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Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing Escherichia coli in the Calgary Health Region: emergence of CTX-M-15-producing isolates. Antimicrob. Agents Chemother. 51: 1281-1286.

Pelczar JR, Harley JP, Klein DA (1993). Microbiology: Concepts and Applications. McGraw-Hill Inc., New York, pp. 591-603.

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Full Length Research Paper

Histopathological changes induced by copepoda parasites infections on the gills of economically important fish mugilidae (*Liza falcipinnis* and *Mugil cephalus*) from Ganvie area of Lac Nokoue, Republic of Benin

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Histopathological changes induced by copepods parasitic infection on the gills of economically important fish, *Mugil cephalus* and *Liza falcipinnis* from Ganvie area of Lac Nokoue were examined from December 2011 to July 2012. Histopathological changes shows that the nature of damage observed in the gill of both *M. cephalus* and *L. falcipinnis* remained the same. Histopathological observation reveals serious damage of lamellae and gill filaments due to attachment and feeding of copepods. The resultant hypertrophy of the underlying epithelial reducing the surface area for effective respiration, could lead to suffocation, particularly at high temperature. The histopathological changes enacted by the copepods parasites will eventually lead to reduced growth, low productivity and mortality resulting in economic loss.

Key words: Copepoda, parasite, histopathology, Mugilidae, Ganvie.

INTRODUCTION

Parasites have recently been highlighted as serious pathogenic problems in mullet fish in marine and brackish water. Among the parasites, copepod family is commonly found on fishes cultured in brackish water (Noor et al., 2012). With the developments of brackish and marine aquaculture, the importance of parasitic copepods as disease causing agents has become more obvious. Copepods parasites attached to gill filaments produce these small foci of eroded host tissue. Apparently, feeding involves external digestion (Halisch, 1940; Kabata, 1970); parasites produce digestive secretions which partially dissolve tissue, allowing easier ingestion. As the number of attached parasites increases, the destruction of respiratory epithelium progresses. Erosion can extend beyond the epithelial lining, resulting in obstructed branchial blood vessels. Irritation often results in responsive hyperplasia of epithelium, which as infestation intensifies, extends over considerable areas (Kabata, 1970; Paperna Overstreet, 1981). Both processes reduce the respiratory function of the gills.

Parasitic surveys of copepods (Figure 1) have been described from different hosts and locations in different

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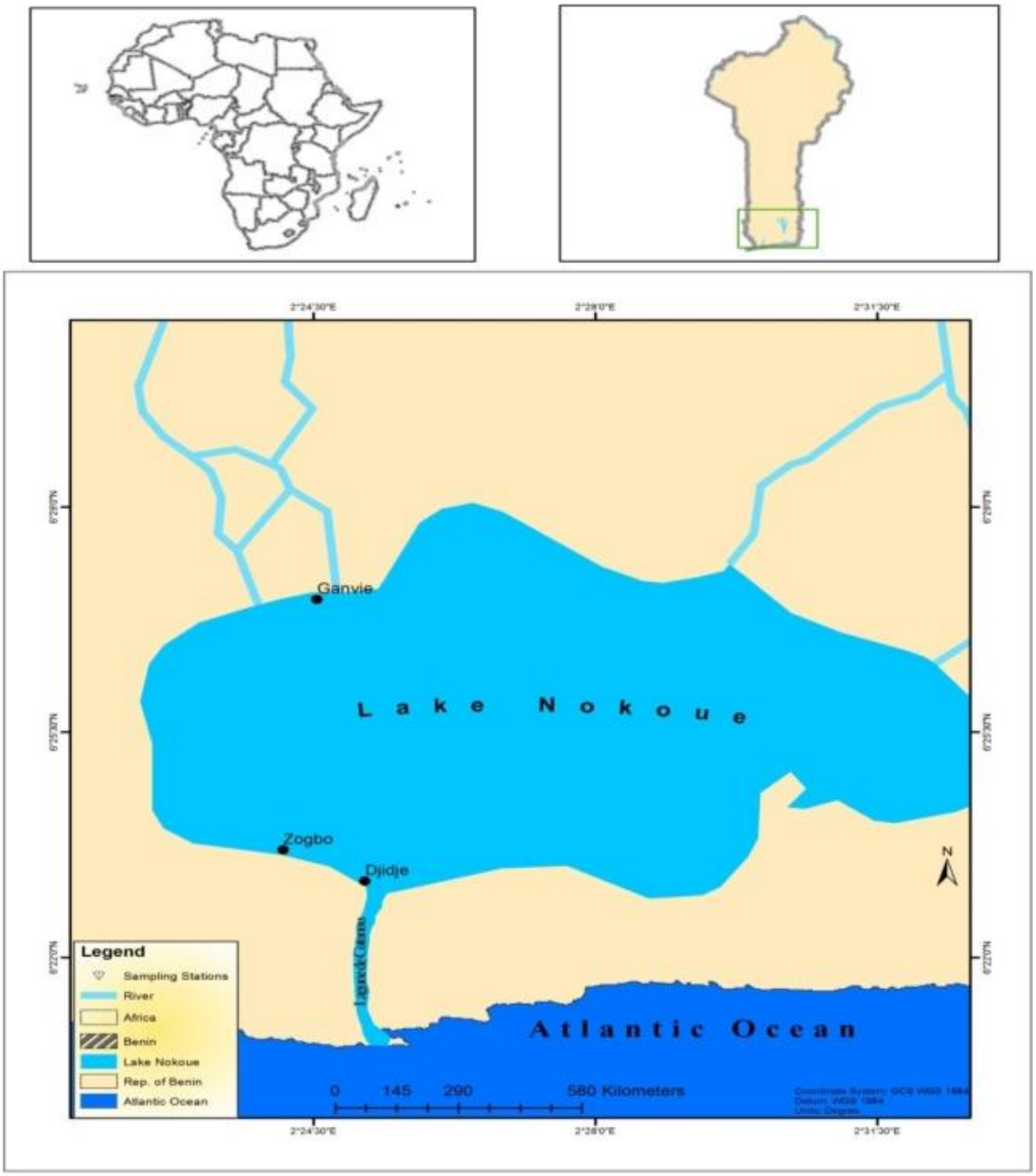

Figure 1. Location of Ganvie in lake Nokoue lagoon.

parts of the world: In Israel, Parpena and Lahav (1971), in Turkey, Koyun et al (2007), in Mexico, Suárez-Morales and Santana-Piñeros (2008), in Canada (Hogans,1989), in Sri Lanka, Vinobaba (2007), in Nigeria, Aladetohun et al. (2013) and in Republic of Benin, Aladetohun et al. (2013). However, histopathological impact of the parasites on their hosts remains to be determined. The aim of this study was to determine the host-parasite interaction, with specific reference to the pathology induced by copepod parasites on economically important fish *Mugil cephalus* and *Liza falcipinnis* in the Ganvie area of Lac Nokoue lagoon in Republic of Benin.

MATERIALS AND METHODS

The study area

The study site, Ganvie area (Figure 1) is located at the northern part of the lake Nokoue lagoon, near the floating village of Ganvie where the water is characterized by a high level of organic pollution (Laleye et al., 2003).

Lake Nokoue (Figure 1) is the largest lagoon (Moreau, 2004), it is a shallow, sub-tropical coastal lagoon (6°25N, 2°36E) with surface of 150 km and stretches 20 km in its east-west direction by 11 km n the north-south direction (Laleye et al., 2003). Lake Nokoue opens directly into the Atlantic Ocean through channel at cotonou which is about 24.5 km long.

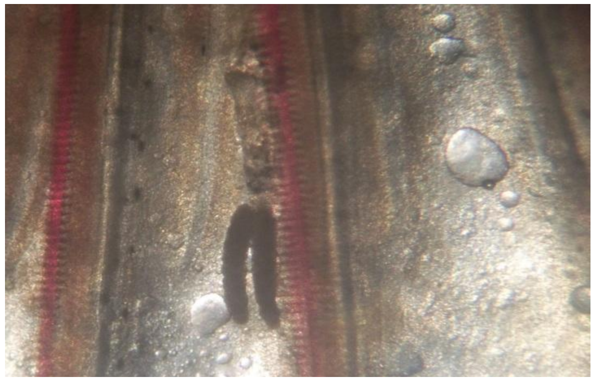

Figure 2. Attachment of copepod in the gill of host fish.

Table 1. Prevalence and mean intensity of *Ergasilus latus* infections in *M. cephalus* and *L. falcipinni* from Ganvie area of Lac Nokoue.

Species of fish	No of fish examined	No of fish infested	No of copapod parasite	Percentage prevalence (%) for MC and LF	Mean intensity for MC and LF
M. cephalus	115	90	18		
L. falcipinnis	132	110	15	80.97	0.165
Total	247	200	33		

Histopathological analysis

Damaged fish tissues (gills) (Figure 2) were taken from the parasite attachment area of infested fishes and were cut out in fresh condition fixed in 10% buffered neutral formalin (Buoins fluid). The tissues were then processed using a 24 h automatic tissue processor for a time ranging from 17 to 19 h to process. The tissue processor contains 12 beakers, 10 glass beakers and 3 thermostatically controlled electric metal beakers containing paraffin wax.

The tissue (gills) were transferred to Beaker 1, containing 10% formal saline for complete fixation and then transferred to beaker 2-8 containing different ascending grades of dehydrating fluids (alcohol ranging from 70% alcohol to absolute alcohol (isopropyl alcohol, which helps in removing water from the tissue samples and then into beakers 9 and 10 containing clearing agents[xylene I and II] which completely clears the dehydrating agent off the tissue sample.

The tissue samples were later transferred into beakers 11 and 12 containing embedding agent, that is, molten paraffin wax which provides solid support upon embedding.

The tissues after being processed are embedded using an automatic embedding centre. Embedding is a process of submerging a tissue in a metal plastic disposable embedding mould containing molten paraffin wax, which became solidified when it was cold. This formed a support medium for the tissue during sectioning.

Sections of the tissue were cut using a microtome and were placed in a clean grease free slide which was then placed on a hot plate for 30 min in order for section to adhere to the slides. The staining method used was the H&E staining method. This method was used in order to demonstrate the general structure of the tissues. These were then dewaxed in xylene. The processed section were later taken to water by using descending grades of alcohol, that is, from absolute alcohol >95% alcohol, >70% alcohol, water. It was stained in haematoxylin for 10 min, then rinsed in water.

These were differentiated in 1% acid alcohol (a dip), rinsed in water and then blued in tap water for 5 min. This was counter stained in 1% Eosin for 2-5 min and rinsed in tap water, then dehydrated using ascending grades of alcohol (70% alcohol9, 5% alcohol absolute). These were cleared in xylen, mounted using D.P.X (a mountant) and viewed under the microscope.

RESULTS

M. cephalus and *L. falcipinnis* were found to be infested ergasilids (*Ergasilus* Latus, *Ergasilus Lizae* and *Nipergasilus bora*), attached to the gill filament (Figure 2). The list of hosts sites species with corresponding hosts parasites species are given in the Tables 1, 2, 3 and 4. The prevalence and intensity of infection varied with the host fish (Tables 1, 2, 3 and 4).

