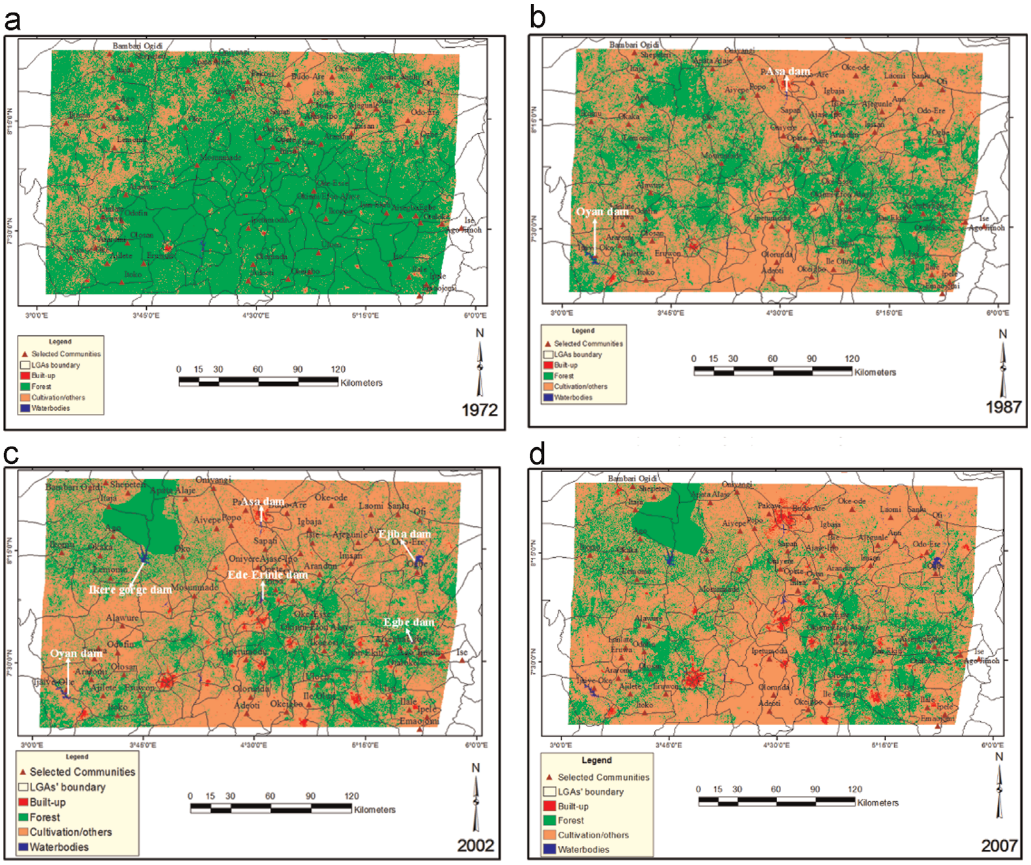

Fig. 3. Classified Images.

Findings showed that little changes occurred between 2002 and 2007 with gain distributions of 36%, 18%, 12%, and 20% for built-up, forest (particularly around the Old Oyo Forest Reserve in north-west of images), cultivation/others, and water-bodies respectively (Table 4, Fig. 3c and d). Although loss and gain changes were detected in each class there were no significant changes as the previous period and is mostly due to the short time span of the assessment (4 years).

The increase in area cover of water is absolutely influenced by area extent of four medium-size earth dams constructed at various times (between 1987 and 2000) vis-à-vis Ikere Gorge (47 km^2), Ejiba (42 km^2), Egbe (37 km^2), and Ede-Erinle (27 km^2) as captured by image classification. Ikere Gorge was constructed in the northern part of the Ogun basin for hydro-

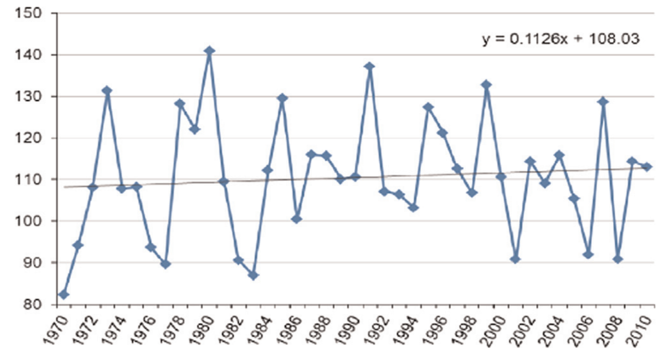

Fig. 4. Historical rainfall (mm).

electric and domestic water supply while Ejiba (in the eastern part of Asa basin) was constructed mainly for irrigation. Unfortunately, Ikere Gorge and Ejiba dams have been abandoned and could not serve the mentioned purposes. On the other hand, it should be noted that the accessible surface waters for communities' use are the small rivers, streams and springs which are not captured in the classification. However, in most of the region, small rivers and surface waters (springs, streams, ponds) are covered by a layer of galleria forest, thus, they are not directly interpretable from low/medium resolution imageries such as Landsat, and therefore creating the erroneous impression that surface water is now converted into forest or something else.

4.2. Trends in rainfall and temperature

The inter-annual variations of the average rainfall from 1970 to 2010 revealed a gradual positive trend in the rainfall with annual increase rate of 0.113 mm (Fig. 4). The annual temperature time-series clearly presented a positive trend over the area with annual increase rate of 0.036 °C (Fig. 5).

4.3. Local experts' knowledge about Environmental Changes

This section discusses the perceptions of local experts on the status of surface water resources availability, land cover and climate changes in their environment between 1970 and 2011. The 65 local experts demonstrated a knowledgeable experience and understanding of the processes affecting changes in surface water, land cover, and climate based on their local observation (Table 5, Figs. 6–8, Appendix A). Almost 95% of the local experts provided meaningful information on surface water resources and land-cover changes, and the perceived associated impacts to their immediate environment. They confirmed that land cover change has occurred for several decades and this is having major impacts on forest, particularly in the southern part of the region. On the average, 86.1% of the experts agreed that there have been changes in the volume of surface water around their communities over the last 40 years Table 5, Fig. 6, Appendix A). It should be noted that the perceptions of local experts on surface water are based on the accessible rivers, springs, streams, ponds and impacts of environmental change on them.

In the woodland, 72.2%, 75.1%, and 77.8% of the experts have observed changes in surface water availability, land cover, and climate (rainfall and temperature) respectively, while 93.1%, 86.2%, and 79.3% of the experts in the forest part of the study area. Considering surface water and land cover, on the average, 47.2% of the woodland LGAs experts claimed to have observed a decrease in surface water and land cover of forest respectively while experts who claimed fluctuation accounted for 13.9% (Table 5, Fig. 7, Appendix A). The forest part revealed a higher variation as 54.0% observed a decrease in surface

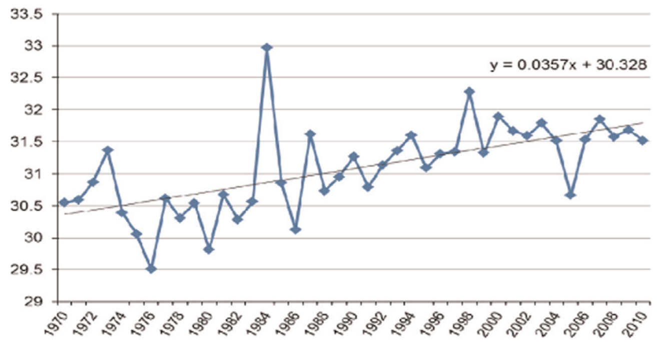

Fig. 5. Historical temperature (°C).

Table 5
Summary of Local experts' perception of changes in surface water, land-cover and climate.