Adult females ergasilids are attached to primary lamella (gill fillaments) of the host fish with their claw-like secondary antennae close to the gill arch near the base of the fillament (Figure 2). The lamellae cells were pyknotic and degenerating as a result of second antannae insertions by the ergasili parasites (Figures 3 and 4).The infested gill rakers and gill lamellae were almost totally lost (Figures 3 and 4). It was also observed that the proliferated epithelium contained hypertrophic cells with intercellular spaces in which wandering cells such as blood granulocites, lymphocites, vacouole cells and coarse eosinophilic granular cells were evident.

Table 2. Prevalence and mean intensity of *Ergasilus lizae* infections in *M. cephalus* and *L. falcipinnis* from Ganvie area of Lac Nokoue.

Species of fish	No of fish examined	No of fish infested	No of copapod	Percentage prevalence (%) for MC and LF	Mean intensity for MC and LF
M. cephalus	115	90	20		
L. falcipinnis	132	110	7	80.97	0.135
Total	247	200	27		

Table 3. Prevalence and mean intensity of *Nipergasilus bora* infections in *M. cephalus* and *L. falcipinnis* from Ganvie area of Lac Nokoue.

Species of fish	No of fish examined	No of fish infested	No of copepod	Percentage prevalence (%) for MC and LF	Mean intensity for MC and LF
M. cephalus	115	90	56	80.97	0.77
L. falcipinnis	132	110	98		
Total	247	200	154		

Table 4. Summary of the percentage prevalence and mean intensity of *E. latus*, E. *lizae* and *N. bora*parasite in *M. cephalus* and *L. falcipinnis* from Ganvie area of Lac Nokoue.

Parasite	No of fish examined		Total	No of infested fish		Total	Percentage prevalence (%)	No of copapod parasite		Total	Mean intensity
	M. cephalus	*L. falcipinnis*		M C	L F			M C	L F		
E. latus	115	132	247	90	110	200	80.97	18	15	33	0.165
E. lizae	115	132	247	90	110	200	80.97	20	7	27	0.135
N. bora	115	132	247	90	110	200	80.97	56	98	154	0.77

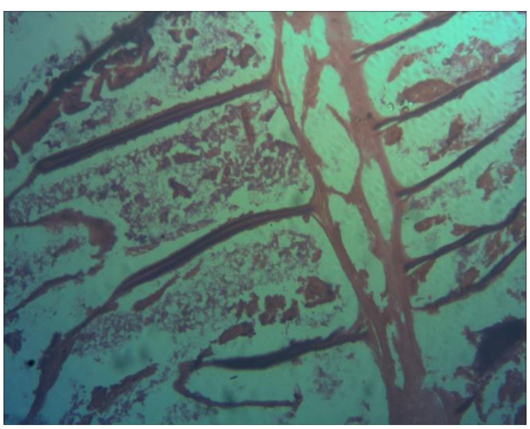

Figure 3. High destruction of gill filaments, gill lamella, gill rakers, gill arches and detachment of epithelial cells in lamella of *M cephalus*.

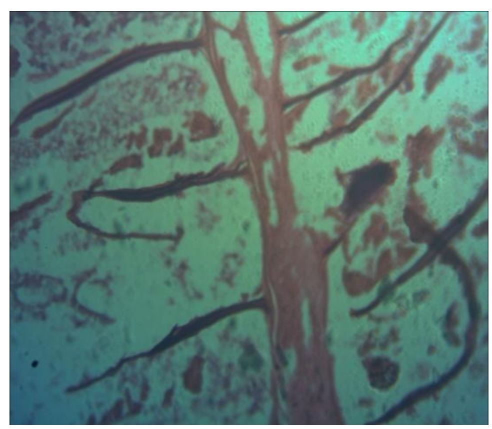

Figure 4. High destruction of gill filaments, gill lamella, gill rakers, gill arches and detachment of epithelial cells in Lamella of *L. falcipinnis*.

DISCUSSION

Copepods feed by browsing on the fish gill epithelium or by ingesting blood from ruptured blood vessels.

Apparently, feeding involves external digestion (Halisch, 1940; Kabata, 1970); parasites produce digestive secretions which partially dissolve tissue, allowing easy ingestion.

The research carried out shows the gill beneath the parasites, it seems like a cavity which is probably related to the enzymatic reaction of the gill epithelium beneath the parasite. This report coincides with that of Vinobaba (2007) in his work on histopathological changes induced by ergasilid copepod infections on the gills of food fish from Batticaloa lagoon, Sri Lanka.

In this work, the copepod parasites found caused changes on the gill fillaments through feeding. Both the gill lamella and the gill arch and gills rakers were badly damaged. This was also reported by Rameshkumar and Samuthirapandian (2013) on histopathological changes in the skins and gills of some marine fishes, Overstreet (1978), Ben-Hassin (1983), Morella and Garippa (2001) in his work on parasites of grey mullets from Mistras lagoon, Western Meditar-ranean, Ben-Hassin (1983) in his work on copepod parasites of mugilidae.

This research work reveals lost of gill fillament and totally almost missing. Parperna and Lahav (1971), reported on copepod parasite (*Ergasilus lizae*) in grey mullets in Israel and Vinobaba (2007) in his work on histopathological changes induced by ergasilid copepod infections on the gills of food fish from Batticaloa lagoon also gave the same report.

Copepod parasites attaches to the host using various appendages modified for gasping and this activity can led to secondary infection by pathogenic organism (e.g bacteria, fungi, and virus) and cause mass mortality.

High intensity of infection of these copepods may lead to serious damage of the gills and therefore show pronounced impact on the histology and lead to mortality (Vinobaba, 2007). Environmental change, especially habitat degradation by anthropogenic pollutants and oceanographic alterations induced by climatic changes and temperature dependent can influence parasitic-host interaction (Abalaka et al., 2010).

In conclusion, the resultant hypertrophy of the underlying epithelial reducing the surface area for effective respiration could lead to suffocation, particularly at high temperature. The histopathological changes enacted by the copepods parasites will eventually lead to reduced growth, low productivity and mortality resulting in economic loss.

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African Journal of Environmental Science and Technology

Review

Performance evaluation of constructed wetlands: A review of arid and semi arid climatic region

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Aiming at environmental pollution control through the use of constructed wetlands systems (CWs) in arid and semi arid climatic region, a detailed review of CWs was undertaken. Given the practical application and simplicity of the technology, principles for building phytotechnology-ecohydrology environment used for wastewater remediation is appropriate. The ability of wetlands to filter, absorb and metabolize suspended and dissolved matter is the basic philosophy behind constructed wetlands. Ecohydrology is the sub-discipline shared by ecological and hydrological sciences that is concerned with the effects of hydrological processes on the distribution, structure and function of ecosystems, and on the effect of biological processes on the elements of the water cycle. It is actually the application of science and engineering to examine problems and provide solutions involving plants. This paper reviewed the efficiency of constructed wetland in arid and semi arid conditions. The use of sub surface flow (SSF) constructed wetland as a post treatment technique have been found as promising technology for wastewater treatment in arid and semi-arid areas.

Key words: Arid, ecohydrology, efficiency, phytotechnology, sub surface flow (SSF), semi-arid.

INTRODUCTION

The threat an environment faces with technological development while using fossil fuels and other inputs for the manufacturing as well as the transportation sector are very immense. Always, nature tries to cope with the changes in the ecosystem, such as contaminants, as long as the adsorption capacity is not surpassed. The rates at which contaminants are released from the sources (point or non-point sources) as compared with the cleaning potential of the components of the ecosystem (Biotic or abiotic) differ.

The major contaminant polluting fresh water ecosystem are macro and micro nutrients from agricultural fields (Barrow,1993; Mihret et al., 2013), heavy metals and carbon dioxide from manufacturing and transportation industries, organic and inorganic contaminants from municipalities and brown fields at the outskirt and inner cities (Rehm and Reed, 2000). To curb the problem of contaminants from municipalities at a certain extent, the author of this review suggested urban farming with partially treated wastewater as a feasible option (Mihret, 2013).

Depending on the effluent sources, the natures of individual contaminants vary. Some are biodegradable with limited spatial and temporal dimensions. Others needs more time and space for degradation or adsorbed by living organisms. Another category of contaminants; conservative contaminants, retain their existence but take part in the assimilation and dissimilation processes. The non-conservative contaminants participate in the assimilation and dissimilation process and are liable for chemical changes. Their destiny may be photochemical degradation, chemical or microbial transformation (Figure 1).

The application of constructed wetlands to facilitate

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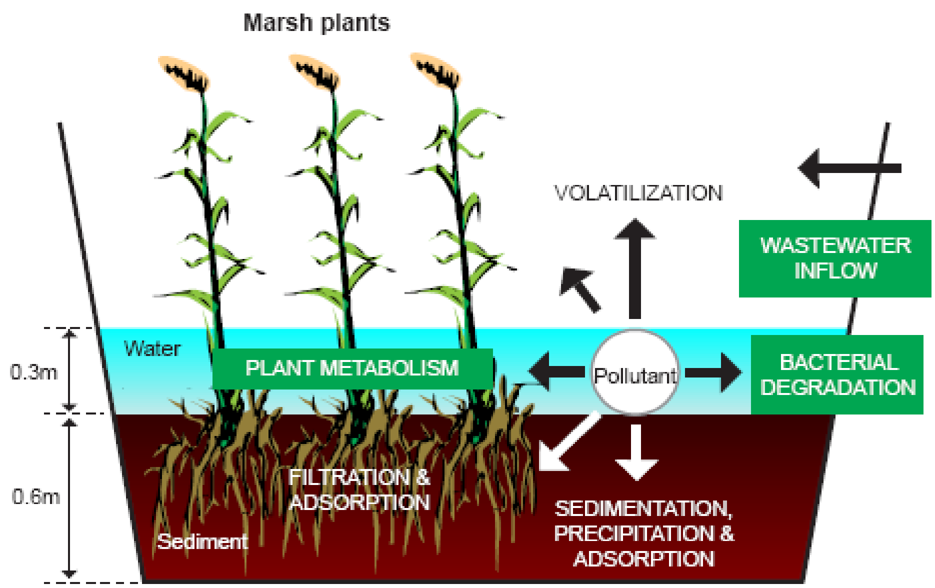

Figure 1. Pollutant removal processes in a constructed wetland system (Wetlands International, 2013).

these processes is a young post treatment technique used in developed countries. How effectively does it purifies contaminated environment? Could be a major question pointed out in relation to constructed wetlands. Competitive efficiency and effectiveness when compared with other techniques leads to the desired sustainability; which calls for evaluation of the existing constructed wetlands in arid and semi arid conditions for proper articulation of future processes.

In the following sections ecohydrology and phytotechnology concepts in the process of sludge treatment are presented, followed by constructed wetland efficiency determination, discussion and finally a conclusion.

Objectives

The plant-water-soil-microorganism interaction plays a major role in the ecohydrology concept. Soil microorganisms and plants connect the lithosphere, hydrosphere and the atmosphere.

The strength of the interaction determines the reliability of the bridge in transferring the contaminated input to environmentally friendly output (Wetland International, 2013). Investigating the efficiency of constructed wetlands in arid and semi arid conditions are the major objective of this paper.