		Change in surface water		Change in land cover		Change in climate			
						Rainfall		Temperature	
		North Freq (%)	South Freq (%)	North Freq (%)	South Freq (%)	North Freq (%)	South Freq (%)	North Freq (%)	South Freq (%)
Change	Yes	26 (72.2%)	27 (93.1%)	27 (75.1)	25 (86.2%)	28 (77.8%)	23 (79.3%)	28 (77.8%)	23 (79.3%)
	No	10 (27.8%)	2 (6.9%)	9 (25.0%)	4 (13.8%)	8 (22.2%)	6 (20.7%)	8 (22.2%)	6 20.7%)
	Total	***36 (100%)***	***29 (100%)***	***36 (100%)***	***29 (100%)***	***36 (100%)***	***29 (100%)***	***36 (100%)***	***29 (100%)***
Rate	Decrease	20 (55.6%)	23 (79.3%)	12 (33.3%)	7 (24.1%)	19 (52.8%)	17 (58.6%)	–	1 (3.4%)
	Increase	2 (5.6%)	3 (10.3%)	10 (27.8%)	6 (20.7%)	3 (8.3%)	4 (13.8%)	22 (61.1%)	20 (69.0%)
	Fluctuation	4 (11.1%)	1 (3.4%)	8 (22.2%)	12 (41.4%)	6 (16.7%)	2 (6.9%)	6 (16.7%)	2 (6.9%)
	No opinion	10 (27.8%)	2 (6.9%)	6 (16.7%)	4 (13.8%)	8 (22.2%)	6 (20.7%)	8 (22.2%)	6 (20.7%)
	Total	***36 (100%)***	***29 (100%)***	***36 (100%)***	***29 (100%)***	***36 (100%)***	***29 (100%)***	***36 (100%)***	***29 (100%)***
Year of observation	> 30 years ago	3 (8.3%)	4 (13.8%)	7 (19.4%)	4 (13.8%)	7 (19.4%)	3 (10.3%)	7 (19.4%)	3 (10.3%)
	30–15 years ago	12 (33.3%)	15 (51.7%)	17 (47.2%)	15 (51.7%)	13 (36.1%)	15 (51.7%)	13 (36.1%)	15 (51.7%)
	< 15 years	11 (30.6%)	8 (27.6%)	6 (16.7%)	6 (20.7%)	8 (22.2%)	5 (17.2%)	8 (22.2%)	5 (17.2%)
	No opinion	10 (27.8%)	2 (6.9%)	6 (16.7%)	4 (13.8%)	8 (22.2%)	6 (20.7%)	8 (22.2%)	6 (20.7%)
	Total	***36 (100%)***	***29 (100%)***	***36 (100%)***	***29 (100%)***	***36 (100%)***	***29 (100%)***	***36 (100%)***	***29 (100%)***

Note: North includes the LGAs and experts located in the northern part of the study area (above Alawure and Efon Alaye communities) while South includes the LGAs and experts located in the southern part of the study area (below Alawure and Efon Alaye). See Fig. 1 and Table 3 for the list of LGAs.

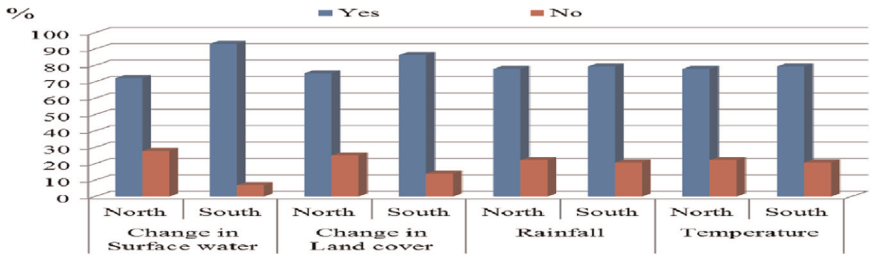

Fig. 6. Perception of occurrence of changes.

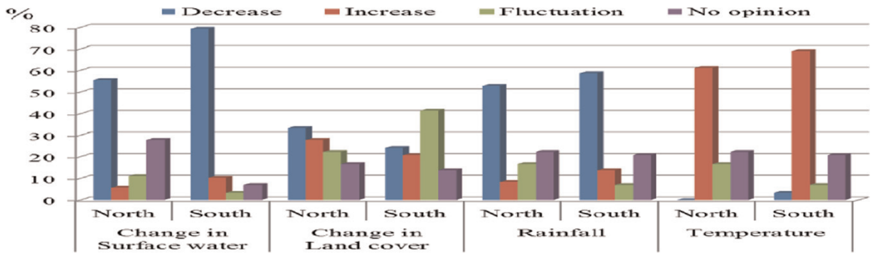

Fig. 7. Perception of rate of changes.

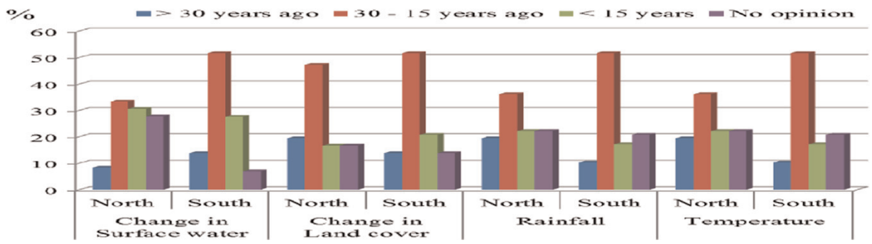

Fig. 8. Perception of year of observation of changes.

water and land cover of forest. On the average, 38.9% of the experts in the woodland and 51.7% of experts in the forest area started observing changes between 30 and 15 years ago (Table 5, Fig. 8, Appendix A) while less than 20% had no opinion in their observations about the changes.

In the region, 53 (81.5%), 52 (80%), and 51 (78.5%) of the experts have observed changes in surface water, land cover, and climate (rainfall and temperature), respectively. Of the 53 experts who observed changes in the surface water, 66.2% claimed to have observed a decrease while experts who claimed fluctuation accounted for 7.7% (Table 5, Fig. 6, Appendix A). The majority of experts (average 41.5%) mostly linked the changes in surface water to some 30 and 15 years (1980–1995) ago (Table 5, Fig. 7, Appendix A). On the average, less than 18.5% had no opinion in their observations about the changes.

Of the 52 experts who observed changes in the land cover, 29.2% and 24.6% claimed to have observed a decrease. About 30.8% experts argued there were fluctuation (Table 5, Fig. 7, Appendix A). The majority of experts (average 49.2%) observed changes in land cover between 30 and 15 years ago (Table 5, Fig. 8, Appendix A). About 16.9% and 18.5% observed changes in land cover in some 30 years (i.e. before 1980) ago and in some 15 years (i.e. between 1995 and 2010) ago, while 15.4% had no opinion on when changes started.

On changing climate, 55.4% of the 51 experts claimed to have observed a decrease in rainfall while 65.1% experts claimed that temperature is increasing. About 10.8% and 11.8 experts claimed to have observed fluctuation in rainfall and temperature respectively while 20.5% and 21.5% in same order could not explain their observation (Table 5, Fig. 7, Appendix A). Almost 43.12% observed changes in weather/climate between 30 and 15 years ago while about 15.4% and 20.5% observed changes in weather/climate in some 30 years ago and 15 years ago (Table 5, Fig. 8, Appendix A).

These findings are coherent with the land cover changes measured with the Landsat images (Fig. 3) and temperature result in Fig. 5 but in contrast with the result of historical rainfall in Fig. 4. The reason is, the local experts' perception was focused mainly on rainfall inconsistency and it impacts on environmental resources, particularly continuous annual decline in agricultural products and stream volume/flow in recent years.

The local experts attributed the causes of changes observed to seven factors including demeaning culture in most communities; intensive farming activities and bush burning; charcoal production activities amongst the youths; low rainfall over the years; rapid urbanization and population increase; poor conservation of water and forest resources, and illegal logging and deforestation activities (Appendix A). Investigations of these factors are outside the scope of this present study. It is a research gap brought by this study that subsequent research should tackle. Nonetheless various studies have discussed these factors in various ways relative to the region e.g. Ayeni et al. (2014) discussed demeaning culture and socio-cultural roles to improve surface water resources in part of the region; intensive farming activities and bush burning (Subair (2009); charcoal production activities amongst the youths (Adebayo et al., 2011; Oriola and Omofoyewa, 2013); low rainfall and variability over the years (Ayeni, 2011; Akinsanola and Ogunjobi, 2014; Ayeni, 2014); rapid urbanization and population increase (Ayeni et al., 2012; Oyeleye, 2013); poor conservation of water and forest resources (Ayeni, 2013), and illegal logging and deforestation activities (Adekunle et al., 2010). Information from the majority of local experts revealed that changes mostly impacted the forest cover in the woodland part except in a few cases where local experts argued that changes has caused a decrease in cultivation/others.