ECOHYDROLOGY AND PHYTOTECHNOLOGY

Ecohydrology is the subdiscipline shared by ecological and hydrological sciences that is concerned with the effects of hydrological processes on the distribution, structure and function of ecosystems, and on the effect of biological processes on the elements of the water cycle (UNEP, 2004). Phytotechnology describes the application of science and engineering to examine problems and provide solutions involving plants (UNEP, 2004). Examples of phytotechnology applications include (UNEP, 2004):

1. The use of plants to reduce or solve pollution problems. Example, the use of natural wetland (W_n) for wastewater treatment.
2. The replication of ecosystems and plant communities to reduce or solve a pollution problem. Examples, constructed wetlands for treatment of wastewater or diffuse pollution sources.
3. The use of plants to facilitate the recovery of ecosystems after significant disturbances. Examples are coal mine reclamation and the restoration of lakes and rivers.
4. The increased use of plants as sinks for carbon dioxide to mitigate the impacts of climate change. Examples of this are reforestation and afforestation.
5. The use of plants to augment the natural capacity of urban areas to mitigate pollution impacts and moderate energy extremes. An example is the use of rooftop vegetation or "green roofs".

Plants possess the ability to absorb carbon dioxide in the process of assimilation from the atmosphere to emit oxygen and thus purify air (Cavalcanti, 2003). Furthermore, in the last three decades, scientists in Europe and America mimicked the way nature coped up polluted environment, and used these naturally pollution adaptive techniques to treat sewage in sewage works, as well as recently to detoxify soil (Rehm and Reed, 2000) and

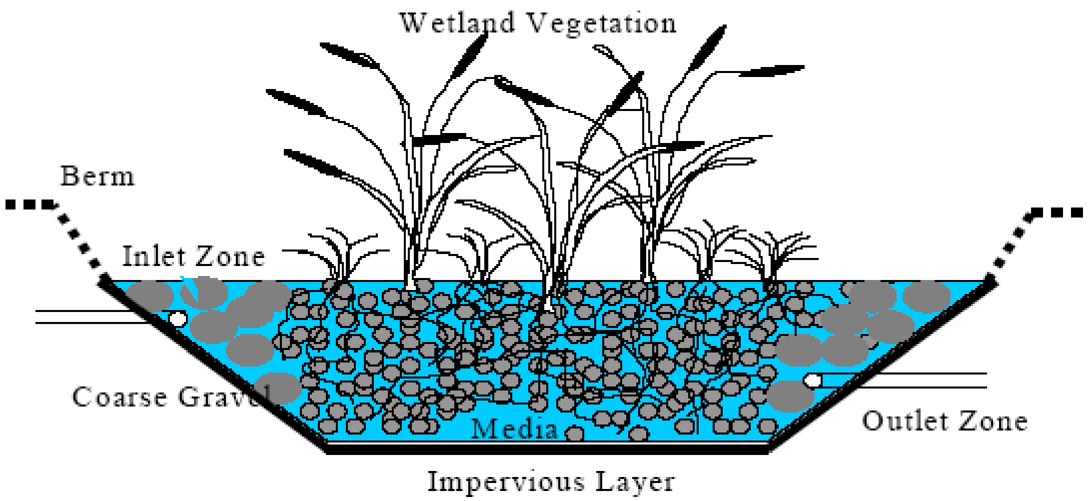

Figure 2. Subsurface flow constructed wet land (Sauer and Kimber, 2001).

sludge using constructed wetlands. Constructed wet lands are among the different techniques used in this field. Constructed wetlands are either free surface flow (FSF) type or sub surface flow type (SSF). The next section deals with the philosophy behind constructed wetlands.

Constructed wetlands

The ability of wetlands to filter, absorb and metabolize suspended and dissolved matter is the basic philosophy behind constructed wetlands. Scientists and engineers are very interested and now working together to mimic these natural systems for handling wastewaters and agricultural run-off (UNEP, 2004). This has prompted the construction of artificial wetlands to cope with the diffuse pollution originating from agriculture, septic tanks, and other sources. In some countries, for instance the U.S., legislation prohibits the drainage of wetlands unless another wetland of the same size is constructed elsewhere (UNEP, 2004).

Constructions of artificial wetlands look like an attractive and cost-effective phytotechnology concept that can be used for controlling various types of wastewater (UNEP, 2004). These wetlands are usually constructed so that water flows primarily over the sediment and through vegetation, or as vegetated submerged bed systems in which water flow is engineered for contact with plant roots.

They are excavated with a shallow gradient in soils of low permeability (Wetland International, 2013; UNEP, 2004) (or lined with an impermeable barrier and then filled with an appropriate soil). They are then either planted or vegetated naturally. Based on the hydrologic scenario in the basin, constructed wet lands are classified into two classes; sub-surface flow and free surface flow types.

Sub-surface flow wetlands

These are shallow excavations (1-1.5 m deep) with a synthetic or clay liner to prevent infiltration of water. They are filled with a media through which the liquid to be purified must flow. All in all, the water flows under the surface of the ground. The filter media can be anything from soil to light, expanded clay aggregate, but 5-10 mm gravel (Wetland International, 2013) is the most common. An inlet zone (Figure 2) made from soil aggregates of larger size ensure the influent liquid is distributed effectively into the media.

A similar outlet zone collects the treated liquid in drainage pipes which pass through the liner into a level control chamber where a simple plastic tube or swivel pipe allows the liquid level in the wetland to be controlled. Area requirement for a sub surface flow depends on the daily BOD_5 loading. The following relation (Equation 1) can be used for calculation (Wetlands International, 2013).

$$A_h = KQ_d (\ln C_o - \ln C_t) \quad (1)$$

Where, A_h = surface area of bed, m^2
K = rate constant, $m\ d^{-1}$
Q_d = average daily flow rate of wastewater ($m^3\ d^{-1}$)
C_o = average daily BOD_5 of the influent ($mg\ l^{-1}$)
C_t = required average daily BOD_5 of the effluent ($mg\ l^{-1}$)

The value of K = 5.2 was derived for a 0.6 m deep bed and operating at a minimum temperature of 8°C

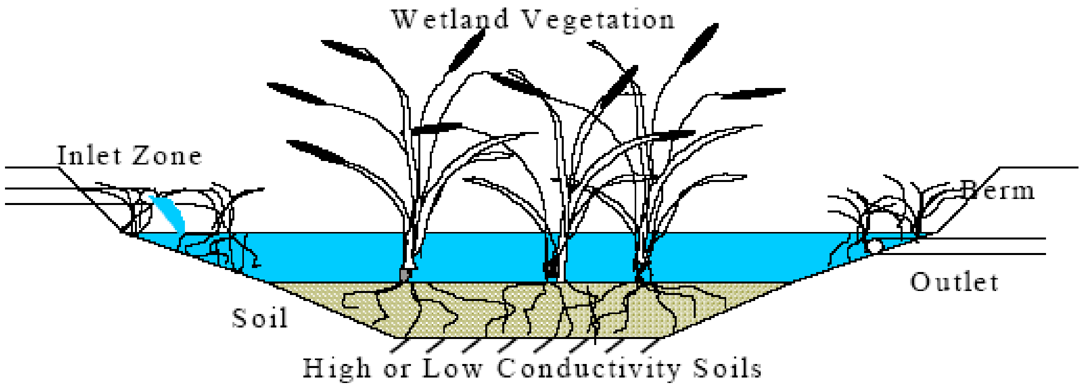

Figure 3. Free surface flow constructed wetland (Sauer and Kimber, 2001)

(Wetlands International, 2013). For less biodegradable wastewater, K-values of up to 15 may be appropriate. Using this formula, a minimum area of 2.2 m^2 $capita^{-1}$ is obtained for the treatment of domestic sewage. In practice, most design systems operate on the basis of 3-5 m^2 cap^{-1} (Wetlands International, 2013).

Free surface flow wetlands

Most free surface flow wetlands are artificial shallow marshy lands or shallow ponds filled with aquatic plants (Wetlands International, 2013). They are very shallow excavations or shallow earth banked lagoons enclosing an area of land demarcated for the purpose. The name free surface comes from the thin free water layers which are formed at the surface (Figure 3).

Soil or some other media such as gravel provides the growing media for the marsh plants. To avoid short-circuiting the surface should be virtually flat with a very gentle slope towards the outlet end (Wetlands International, 2013). The inlet zone distributes the waste-water (Figure 3) over the inlet end of the wetland, and a collection channel collects the treated liquid at the outlet end. The wastewater flows along the surface allowing settlement of solids and coming into contact with the bacterial populations on the surface of the media and plant stems.

These wetlands can serve small communities as natural wetlands and can be incorporated into the treatment systems for larger communities as well (UNEP, 2004). They can also be constructed to treat agricultural runoff or other non-point sources of pollution and are especially well suited for use in surface-mined areas (UNEP, 2004). This reference also mentioned additional ecological advantages, such as nitrogen and saltwater filtering, supply of water and nutrients, production of food and support of endangered species that can possibly increase the economic advantages as compared to conventional wastewater treatment plants.

In general, the effectiveness of phytoremediation technique in constructed wet lands depend on: geology of the site selected, hydrogeology, aquifer characteristics, soil conditions, air quality, climatic conditions, geochemistry, type and distribution of microorganisms, presence and distribution of contaminants and vegetation (UNEP; 2004). Vegetation type and characteristics, microorganism type and distribution, and soil characteristics remains influential through out the life time of constructed wetlands. Better insights of these three parameters are very crucial when dealing with the effectiveness and efficiency of constructed wetlands. In the following sections, some facts about sludge microorganisms, site soil conditions and plants adaptive to highly sludge loaded wastewater and their role in waste water treatment are presented.

Vegetation

Hydrophytes (wetland plants) serve as storage sites for carbon and nutrients and play a role in the movement of gases to and from the hydrosol (wetland soils) (UNEP, 2004). Oxygen is transported from the air through the plant into the rhizome (root zone) and from the soil too. Special types of plants (plants having aerenchym tissue) which are capable of trapping atmospheric oxygen to incorporate it into the soil with their root system are preferred for constructed wetlands. This process ensures that aerobic respiration can be maintained by the non-photosynthetic portion of the hydrophyte tissues; aerenchym tissue; that are buried in the anoxic hydrosol (Wetland international, 2013). Through symbiotic relation-ship some of this oxygen becomes available to the microbes associated with the rhizome.

Various plant species can be used in constructed wetlands (De Sousa et al., 2003). Depending on the nature of the plants they can be used for shallow marsh, marsh and deep marsh lands. Some of this plant species are presented in Table 1.

Table 1. Wetland plant species (Source; Wetland international, 2013).

Planting zone	Common name	Scientific name
Marsh and deep marsh (0.3-1.0 m)	Common Reed	*Phragmites karka*
	Spike Rush	*Eleocharis dulcis*
	Greater Club Rush	*Scirpus grossus*
	Bog Bulrush	*Scirpus mucronatus*
	Tube Sedge	*Lepironia articulata*
	Fan Grass	*Phylidrium lanuginosum*
	Cattail	*Typha angustifolia*
Shallow marsh (0-0.3 m)	Golden Beak Sedge	*Rhynchospora corymbosa*
	Spike Rush	*Eleocharis variegata*
	Sumatran Scleria	*Scleria sumatrana*

Soil nutrients

Hydrophyte growing in the constructed wetland as well as microorganisms in the soil needs optimum level of nutrients in the soil. The levels of essential nutrients control how well the plants (and microbes) grow. For optimum growth, plants require a certain ratio of specific nutrients.