4.4. Associated risk

The changes in land cover and climate will affect the surface water system of the area and this will subsequently have direct impact on the water resources base-availability, usage, and management. The threats of water shortage/stress in the region of Nigeria (see also Vörösmarty et al., 2005, Ayeni et al., 2015) may increase in magnitude and scope due to the direct impact of uncontrolled deforestation which may likely in future results to the drying up of freshwater resources. For instance, uncontrolled land cover change coupled with climate variability/change and the rapid economic growth in recent years have resulted in a situation where increase in water consumption is fast exceeding supply and have led to severe groundwater over-exploitation in regions of the world (World Bank, 2014). This therefore portends high risks in the region and will continue to have negative impacts on the availability, quantity and quality of water resources (Adeniji-Oloukoi etal., 2013). Uncontrolled land cover and climate changes, whether natural or human-induced, will increase occurrences of water stress and indirectly exacerbate the impacts of deforestation through direct long-term impacts on land and soil quality, soil structure, organic matter content and ultimately on soil moisture levels. Poor land management, techniques and excessive deforestation through intensive cultivation and over overgrazing may exacerbate undue stress on water resources. The region is also at risk of reduction in flow of rivers and streams that feed various dams in the region since the future social, economic and environmental impacts on natural systems will be widespread through further alteration in precipitation and runoff, changes in water use etc. In addition, urbanization, intensified land use and forestry/climate-change related alterations in rainfall, surface water availability and water quality can substantially alter the risks of floods (EEA, 2005) and increase the burden of water related diseases.

4.5. Adaptation measures and recommendations

To manage these risks, this study therefore put forward the following adaptation measures and recommendations that would promote a sustainable environment in the region

- Changing to adaptable cropping patterns where less water-demanding and drought resistant crops are encouraged. The policy should incorporates surface water catchments conservation in the rural communities via planting of trees with dense canopy and highly adapted to tropical environment (Russell-Smith et al., 2007; Buijs, 2009; Tran et al., 2010).
- Land use changes should be considered where current agricultural patterns are no longer sustainable in terms of water consumption. This would ultimately bring global environmental and socio-economic benefits for rural and urban

Table A1
Summary of information generated from local Experts in the North LGAs.

S/n	North LGAs	*Local Expert's Communities*	Surface water			Land cover				Climate			*Causes/Remarks*
			Change in surface water	*Rate*	*Time start*	*Change in Land cover*	*Impacts*	*Changing rate*	*Time start*	*Change in climate*	*Rate*	*Time start*	
1	Asa	1. Oniyangi	No	–	–	Yes	FC −ve	Gradual	45 years	Yes	Rf −ve, Temp +ve	40 years	Farming and bush burning
		2. Oniyere	No	–	–	No		–	–	No	–	–	–
		3. Pakoyi	Yes	Decrease	30 years	Yes	FC −ve	Slow	30 years	Yes	Rf −ve, Temp +ve	30 years	Farming and bush burning
		4. Popo	Yes	Decrease	20 years	Yes	FC −ve	Slow	20 years	Yes	Fluctuating	20 years	Farming and sand mining
		5. Sapati	Yes	Decrease	12 years	Yes	BU +ve	Fast	12 years	Yes	Rf −ve, Temp +ve	10 years	Closeness to the city
2	Ifelodun	1. Ajegunle	Yes	Fluctuating	40 years	Yes	FC −ve	Gradual	40 years	Yes	Rf −ve, Temp +ve	40 years	–
		2. Abudu	Yes	Fluctuating	45 years	Yes	FC −ve	Slow	25 years	No	–	–	Rural farming and bush burning
		3. Budo-Are	Yes	Decrease	10 years	Yes	FC −ve	Fast	25 years	Yes	Rf −ve, Temp +ve	30 years	Poor conservation
		4. Igbaja	Yes	Decrease	15 years	Yes	FC −ve	Fast	20 years	Yes	Fluctuating	20 years	Population and rural farming
		5. Laomi	Yes	Decrease	12 years	No	FC −ve	–	–	Yes	Rf −ve	5 years	Low rainfall over the years past
		6. Oke-ode	No	–	–	Yes	FC & CO −ve	Gradual	40 years	Yes	Rf −ve, Temp +ve	40 years	Low rainfall over the years past
		7. Oloruntele	No	–	–	No	–	–	–	No	–	–	–
3	Irepodun	1. Ajase-Ipo	Yes	Decrease	18 years	Yes	FC −ve, CO +ve	Slow	30 years	Yes	Rf −ve, Temp +ve	30 years	Population and rural farming
		2. Arandun	Yes	Decrease	20 years	Yes	FC −ve, CO +ve	Slow	25 years	Yes	Rf −ve, Temp +ve	20 years	Population and rural farming
		3. Inisan	Yes	Decrease	5 years	Yes	FC −ve, CO +ve	Fast	10 years	Yes	Rf −ve, Temp +ve	10 years	Demeaning culture
		4. Isie	No			Yes		Gradual	40 years	Yes	Rf −ve, Temp +ve	40 years	Demeaning culture
4	Itesiwaju	1. Ago	No	–	–	No	–	–	–	No	–	–	–
		2. Ikomu	Yes	Decrease	30 years	Yes	FC −ve, CO +ve	Slow	30 years	Yes	Rf −ve, Temp +ve	30years	Low rainfall, farming, logging and bush burning
		3. Lemomu	Yes	Decrease	20 years	Yes	FC −ve, CO +ve	Slow	20 years	Yes	Fluctuation	20 years	Low rainfall, farming, logging and bush burning
		4. Okaka	Yes	Decrease	12 years	Yes	FC −ve, CO +ve	Fast	15 years	Yes	Rf −ve, Temp +ve	10 years	Gods of land are angry