If this nutrient ratio is not balanced, plant and microbial growth is badly affected. Unbalanced nutrient availability affects the growth rate of preferred microbes for waste treatment. Unbalanced ratios change the microbial population and generate smelly metabolites from anaerobic pathways with sulfur and nitrogen containing compounds (Rehm and Reed, 1999).

Microbial activity

Wetland bacteria consume the water soluble organic compounds such as hydrocarbons and BOD (see the reverse mineralization processes in the above reaction). Bacteria contain unique enzymes which allow them to metabolize the suspended organic compounds. In the dissimilation process, the aerobic bacteria produces metabolites which are incorporated into cell mass, used as energy, and/or are converted to nontoxic biological wastes (Rehm and Reed, 1999). Water soluble organic compounds are used as an energy or carbon source by other bacteria, fungi and hydrophytes. Another specific example could be the conversion of ammonium to nitrate by the bacteria nitrosomonas.

$$NH_4^+ + 2O_2 \xrightarrow[\text{Bacteria}]{} NO_3^- + N_2 \;\; H_2O$$

This reaction to get to completion about 4.6 mg.L^{-1} of oxygen is required per gram of ammonia nitrogen (Cheremisinoff et al., 1990). The optimum combined effect of all the parameters stated above gives optimal effectiveness and efficiency for constructed wetlands. Constructed wetland efficiency evaluated in arid and semi arid climatic conditions are presented in the following section.

APPROACH

Analysis on the performance of constructed wetlands was done to evaluate research outputs in arid and semi arid climatic regions. Research outputs based on the numbers of papers published in over 13 journal sources, web pages and papers accepted for publication from presentation on an international conference on constructed wetlands for water pollution control were used for this review.

In view of the current demand of this review, the performance assessment assignment employed a range of tools to gather and analyze data from secondary sources. The review approach considered and used specific indicator parameters important for the environment. The parameters used include:

1. Chemical oxygen demand (COD)
2. Biological oxygen demand (BOD)
3. Total suspended solids (TSS)
4. NH_4-N (ammonia nitrogen)
5. Total Kjeldahl nitrogen (TKN)
6. Total phosphors (TP)
7. Fecal coliforms (FC)

Relevant research documents have been reviewed during data collection and thoroughly reviewed during the preparation of this report. The data collected includes a summary of performance reports, scientific reviews and project completion reports and others.

Performance indicator parameters were computed as a percentage of pollutant reduction as compared to its initial pollutant level. The specific methods used for the study was presented below each case studies investigated.

Findings from a case study held in arid climatic condition (Egypt) and another in semi arid climatic condition are investigated. In addition, a summary of the efficiency of constructed wetlands in tropic and sub-tropic condition are taken from a PhD work of Hristina Bojcevska (Bojcevska, 2010), PhD student in Ecology/Wetland Engineering, Linköping, Sweden. The main intention of this study paper was to find an effective wetland type that can best suit arid and semi arid conditions.

Case study 1: Combining UASB technology and constructed wetland for domestic wastewater reclamation and reuse (El-Khateeb and El-Gohary, 2003)

In this paper the performance efficiency of constructed wetlands in Egyptian conditions are compared. For the study, two treatment schemes consisting of an up-flow anaerobic sludge blanket reactor (UASB) followed by either subsurface flow (SSF) or free surface flow (FSF) constructed wetlands have been investigated. UASB reactor can be briefly described as a system in which substrate passes first through an expanded sludge bed containing a high concentration of biomass (Cavalcanti, 2003; De Sousa et al., 2003).

The sludge in the reactor may exist in granular or flocculent form, but the granular sludge offers advantages over flocculent sludge.

Most of the substrate removal takes place in sludge bed. The remaining portion of the substrate passes through a less dense biomass, called the sludge blanket. The common macrophyte in Egypt *Typha latifolia* (cattail) was used at a planting density of three rhizomes m^{-2}. To evaluate the role of plants in the treatment process, an unplanted gravel bed identical to the SSF unit was operated as control.

During the study period, the wetlands were fed with the UASB effluent at an organic loading rate ranging from 17.3 to 46.8 kg BOD_5/ha·d (55.1 to 134.6 kgCOD.ha^{-1}·d^{-1}). Effectiveness of the system for the removal of key constituents (COD, BOD, TSS, nutrients and FC (fecal coli form) has been investigated.

The results show that, the level of COD_{tot}, and TSS in the final effluent of SSF was lower than that of FSF. The possible justifications could be low flow velocity and higher surface area in the SSF media and lower microbial activities as a result of temperature variation in the case of FSF media.

Subsurface flow wetland has demontrated higher overall efficiency than the unplanted control. FC count showed FSF media's superiority over the control and SSF. The reason could be the possible exposure of the bacteria's for UV in the case of FSF. BOD_{tot} showed more or less the same pattern in both SSF and FSF media (Table 1).

Case study 2: River water quality improvement by natural and constructed wetland systems in the tropical semi-arid region of Northeastern Brazil (Ceballos et al., 2001)

In this paper the performance efficiencies of a natural *Typha* spp. wetland (W_n) and constructed wetland (W_c, SSF type) were compared in northeastern Brazil (Paraiba State). The summary of the outcomes from the evaluation are presented in Table 3.

In the natural wetland, removal values were: 75 and 81% BOD_5; 10-53% total phosphorus; 13-55% ammonia; 89-91% FC. Constructed wetland removals increased with HRT with best results on 10 day. Observed removal values were: 74-78% BOD_5; 58-82% ammonia; 94-98% FC. Despite the high remaining values of FC (1.4 x 10^4CFU in 100 ml), the removals were satisfactory and hydraulic retention time (HRT) dependent, suggesting a gradual optimization of the system with time. The W_c exhibited good efficiency for improving water quality from polluted river.

On her PhD work, Bojcevska (2010) did a summary of the research findings of four different researchers who made their researches using different macrophytes other than *Typha* spp. Here this summary is presented to justify the factors which affect the performance efficiency of the two types of constructed wetlands. Different efficiency values are observed as a function of (Tables 2, 3 and 4):

1. Different types of constructed wetlands used
2. Types of hydrophytes used
3. Hydraulic loading rate
4. Hydraulic retention time

CONCLUSION

A Well-designed constructed wetland can perform better than natural wetlands due to easier control and management (Babatunde et al., 2008). Removal efficiencies of different types of constructed wetlands are different.

FSF wetland is better in some aspects (FC removal) than SSF. SSF wetland also showed some superiority over FSF. Even though both of them showed a similarity in BOD_5 removal, SSF wetland showed higher efficiency in COD and TSS removal.

The type and constituents of waste water in the effluent side deter-mines the type of constructed wetland to be used. For waste water rich in fecal coliform and nitrogen, FSF wetland could be a better preference than SSF. For waste water rich in COD, TSS and TP, SSF is a good choice.

Therefore, appropriate decision during wetland construction affects the performance of the system. Performance efficiency can also be dependent on climatic conditions, hydraulic retention time, macrophytes

Table 2. Main characteristics of the sewage measured at the out let of raw sludge conduit, ASB reactor, SSF and FSF wetlands (standard deviation in brackets) (El-Khateeb and El-Gohary, 2003).

Sludge characteristic	Effluent measured at the out let of			
	Raw sludge	UASB Reactor	Constructed wetland type	
			SSF	FSF
COD_{tot} (mg/L)	620.9 (±189)	241 (±66)	53(±19)	3(± 26)
BOD_{tot}(mg/L)	282 (±68)	99 (±27)	22(±(8.5)	20(± (8)
TSS (mg/L)	191 (±68)	59 (±24)	12± (5.5)	26(± 17)
NH_4-N (mg/L)	31 (±5.5)	33 (±5)	24(±6.6)	16(±5)
TKN(mg/L)	61 (±20)	55 (±16)	40(±15)	32(±16)
TP(mg/L)	5.2 (±1.6)	3.4 (±0.7)	2.1(± 0.9)	2.4(±1)
FC (CFU/100 ml)	2.4×10^9 ($\pm 2.18 \times 10^9$)	1.8×10^8 ($\pm 2.5 \times 10^8$)	8.3×10^4 ($\pm 9 \times 10^4$)	7.2×10^4 ($\pm 8.5 \times 10^4$)

Table 3. Summary of the efficiency observed in natural and constructed wetlands (Ceballos et al., 2001).

Effluent characteristic	Natural wetland (W_n) average efficiency (%)	Constructed wetland (W_c) average efficiency (%)	Remark
BOD_5	78	76	Constructed wetland showed relatively modest efficiency over the natural one
TP	24	12	
NH_4-N	27	70	
FC	90	90	
SS	50	66	

Table 4. Performance efficiencies in relative percentage of some constructed wetlands (CW) located in tropical and subtropical regions concerning a selected number of water quality parameters.

CW type	Area (m^2)	HLR (m/d)	HRT (d)	Mean influent concentration (mg/L)		Reduction in concentration (%)		Reference
FSF	300	-	7-12	COD	155.2	C.P	63	Okurut et al. (1999) as cited by Bojcevska, 2010
						P.M	43	
				PO_4	3.71	C.P	16	
						P.M	37	
SSF	n.i	6.48	n.i	SS	104.8		80	Mashauri et al. (2000) as cited by Bojcevska (2010)
				COD	100.8		66	
		55.2	n.i	SS	101.8		50	
				COD	125.8		50	
FSF and SSF	10	0.018	12.8	PO_4-P	2.39		69	Lin et al. (2002) as cited by Bojcevska (2010)
		0.034	6.8		10.45		45	
		0.135	1.7		5.19		35	
SSF	9.36		5	TRP	15,5	C.P	83	Kyambadde et al. (2004) as cited by Bojcevska (2010)
						M.V	48	

n.i = No information; C.P = *Cyperus papyrus*; P.M = *Phragmites mauritianus*; M.V = *Miscanthidium violaceum*; FSF = free surface flow; SSF = sub surface flow, HLR = hydraulic loading rate; HRT = hydraulic retention time.

growth rate and type, root zone maturity and biofilm formation, substrate characteristics and rate of microbial growth and activity. Selecting an appropriate substrate media that suits the type of available hydrophyte species facilitates better removal efficiency. It is essential to avoid the introduction of an invasive hydrophyte species which does not belong to the prevailing wetland ecosystem (personal view). Constructed wetlands are not recommended for treatment of raw waste water. Combining SSF with UASB gives a higher performance efficiency and longer operation time. The different scenarios presented shows that the use of SSF wetland as a post treatment technique after a UASB reactor is a promising technology for wastewater treatment in arid and semi-arid areas.

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Review

Promoting a low cost energy future in Africa

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With a large part of the population not having access to modern energy services in their daily life, energy poverty remains one of the most pressing development challenges on the African continent. Africa's fossil fuel resources as well as its renewable energy potential can serve as the means to achieve this. For Africa's social and economic development in the 21st century, however, the benchmark for these sources is to deliver energy that is affordable, reliable and sustainable. The following study offers a comparison between the two energy sources according to economic, social and environmental indicators. As the analysis shows, renewable energy technologies increasingly become the preferred option for Africa's energy challenge. The study then concludes with a description of policies for African countries to realize the up-scaling of these technologies.

Key words: Renewable energy, green growth, energy transition.