5	Ibarapa East	1. Alawure	Yes	Increase	40 years	Yes	FC -ve, CO +ve	Gradual	40 years	Yes	Rf −ve, Temp +ve	40 years	Poor conservation
		2. Eruwa	Yes	Low flow	35 years	Yes	FC −ve, CO +ve	Slow	25 years	No	–	–	Low rainfall, farming, logging and bush burning
		3. Lanlate	Yes	Decrease	10 years	Yes	FC −ve, CO +ve	Fast	32 years	Yes	Rf +ve, Temp +ve	30 years	Low rainfall, farming, and logging
6	Orire	1. Aiyepe	Yes	Decrease	15 years	Yes	FC −ve, CO +ve	Gradual	30years	Yes	Rf −ve, Temp +ve	20 years	Low rainfall, farming, and logging
		2. Apata Alaje	Yes	Decrease	12 years	No	FC −ve, CO +ve	–	–	Yes	Rf −ve	5 years	Low rainfall, farming, and logging
		3. Mosunmade	No	–	–	Yes	FC -ve, CO +ve	Gradual	40years	Yes	Rf -ve, Temp +ve	40 years	Low rainfall, farming, and logging
		4. Oko	No	–	–	No	–	–	–	No	–	–	Farming and charcoal activities
7	Saki Eest	1. Ibudo Agbede	Yes	Decrease	8 years	Yes	FC −ve, CO +ve	Slow	30 years	Yes	Rf +ve, Temp +ve	10 years	Low rainfall and farming
		2. Bambari Gidi	No	–	–	Yes	FC +ve	Slow	20 years	Yes	Fluctuating	15 years	Forest onservation
		3. Itaja	Yes	Decrease	10 years	Yes	FC −ve, CO +ve	Slow	10 years	Yes	Rf +ve, Temp +ve	5 years	Low rainfall and farming
		4. Shepeteri	No	–	–	Yes	FC +ve	Slow	10 years	Yes	Fluctuating	20 years	National forest reserave
8	Yagba West	1. Aun	Yes	Decrease	10 years	No	–	–	–	Yes	Rf −ve	5 years	National forest reserave
		2. Odo-Ere	Yes	Increase	12 years	Yes	WB +ve	Fast	12 years	Yes	Fluctuating	15 years	Irrigation scheme
		3. Ofi	Yes	Disappearing	25 years	No	FC −ve	Gradual	–	No	–	–	Low rainfall and farming
		4. Ogbe	Yes	Decrease	30 years	Yes	FC −ve	Gradual	40 years	Yes	Rf −ve, Temp +ve	40 years	Low rainfall and farming
		5. Sanlu	Yes	Decrease	20 years	Yes	FC −ve	Fast	–	No	–	–	Low rainfall and farming

Note:- BU +ve – Increase in built-up, CO −ve – decrease in cultivation/others, CO +ve – increase in cultivation/others, FC −ve – decrease in forest cover, FC +ve – increase in forest cover, WB +ve – increase in waterbodies, Rf −ve – decrease in rainfall, Rf +ve – increase in rainfall, Temp −ve – decrease in temperature, Temp +ve – increase in temperature

Table A2
Summary of information generated from local Experts in the South LGAs.