INTRODUCTION

Energy poverty remains a pressing development challenge in the African continent. A large part of the African population does not have access to power in their daily life. Improving this situation can be achieved through the use of fossil fuel technologies. Indeed, Africa is endowed with immense resources of oil, gas and coal making this an appealing solution. According to estimates, 45 out of the 54 African countries possess proven and/or probable oil and/or gas reserves, and most of these resources are untapped. Nevertheless, Africa is also well-placed to use renewable energy technologies [1](RETs) to address energy poverty due to its abundant renewable energy potential. The hydro potential in Africa alone equals three times Africa's current electricity production (IRENA, 2011a).

Whether Africa relies on fossil fuels or renewable energy technologies for its energy future, is subject of a detailed comparison between these two sources of energy provision. Important criteria are their levelized costs of energy[2] as well as their impacts on energy independence and sustainability. After all, Africa's social

[1]Throughout the text renewable energy is defined as any energy resource that is naturally regenerated over a short time scale and derived directly from the sun (such as thermal, photochemical, and photoelectric), indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy) (EREC, 2004)

[2]Levelized cost of energy (LCOE) is the ratio of lifetime costs to lifetime electricity generation, both of which are discounted back to a common year using a discount rate that reflects the average cost of capital. As an economic assessment of the cost of the energy-generating system including all the costs over its lifetime, it is a useful indicator to compare the electricity costs from different sources.

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Abbreviations: CCS, Carbon Capture and Storage**; CIF,** Climate Investment Fund**; CSP,** Concentrated Solar Power**; GHG** , Greenhouse Gas**; LCOE,** Levelized Cost of Energy**; NAMA,** Nationally Approriate Mitigation Actions**; PV,** Photovoltaic**; RET**, Renewable Energy Technology**; SEFA,** Sustainable Energy Fund for Africa.

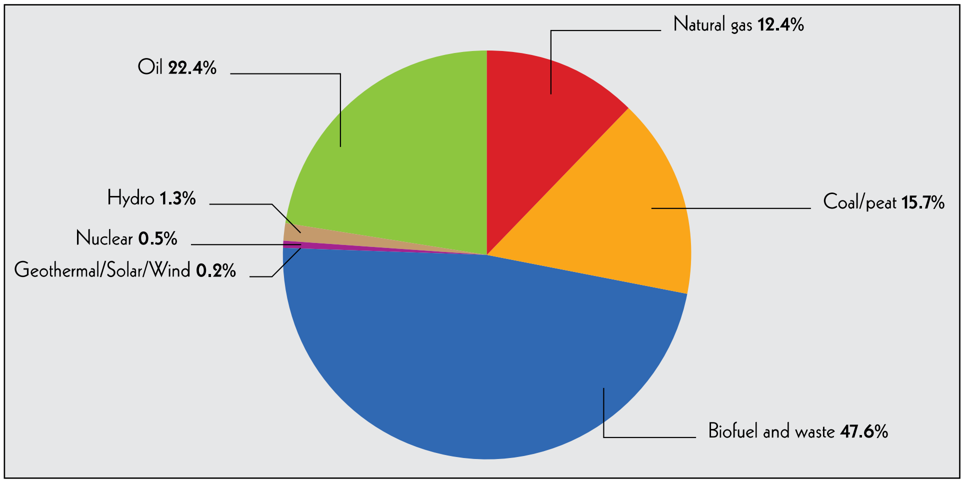

Figure 1. Share of Total Primary Energy Supply in Africa in 2009. Source: IEA (2012).

and economic development in the 21st century depends on affordable, reliable, and sustainable energy. Current trends show that RETs become the more suitable solution over time to reach these objectives.

This study offers a comparison of the two different models for Africa's energy future according to the criteria mentioned above. It summarizes policy options for African policymakers for the large-scale diffusion of the more suitable model, namely RETs, to reach a low cost energy future in Africa. First, a short overview of the energy sector in Africa is given. Then, the study discusses the potential of RETs as compared to fossil fuel technologies. In the end, the study recommends policy options that will contribute to the diffusion of RETs within African countries.

THE ENERGY SECTOR IN AFRICA- FOSSILS FUELS AND RURAL ENERGY POVERTY

Fossil fuels, biofuels and waste currently take up a pivotal role in Africa's energy mix as the most important sources of energy. Fossil fuels represent about 54% of total primary energy supply. As shown in Figure 1, oil, coal and natural gas contributed respectively 22, 16 and 12% of the continent's total primary energy supply in 2009. In 2010, about 80% of the continent's electricity was generated from fossil fuels.

Biofuels and waste, in comparison, amounts to 48% of energy supply (Figure 1). The reliance of many Africans on traditional biomass shows that Africa is still lagging behind the rest of the world in terms of access to modern energy, energy infrastructure, and institutional and technical capacity. Yet, access to modern energy is vital for improving the social and economic conditions for the African population. For instance, electrification enhances lighting, gives access to communication tools, allows the mechanization of production, and enables refrigeration, which in turn helps in improving food security and health-care conditions. Figure 2 shows that the majority of the African population (58%) lacks access to modern energy. However, out of this 58%, 47% are located in rural areas compared to only 11% in urban ones. This trend will not undergo an alteration at least until the near future (Figure 2). As a result, efforts to address energy poverty will have to focus on rural areas.

POTENTIAL OF RENEWABLE ENERGY TECHNOLOGIES COMPARED TO THEIR FOSSIL-FUEL COUNTERPARTS

The most economical solution (in rural areas)

Renewable power generation now represents close to half of new annual capacity additions globally (IRENA, 2013). This massive up-scaling is the main driver behind the trend of falling costs of RETs through economies of scale, learning-by-doing mechanisms and increased competition in the various RETs markets. At the same time, it also shows how increasingly cost competitive RETs are becoming towards fossil fuel technologies.

In fact, renewable energy solutions such as hydro-power, wind power, biomass and solar photovoltaic (PV) are already the most economical solution for off-grid and mini-grid electrification in remote areas in Africa, as well as in some cases of centralized grid supply too (IRENA, 2013). The cost advantage of RETs with regards to off-grid and min-grid electrification can be explained on the basis that only 15% of the rural population in Africa lives within 10 km of a substation (or within 5 km of the medium-voltage line) so that only a small proportion of the rural population can be added to the electricity grid at relatively low cost (Mafalda et al., 2010). But even for grid-connected projects, RETs are increasingly becoming the most economical solution compared to fossil fuel

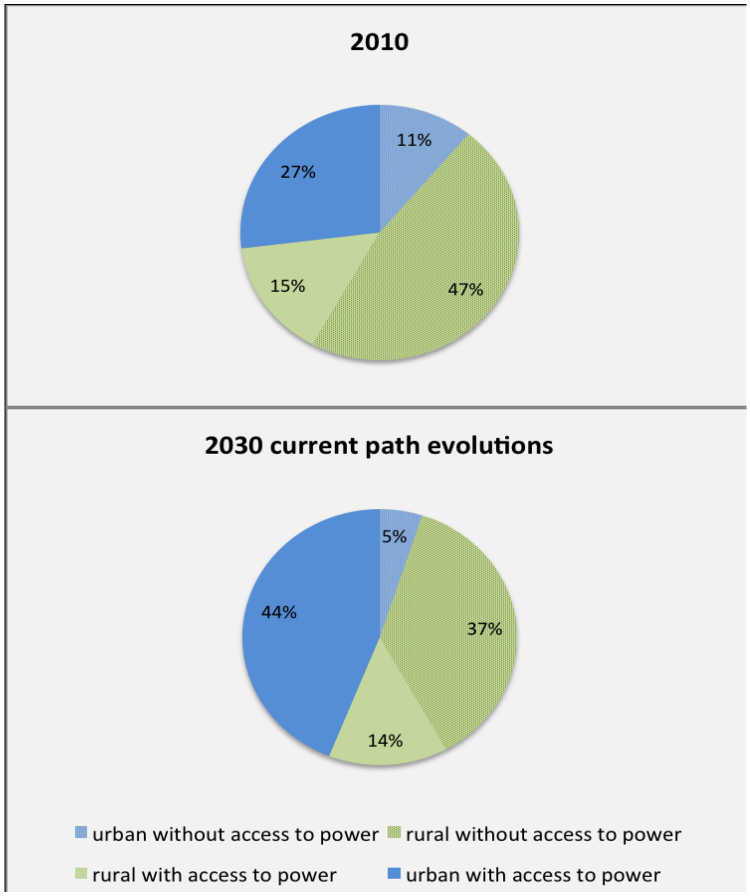

Figure 2. Comparison of Rural and Urban Electricity Access in 2010 and 2030, if current trends in Africa continue. Source: IRENA (2013).

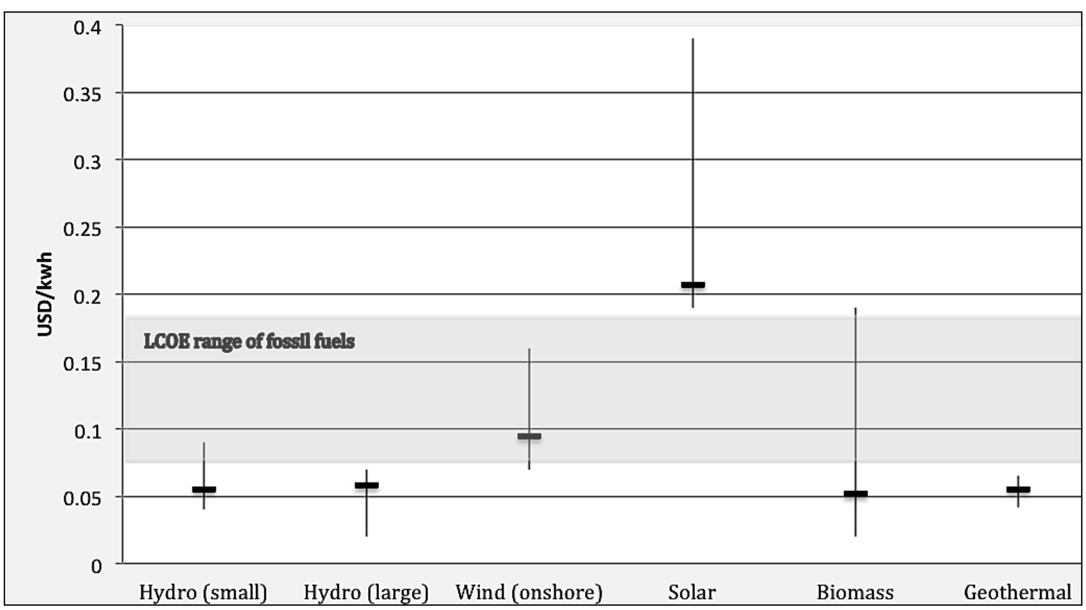

Figure 3. LCOE Ranges of Renewable Energy Technologies in Africa as compared to Fossil Fuels (for selected grid-connected projects). Source: IRENA 2013; IRENA 2012. Note: The horizontal black bars are the capacity weighted average value. Values for LCOE range of fossil fuels summarize ranges from South and East Africa as in IRENA 2013.