S/n	South LGAs	*Local Expert's Communities*	Surface water			Land cover				Climate			*Causes/Remark*
			Change in surface water	*Rate*	*Time start*	*Change in Land cover*	*Impacts*	*Rate*	*Time start*	*Change in climate*	*Rate*	*Time start*	
1	Akoko N/E	1. Ago Jimoh	Yes	Decrease	15 years	Yes	CO +ve, BU +ve	Fast	10 years	Yes	Rf −ve, Temp +ve	20 years	Farming and urban influence
		2. Ise	Yes	Decrease	12 years	Yes	FC −ve, CO +ve	Fast	20 years	Yes	Rf −ve, Temp +ve	20 years	Farming and herds men
		3. Otaloke	Yes	Decrease	30 years	Yes	FC −ve, CO +ve	Slow	30 years	Yes	Rf −ve, Temp +ve	30 years	Farming, bush burning and logging
2	Efon	1. Okinni/Efon	Yes	Decrease	20 years	Yes	FC −ve, CO +ve	Gradual	20 years	Yes	Rf −ve, Temp +ve	20 years	Farming, logging and bush burning
		2. Ikogosi	Yes	Decrease	12 years	Yes	FC −ve, CO +ve	Slow	10 years	Yes	Rf −ve, Temp +ve	10 years	Farming, logging and bush burning
		3. Oke-Esse	Yes	Fluctuating	40 years	Yes	FC −ve, CO +ve	Gradual	40 years	Yes	Rf −ve, Temp +ve	40 years	Intensive rural farming and bush burning
3	Gboyin	1. Aisegba	Yes	Decrease	30 years	Yes	FC −ve, CO +ve	Slow	25 years	No	–	–	Intensive rural farming
		2. Egbe	Yes	Increase	30 years	Yes	CO +ve, WB +ve	Slow	25 years	Yes	Rf +ve, Temp +ve	30 years	Surface dam and bush burning
		3. Ijan Ekiti	Yes	Decrease	25 years	Yes	FC −ve, CO +ve	Gradual		No	–	–	Intensive rural farming
4	Odo-Otin	1. Inisa	Yes	Decrease	12 years	Yes	FC −ve, CO +ve	Fast	10 years	Yes	Rf −ve	10 years	Farming and charcoal activities
		2. Opete	Yes	Decrease	20 years	Yes	FC −ve, CO +ve	Fast	20 years	Yes	Rf −ve, Temp +ve	20 years	Farming and charcoal activities
		3. Oyan	Yes	Decrease	15 years	Yes	FC −ve, CO +ve	Fast	15years	Yes	Rf −ve	15 years	Farming and charcoal activities
		4. Eripa	Yes	Decrease	18 years	Yes	FC −ve, CO +ve	Gradual	30 years	Yes	Fluctuating	30 years	Farming and charcoal activities
5	Ife North	1. Adeoti	Yes	Increase	20 years	Yes	FC −ve, CO +ve	Fast	20 years	Yes	Rf −ve, Temp +ve	20 years	Demeaning culture
		2. Ipetumodu	Yes	Decrease	12 years	Yes	FC −ve, CO +ve	Fast	10 years	Yes	Rf −ve, Temp +ve	10 years	Demeaning culture
		3. Olorunda	Yes	Decrease	12 years	No	FC −ve, CO +ve			Yes	Rf −ve	15 years	Abuse of tradition
6	Ile Oluji/ Oke Igbo	1. Okeigbo	No	–	–	No	–	–	–	No	–	–	There is still virgin forest
		2. Ile Oluji	Yes	Decrease	30 years	Yes	FC −ve, CO +ve	Slow	30 years	Yes	Rf +ve, Temp −ve	30 years	Low rainfall and logging
		3. Uloen	Yes	Decrease	20 years	Yes	FC −ve, CO +ve	Gradual	20 years	Yes	Rf −ve, Temp +ve	20 years	Low rainfall, logging and bush burning