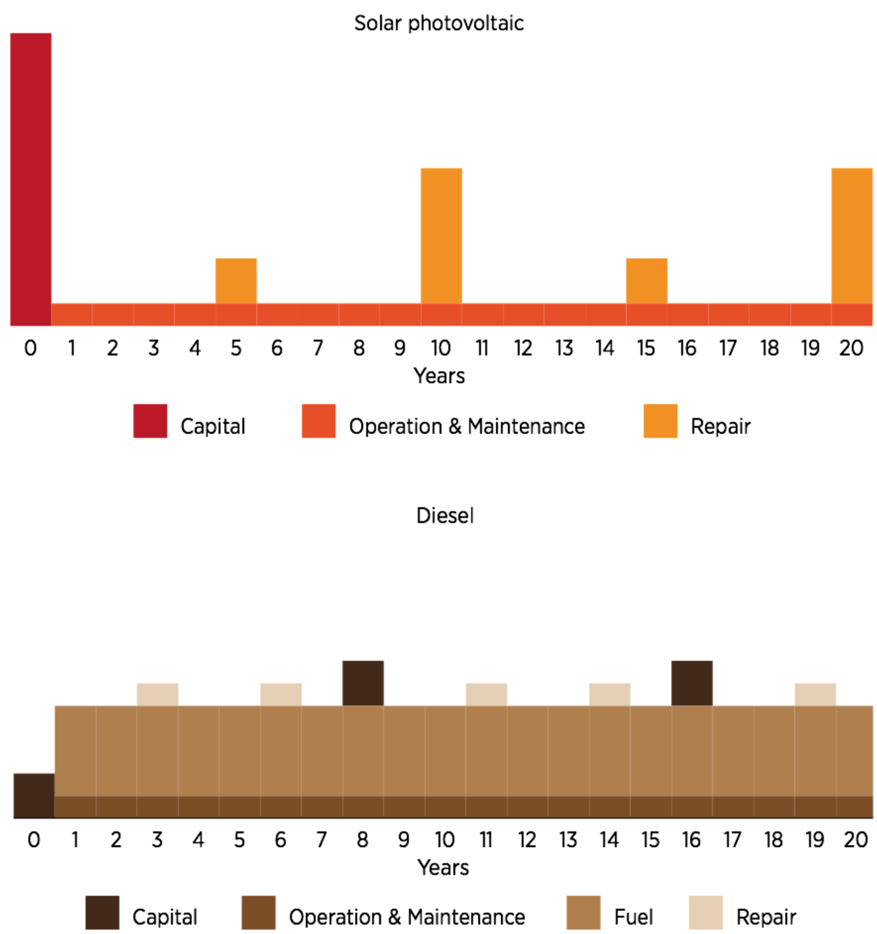

Figure 4. Comparison of Lifetime Costs of PV Project with Diesel Generator (indication). Source: IRENA 2013.

options. As shown in Figure 3 that compares the LCOE ranges of renewable energy and fossil fuels in Africa, hydropower is the cheapest option to generate electricity. Wind, biomass and geothermal remain below or on the same cost level as fossil fuel options. Only solar energy including concentrated solar power (CSP) and PV remains on a level slightly above fossil fuel technologies.

A safe energy model for Africa’s future

RETs have the potential to strengthen the self-sufficiency of African countries, in particular for the countries that depend on the imports of fossil fuels. Figure 4 shows exemplary for PV that RETs see their on-going costs fall once installed. Their lifetime costs are mainly composed of upfront investment costs; costs for operation, maintenance, and repair compose only a smaller fraction. The costs of fossil-fuel technologies represented by the diesel generator in Figure 4, in contrast, are more evenly distributed throughout their lifetime. Lower upfront capital costs are offset by higher ongoing costs, mainly because fossil fuels are continuously needed as input to produce electricity. The oil price as an example of these fossil fuel inputs more than quadrupled to US$ 112 per barrel in 2012 from less than US$ 20 per barrel in 1999 becoming less and less affordable for customers (AfDB, 2013). Thus, fossil fuel technologies have higher ongoing uncertainties in their costs, due to fluctuations in fuel prices whereas all renewable costs are known. Limiting the exposure to the volatility of global fossil fuel markets in terms of price and supply contributes to the energy security[3] of African countries and reduces possible negative economic impacts.

Furthermore, the current prices of oil pose a burden on government budgets in Africa. Fossil fuel subsidies have become more and more unsustainable for many African governments. In 2010-2011, over half of all African countries had some subsidy in place for fuel products, and these subsidies consumed, on average, 1.4% of GDP in

[3]Defined as the availability of sufficient supplies at affordable prices following Yergin, 2006

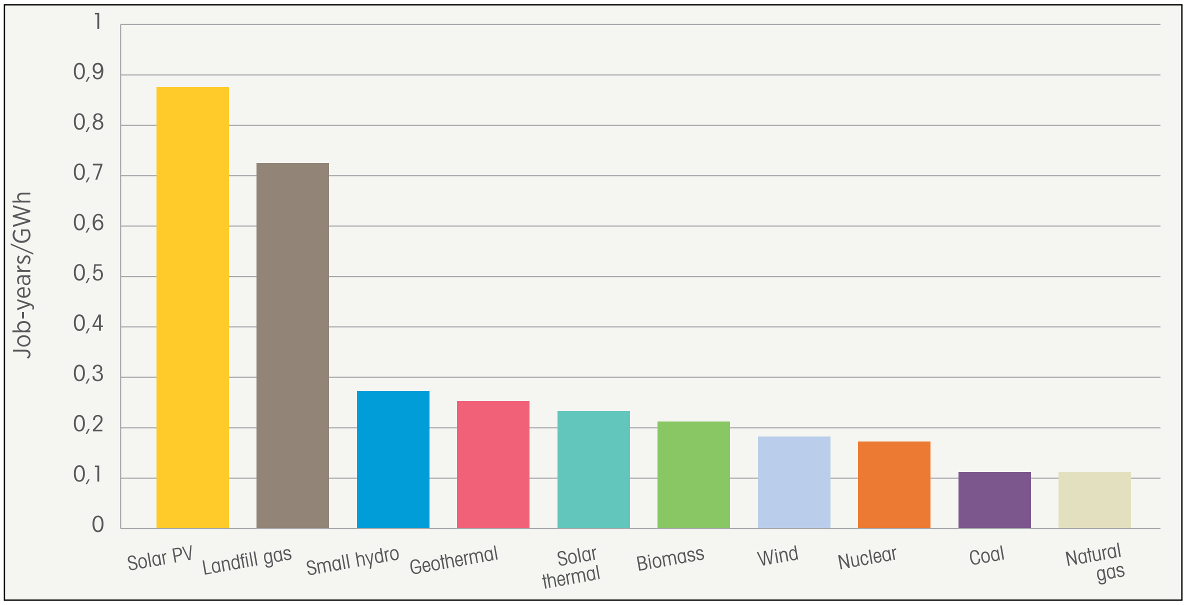

Figure 5. Comparison of Job-Years across different Energy Technologies (Job-Years/GWh). Source: Wei et al. 2010 as illustrated in IRENA (2011b).

public resources. Of the 25 countries with fuel subsidies, the fiscal cost of subsidies in six countries—primarily oil exporters—was at or above 2% of GDP in 2011. The fiscal cost for oil exporters was almost two-and-a-half times the levels observed for oil importers (World Bank, 2012).

The engines of job creation

The promotion of RETs is an efficient way of addressing poverty by creating additional income opportunities and new enterprises. There are important details about job creation with respect to RETs, particularly small scale RETs and their use in rural areas. Many of the jobs are in the service end of the supply chain and include distribution and sales, installation, maintenance, and so on. For some RETs (biogas plants and improved cook stoves) there are also opportunities for manufacturing or construction jobs at the beginning of the supply chain, which are unlikely in the case of PV modules because of the high level of skills required. These job opportunities could potentially benefit women and thus promote gender equality in access to labor markets.

Compared to fossil fuel technologies, the promotion of renewable energy will imply the creation of more job opportunities. Wei et al. (2010) averaged estimates about the labor intensity of different energy technologies over a range of studies. Their findings presented in Figure 5 show that all RETs have higher labor intensity than fossil fuel technologies. For example, the labor intensity of solar PV is more than eight-times that of natural gas. Within RETs, the above-mentioned solar PV has the highest labor intensity whereas wind has the lowest.

The environmentally sustainable energy generation

The deployment of RETs puts Africa on a more environmentally sustainable development path. Firstly, it leads to reduction in GHG emissions. Figure 6 gives a summary overview of lifecycle GHG emissions from a selection of technology groups. The figure reports this number within a range, particularly with regards to bioenergy. This has partly to do with the way lifecycle assessments are conducted. Some will be more comprehensive than others. But it is also related to the range of technologies within each group. Nevertheless, there is little overlap between the worst performing biofuels and the fossil energy sources, all of which produce much higher levels of GHG emissions than the “other renewables”, except when carbon capture and storage (CCS) is used.

Secondly, RETs also result in the reduction of local pollutants, especially particulates. According to Johansson et al. (2012), this could mean “a saving of 20 million disability adjusted life years (DALYs) from outdoor air pollution and more than 24 million DALYs from household air pollution” compared with just the introduction of air-quality legislation that is currently planned. The authors also suggest that these positive health impacts could help to persuade individuals to adopt RETs, more so than asking them to make changes to achieve global benefits such as the mitigation of climate change.

Lastly, non-bioenergy RETs can significantly reduce the rate of deforestation within Africa[4]. The clearing of forests serves as an important source of energy and food

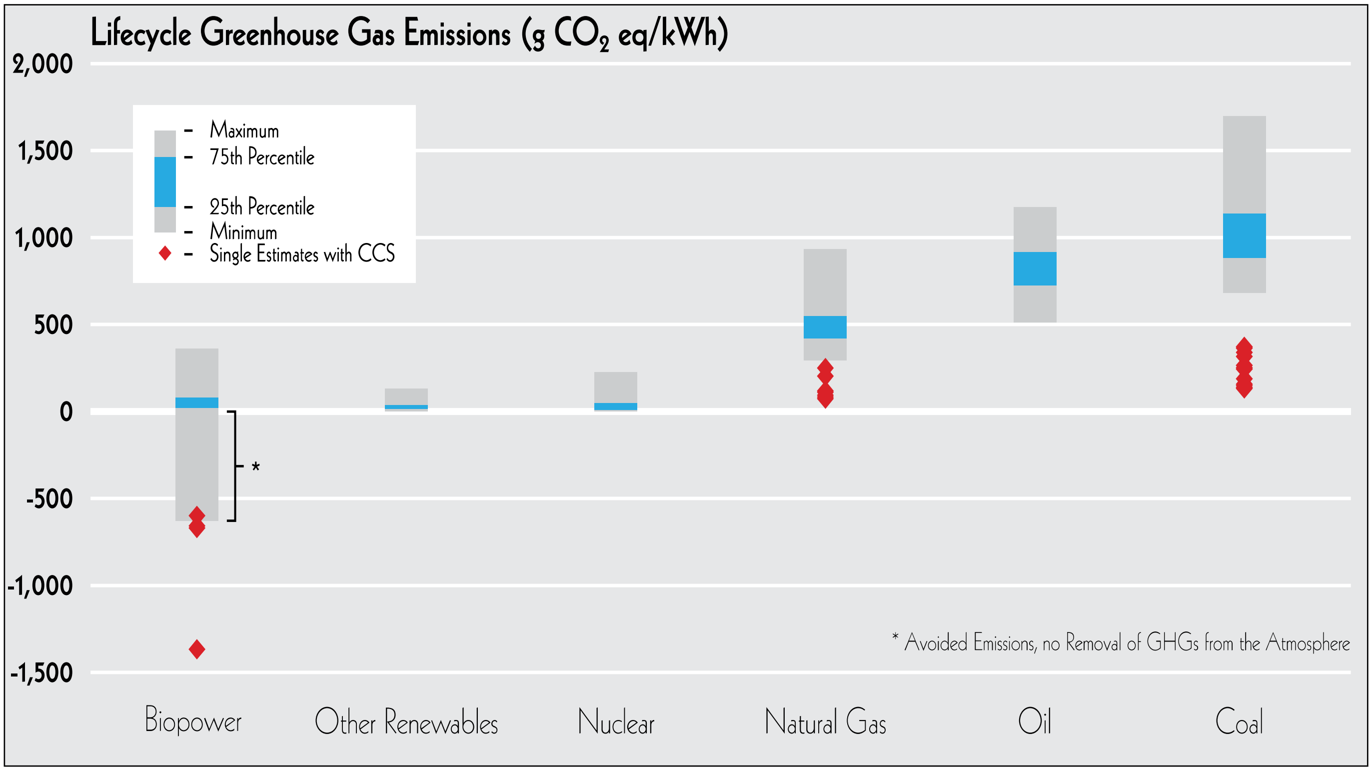

Figure 6. Lifecycle GHG Emissions of Renewable Energy, Nuclear Energy and Fossil Fuels. Source: Moomaw et al. (2012) as illustrated in AfDB (2013).

security, especially for Africa's rural poor. This trend is likely to continue as the total number of households in absolute terms relying on this traditional biomass is predicted to increase from 657 million to 922 million (OECD/IEA, 2010). This indicates, on the one hand, that increases in population outweighs shifts to "modern" energy services but, on the other hand, stresses the need to up scale the deployment of RETs to stop this trend.

POLICY OPTIONS

Policies play a crucial component in the large-scale deployment of RETs. Investments in the energy sector last for decades so that investors and the industry need the right policy environment ensuring reasonable returns over the lifetime of projects. This can be achieved through a mix of policies that send reassuring signals, provide relevant information, and offer long-term guarantees. Furthermore, governments need to ensure financing is adequate to set the right incentives for customers to uptake renewable energy.

[4]In contrast, bioenergy could potentially lead to deforestation (or negatively affect food production). Policies to promote bioenergy need to take these negative effects into consideration for their design.

Announcing a long-term target for the share of renewable energy

Announcing a long-term target for the share of renewable energy in total energy supply can signal investment security in RETs. This can leverage private investment for the diffusion of RETs because having such a target as part of national strategies ensures the investors of the long-term commitment on the side of the corresponding government. As of 2011, 16 African countries had already announced a long-term renewable energy target (UNEP, 2012). Morocco, for example, aims at an ambitious target of 20% of power supply coming from renewable energy in 2020.

Providing detailed information on the country's renewable energy potential

Providing detailed information on the country's renewable energy potential can contribute to strengthen the confidence of financial institutions and investors in RETs. The publication of a national solar and wind atlas, for example, informs potential investors about suitable areas and reduces the costs for feasibility studies (Renewable Energy Ventures, 2012). Due to a lack of knowledge and project experience with RETs, obtaining financing for RETs is currently more difficult than for fossil-fuel plants despite a comparably better economic case (IRENA, 2013). Banks are often reluctant to finance projects, or agree to finance but only at premium rates. Mapping renewable energy potentials including their techno-economic feasibility can contribute to overcoming financial burdens faced by investors and in helping financial institutions making profitable investments.

Offering long-term guarantees to renewable energy producers

Offering long-term guarantees to renewable energy producers through power purchase agreements such as feed-in-tariffs is the key policy for the diffusion of RETs. Market liberalization is an important prerequisite for renewable energy producers to be able to enter energy markets currently dominated by national utilities in a lot of African countries. Long-term guarantees along with market decentralization policies can ensure the easy access for new renewable energy producers. At the same time, these guarantees mean to obtain necessary financing for projects because producers are offered a price guarantee for a fixed period of time. In 2011, 7 African countries had already used feed-in tariff policies (UNEP, 2012). This group of African countries includes a small-island state dependent on fuel imports (Mauritius), the continent's biggest carbon polluter (South Africa), countries with less than 3% rural electrification (Tanzania), and others with almost universal access to electricity (Egypt and Algeria) (Renewable Energy Ventures, 2012). The design of feed-in tariffs can be aligned towards achieving a country's specific development objective whether this is the building of large-scale renewable energy plants or an increase of energy access in rural areas. In the first case bidding processes are the preferred options whereas for the latter ones differentiated tariffs ensuring that smaller installations are included are better (Renewable Energy Ventures, 2012). For the design of the tariff costs of generation, return on investment, impact on electricity prices and the costs of the support need to be taken into account; the choice of a tariff structure should be based on a holistic and long-term analysis based on the lifetime costs of RETs (IRENA, 2013; Renewable Energy Ventures, 2012)

A financing strategy for the diffusion of RETs

A financing strategy for the diffusion of RETs should be in place that ideally sets incentives for the poorer population to use renewable energy sources. In Africa, energy subsidies benefit industrial user and richer households. For example, an estimated 44.2% of fossil fuel subsidies go to the richest 20%, while the poorest 20% benefit from only 7.8% of these subsidies (AfDB, 2013). Social-transfer mechanisms and the cross-subsidization of low-income households through higher tariffs to rich customer could potentially change the current status-quo in favor of the poorer population. As an example for the former, South Africa already provides a monthly quota of free electricity to low-income households. For the latter, tariff structures in Kenya and Ethiopia are based on a pricing scheme with low prices for low consumption. Minimally, a financing strategy needs to ensure that feed-in tariffs will not incur an additional cost burden for households, especially in poor rural areas. This could potentially have negative consequences to achieve the objective of improving energy access. Additional funding will thus become necessary to protect poorer households from higher prices. For African countries, there are several strategies to finance feed-in tariffs by focusing on inter alia harnessing fiscal and environmental policy tools and leveraging global financing options (AfDB, 2013). Algeria and Mauritius have both taxed fossil fuels in order to fund renewable energy. Meanwhile Ghana and Uganda are looking to international climate finance such as through Nationally Appropriate Mitigation Actions (NAMAs) under the UNFCCC and the new Green Climate Fund (Renewable Energy Ventures, 2012). The African Development Bank and other organizations can help African countries here by facilitating awareness, knowledge sharing and upstream technical support or through their role as manager or host of a range of innovative financing instruments. For example, throughthe Climate Investment Funds (CIFs) and the Sustainable Energy Fund for Africa (SEFA), the Bank has several funding instruments that help promote scaling up of clean energy solutions at different levels. Robert et al. (2013) reported about the Ecological Modernization of the German Economy by a modern environmental policy. Dessau-Roßlau: German Federal Environment Agency.

CONCLUSION

The study has shown that RETs provide the better economic case for Africa's energy future compared to fossil-fuel technologies. They are the lowest cost option for different kinds of electrification projects and will even improve this status if current trends of rising fossil-fuel prices will continue. More income earning opportunities can be created through the deployment of RETs and customers can expect lower energy costs in the middle-to long-term. Also, in terms of energy independence and environmental sustainability, RETs make a more compelling case than their fossil-fuel counterparts.

For the large-scale deployment of RETs, the study recommends policy options to address two critical issues for a low cost energy future in Africa: ensure investment security and set incentives for low income households. For the former, a mix of policies is necessary that send signals of the government's long-term commitment, provides relevant information for profitable investments and offers guarantees for reasonable returns over the lifetime of projects. For the latter, a financing strategy needs to be put in place that ideally sets incentives, but minimally ensures that guarantees will not result in additional costs for low-income households. For African countries, options include the harnessing of fiscal and environmental policy tools and leveraging global financing options.

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Full Length Research Paper

The relationship between landscape planting patterns and perceived safety in urban parks in Tabriz, Iran

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The relationship between plants and perceived safety in residential areas has been argued by landscape researchers, but there is inadequate or no relevant literature available on the effect of plants in urban parks' safety. Therefore, a photo-questionnaire survey was conducted among urban park users in Tabriz, Iran to gauge the perceived safety of landscape scene with diverse types of texture to discover its effectiveness, especially in relation to the content of the scene. The survey was composed of 296 participants in November, 2012. The result suggested that landscape scene with vast aspect and physical access was perceived safer than the scene with crowded plants and blocked view. The findings demonstrated that a scene without lawn and water is perceived to be less safe than a scene with lawn and features of water. Moreover, landscape scene with more plant species was unsafe as compared to a scene with fewer plant species. This study proved that a landscape designed with ground cover such as lawn, grass and water feature implies increment of perceived safety in urban parks. Likewise, landscape designers should avoid crowded planting in areas, which obstructs visibility in urban parks and reduces perceived safety. The results expand the application of routine activity (RA) theory in park landscape design in Tabriz, Iran.

Key words: Urban parks, landscape content and perceived safety.

INTRODUCTION

Urban park is one of the most important and public open space in big cities. It is a multifunctional area that can be used for wide range of activities. It can at times be a place for anti-social activities such as drug use and criminal activities. This makes people to feel unsafe in the environment and can quickly decrease the usability of urban parks. Anti-social activities not only correlate with social, cultural and personal traits but also the physical environments and the condition of the place. Anti-social behaviors are given more attention and consideration by humans and they can be the cause of death, injury, fear, damage, inconvenience, and huge financial expanses as mentioned by Branthinghams (1984). Fear is the result of illegal and anti-social activities. In brief, it was explained that anti-social behaviors as event are the result of the coincidence of four things: a law, an offender, a target and a place (Brantingham and Patricia, 1984). Place is referred to as the physical environment where illegal activity happens. It is argued that the quality of a place can prevent or enhance anti-social activities thus reduces

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fear of crime. Therefore, it is important to understand how people perceive safety in urban parks especially in relation to design, specific and roles of plant management. The questions such as which type of planting pattern correlates positively with perceived safety in urban park is posed and develops a basis for this study. This study tends to identify people's preferences of landscape patterns in relation to perceived safety and introduces the most agreed reasons for unsafe feeling in urban parks.

Plants are important elements for green spaces; they not only make spaces attractive but also use in engineering, for climate control and aesthetic purpose (Robinette, 1972). In addition, plant has a wide range of uses and not only for decorative intention (Sommer, 2003). Understanding the relation between fear of crime and setting condition has been studied earlier and the recent conclusion shows that the spatial configuration of a place has an effect on fear of crime more than the crime itself. Therefore, it is necessary to understand that plants' configuration contributes to perceived safety. Cohen and Felson (1979) argued that the role of plants in safety can be explained by Routine Activity (RA) theory. The RA theory explains there are three conditions to be met before a crime can occur. The conditions are potential of crime, potential of victim, and lack of effective authority and control power to observe and respond to a crime.

It is rational that before deciding to act, a criminal would consider the costs and benefits expected of the action. It is argued that in the context of RA theory, plants could influence crime activity in relation to the condition of 'potential of crime'. For instance, if the plants obstruct view, there is a high chance of criminal activity to occur. The plants could reduce the probability of the crime to be observed, which would eventually reduce the expected cost of doing a criminal activity. A study emphasizes that trees and high bushes have negative effect on safety feeling (Fisher and Nasar, 1995). The other study shows the moderation roles of plants in the reduction of aggression and violent behavior (Jieun, 2005), which helps to augment self-control and reduce criminal activity.