7	Odeda	1. Araromi	Yes	Decrease	12 years	Yes	FC −ve, CO +ve	Fast	10 years	Yes	Rf −ve, Temp +ve	10 years	Low rainfall and logging
		2. Ajilete	Yes	Decrease	40 years	Yes	FC −ve, CO +ve	Gradual	40 years	Yes	Rf −ve, Temp +ve	40 years	Low rainfall and farming
		3. Eruwon	Yes	Decrease	35 years	Yes	FC −ve, CO +ve	Slow	25 years	No			Low rainfall and farming
		4. Ijaiye-Oke	Yes	Decrease	10 years	Yes	FC −ve, CO +ve	Fast	25 years	Yes	Rf −ve, Temp +ve	30 years	Low rainfall and farming
		5. Olosan	Yes	Increase	35 years	No				No			Low rainfall and farming
		6. Itoko	Yes	Decrease	12 years	Yes	FC −ve, BU +ve	Fast	12 years	Yes	Rf −ve	5 years	Low rainfall and farming
8	Owo	1. Emaojomi	No			No				No			Nature
		2. Ilale	Yes	Decrease	18 years	Yes	FC −ve, CO +ve	Slow	30 years	Yes	Rf −ve, Temp +ve	30 years	Demeaning culture, rainfall and farming
		3. Ipele	Yes	Decrease	20 years	Yes	CO +ve, BU +ve	Fast	20 years	Yes	Fluctuating	20 years	Urbanization, culture, farming
		4. Iso	Yes	Decrease	30 years	Yes	CO +ve, BU +ve	Fast	40 years	Yes	Rf −ve, Temp +ve	40 years	Demeaning culture and rainfall

Note:- BU +ve – Increase in built-up, CO −ve – decrease in cultivation/others, CO +ve – increase in cultivation/others, FC −ve – decrease in forest cover, FC +ve – increase in forest cover, WB +ve – increase in waterbodies, Rf −ve – decrease in rainfall, Rf +ve – increase in rainfall, Temp −ve – decrease in temperature, Temp +ve – increase in temperature populations through sustainable land management practices that would help in maintaining significant biodiversity and resilient agro-ecosystems in preserving and conserving forest for improved surface water catchment and water availability (Fasona et al., 2013).

- As the region is under the influence of an appreciable quantity of annual rainfall, water harvesting techniques should be initiated and encouraged among the water users through the construction of dams, pans and storage tanks etc.
- Governments and stakeholders should adopt environmental risk management approach which focus on the resilience of development efforts to present-day land cover change, weather variability as well as projected climate change and water-related investment projects.
- Raising of risk awareness to the grassroot populations by governments and environmentalist/stakeholders by means of rural public events or face-to-face communication. Risk awareness via this approach is inevitable to find ways to disseminate information on natural hazard and risk continuously, especially in times of climate change.
- Environmental education using adapted teaching materials to both learned and unlearned populations e.g. framing images, posters, public presentations, video etc on impacts of land cover and climate change will be a crucial to achieving sustainable adaptations (See.
- Lastly, the use of state-of-art remote sensing technologies is very important in today's forest monitoring and management and assists in monitoring land cover, surface water extent and availability in the area (Ayeni, 2013). This will help populations to plan ahead against dry season.

5. Conclusion

Although local experts' perceptions have some rules of rationality and origins that differ from an empirical science assessment, this study shows that local experts were able to qualitatively describe their understanding of spatio-temporal changes in complex social–ecological systems. Such historical information and perceptions have great potential to complement scientific information and enhance our understanding of ecosystem processes. This is especially important in places where scientific information on changes in environmental variables is not well documented. In conclusion, local experts' knowledge has often been ignored in environmental management due to scientific ability to use technologically acquired data/information (e.g. rainfall, temperature, remotely sensed data etc.) to monitor variables (climate change, land-use/land-cover changes etc.) that are difficult to detect through mere observation. This study shows a high consistency between indigenous people's perception of LCC, remotely sensed LC products, climate and surface water situations. Therefore, local experts knowledge as part of indigenous people's perception could be used as participatory approach involving the communities in assessing the impact of environmental change on an important service of forest ecosystems such as fresh water provision.

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Appendix A

See Tables A1 and A2

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