Safety of the urban environment and its relation to plant has been an interesting subject for researchers during the last decades. Even though, plant positively contributes to overall safety feeling, a study in urban residential areas showed a negative relationship between plants and safety feeling (Kuo and Sullivan, 2001). A common assumption is that plant can facilitate crime because it helps to hide the perpetrators and their criminal activities and it is particularly implied in the areas with dense vegetation. In one study, participants ranked safety for 180 scenes in urban forests and they feel danger in a densely forested area but feel safe in open areas (Schroeder and Anderson, 1984). A different study showed participants' responses to open-ended questions in which photographs of urban parks revealed that dense vegetated settings were perceived as dangerous areas (Talbot and Kaplan, 1984) and they asserted that participants not only feared the heavily vegetated areas but some of them had fear of crime in their mind by anticipating that the area is fit for muggers to hide. Michael and Hull (1994) explained that criminals use regularly dense vegetated areas to hide their activities and fear of crime is more tangible when the vegetated close views of scenes and visibility of areas are limited (Michael and Hull, 1994).

On the other hand, some studies show that vegetation reduces fear of illegal and undesirable activities. According to Macdonald and Gifford (1989), well-used residential areas and outdoor spaces with trees are avoided by criminals than treeless spaces because vegetation not only preserves the visibility of space but also increases spatial surveillance (Kuo and Sullivan, 2001). Nasar (1982) explained that landscape features such as plants with high heights are associated with less fear of crime and the result supports a study by Brower et al. (1983). They said that properties with trees and shrubs appear safer than they do not. A study by Kuo and Sullivan (2001) reports that based on police crime reports, the relationship between vegetation and crime in the inner-city is negative. Their study described that significant negative correlation exists between existence of vegetation with total crimes, properties and violent crimes in the inner-city neighborhood areas. They explain that vegetation enhances illegal activities via providing settings for hiding and to prevent the phenomenon proper visibility should be enhanced in the vegetated areas. In addition, people cited landscape with blocked view makes them feel unsafe in the inner-city landscape (Kuo *et al.*, 1998). The literature above shows that the level of vegetation is important for perceived safety and level of vegetation refers to high density. Thus, low and dense vegetated areas will give less safety feeling. It seems that the arrangement of vegetations and visibility of the areas might affect vegetation roles in increasing or decreasing safety feeling in the setting.

Previous researches show that there is relationship between vegetation and criminals as anti-social behaviors. Some of them show positive correlation whilst the others show negative correlation. However, the question remains about the relationship between perceived safety and landscape content such as trees, shrubs, grass, water, and a combination of them. As Kuo et al (1998) have argued that there might be enough information about relationships among grass, trees and safety, but it is unclear if shrubs should be added. Furthermore, parks are places where plants have important role in forming their shape; therefore plants' role in park safety is very important for investigation than inner city areas.

To understand the effect of vegetations on cost of criminal activity, there is an empty room to work on the different vegetation patterns. The quality content of various vegetations can reduce or increase possibility of observing a crime. The combined forms of vegetation and their placement are other important options that should

Table 1. Identified planting patterns in urban park in Tabriz.

Number	Planting patterns in urban parks in Tabriz
1	Trees and shrubs without grass
2	Trees and Shrubs with grass
3	Water, trees and shrubs

be taken into consideration. As the previous study suggested not only vegetation type, size, and location are important but the changes of visual limitation based on the plants' body and properties. The review of vegetation patterns in urban parks of Tabriz shows that the vegetations can be classified into 3 categories: 'Trees, Shrubs with Grass', 'Trees, Shrubs without Grass', and 'Water, Trees, and Shrubs'. Thus, this research tends to answer these following questions: what is the most preferred planting pattern for urban parks in Tabriz? In general, what is the most preferred planting pattern in Tabriz urban parks? How is the relationship between landscape patterns and perceived safety in urban parks in Tabriz? The procedure and methodology used in this study are explained below.

METHODOLOGY

Tabriz location and green spaces

Tabriz is located at '38° 8° and 46° 15° East of Greenwich with an area of about 131 square kilometers (Ghorbani, 2006). Therefore, the city is located in 1200 m above sea level (Rahimi, 2006)'. In the winter, the average temperature is 12.4°C (88.4°F) and in the summer the average temperature can be up to 34.1°C (110.1°F). Lack of water resources is the most important climatic problem in the city; meanwhile the annual rainfall (snow and rain) is only about 321 and most of the rains occur during winter and spring. Despite harsh weather, the population of this city is 1,579,312, according to the Census Central Organization of Iran (2006).

In total, green space area in Tabriz is about 4.7 m^2 per capita (in 2006) and this amount is less than the proposed per capita (7-12 m^2) by the Ministry of Housing and Urban Development (Ghorbani, 2006). However, in 2011, the green spaces per capita in Tabriz have reached 12 m^2/capita which is exactly the ministry's requirement. However, the number is less than that required by the Environment Department of United Nations Organization, which is 20-25 meter square/per capita. Therefore, based on "Tabriz view in 2016", the green space per capita should be increased to 25 m^2/per capita. Even though the commitment is applicable, Tabriz like other city in Iran is faced with lack of rain and snow so development of green areas will be highly cost. Therefore, landscape development should fulfill residents' needs and preferences to minimize operational cost. However, despite good number of green spaces in Tabriz, safety is an issue and to tackle this problem, the park design should constantly change. So, there is a need to know the designs that can reduce fear and increase safety. It is proposed that the relation between planting patterns and perceived safety should be investigated.

A survey method was used to gather data in this study because it allows large number of population to participate and also accurate answer can be achieved via photo-questionnaire as survey instrument. Photo questionnaire has been acknowledged as a valid and reliable method to represent real and actual environment (Gau and Pratt, 2008). The questionnaire for this study included set of questions regarding the degree of safety feeling in each landscape scene as dependent variable (10 landscape scenes), plants' role in perceived safety measured by a Likert scale (1 = strongly disagree to 5 = strongly agree), and demographic questions (measured by categorical technique) as independent variables. In other words, how do the landscape patterns contribute to perceived safety in urban parks? In order to prepare a photo - questionnaire of the survey, there should be a systematic process to prepare scene, which is described in the following subsection.

Scene classification procedure

The scenes are prepared according to 3 planting patterns in urban parks in Tabriz as pre-discussed; therefore, the nature of the work is confirmatory. Landscape content of urban park was classified into three categories (Table 1).

Summer season was selected to take photos since vegetations of the parks have the maximum growth and fully covered in green. The scenes were collected from El Gholi Park and Big Park as predominant urban parks in Tabriz. These parks were selected because they have been known as the most famous and more used urban parks in Tabriz City; meanwhile, the problem of unsafe feeling still exists. The photos were taken from the soft - landscapes of the parks and hard-landscapes such as buildings, walkways, and other constructions were excluded. In addition, the scenes with slight construction in context were also excluded because the researcher believes that the scene includes landscape variety construction that might influence people's preference for plants. The photos were only captured when the place was cleared of users; therefore, the researcher waited until the place becomes free to prevent any effect on peoples' preferences. The photos were taken at the eye levels to avoid the effect(s) of various viewpoints. These photographs did not include any noise such as hard-landscape and presence of users. In the first stage, the photographs were grouped into the 3 planting patterns by landscape architects. In the next stage, the scenes were printed out on A3 size and colourful paper, whilst 4 scenes were located in each paper. Each group of planting pattern included 15 scene numbered from 1 to 15. A group of public (10 males and 10 females) ranked the scenes according to different content class (trees and shrubs with grass, trees and shrubs without grass, water, trees, and shrubs). The researcher explained to the participants to indicate the smallest number for more related scene. At the end of this part, 27 scenes (9 scenes for each label), those that received the highest agreement, were selected by the public participants. The results of public photo selection procedure were emailed to the experts in Universiti Putra Malaysia (UPM). These photos were grouped at three content classes (Trees and shrubs with Grass, Trees and Shrubs without Grass, Water, Trees, and Shrubs) and they were asked to rank the top five related photos at each planting pattern (1= strongly disagree to 5= strongly agree). From the result of the email survey, three scenes, those that received highest rank in each group, were picked up for final survey; however, 4 scenes were maintained for 'trees and shrubs with grass group because scenes number 3 and 4 received very close place based on the experts' ranking. All together, 10 scenes were selected for final survey presentation. The respondents were taken through using a systematic sampling method. Systematic sampling was used to select samples from the population because it provides a statistical base for stating this point that a sample is the representative of the target population (Fink, 2003). Among different methods, the systematic sampling method was proposed to be more suitable for sample selection, because the population is without name, so the other sampling methods are not applicable. In addition, the data were analyzed by using SPPS software.

Table 2. Participants' Backgrounds.

Participant		Number	Percent
Total public participation		296	100.0
Factors	**Sub-category**		
Gender	Male	163	55.1
	Female	130	43.9
Marital status	Single	121	40.9
	Married	173	58.4
Age(years old)	19-29	140	47.3
	30-39	87	29.4
	40-49	36	12.2
	Above 50	30	10.1
Education	Secondary and below	25	8.4
	Under diploma	26	8.8
	Diploma	88	29.7
	University	152	51.4
Income(Toman)	Under 350,000	86	29.1
	Between 350,000 and 900,000	126	42.6
	Between 900,000 and 1,500,000	24	8.1
	Above 1,500,000	11	3.7
Occupation	Governmental employee	45	15.2
	Private sector	30	10.1
	Student	56	18.9
	Household	31	10.5
	Business	30	10.1
	Others	70	23.6

RESULTS

Demographic profile of the participants

Participants for this survey can be classified according to gender, marital status, age group, education level, income level, and occupation status. 296 questionnaires were collected in this study and males are n = 163 (55.1%) and females are n = 130 (43.9%) of the participants (Table 2). The data reflect the study by Nohorly (1999) where he shows that males are the main users of parks in Tabriz. Regarding marital status, the majority of participants (n = 173, 58.4%) are married and n = 121 (40.9%) are single. In terms of age groups, 47.3% (n = 140) are between 18 – 29 years, 24.9% (n = 87) are between 30-39 years, 12.2% (n = 36) are 40-49 years, and 10.1% (n = 30) of the participants are above 50 years.

For educational level, the data show the majority of the participants have university education (n = 152, 51.4%). For income status, the majority of the participants have income between 350 and 900 thousands Tomans. The studies have shown that greater education (Kelly and Steinkamp, 1987; Hami, 2009) and high income (Kelly and Steinkamp, 1987) are associated with participation of leisure activities. The data show the participants vary when it comes to age groups, job classes and education levels

Plants' role in perceived safety

The participants were asked to rate items about plants' role in park safety by using 5 points Likert scale (1 = strongly disagree to 5 = strongly agree) and the question includes 6 items regarding plants' role in relation to criminal activity, alcohol drinking, drug usage, sexual attacks, presence of loiters, and scariness of planting areas. Gathering of addicted people in planting areas received the highest mean score (mean = 3.76, sd = 1.16), followed by "offenders can easily vanish among dense plantings' (mean = 3.68, sd = 1.18), and the item that received the lowest mean is "dense planting enhances the presence

Table 3. Mean analysis for plants' role in park safety.

Safety Dimensions	Label	N	Mean	Standard deviation	Alpha
1. Criminal activities	-	**284**	**3.60**	**0.94**	**0.70**
a) Criminal people can easily vanish among dense plantings	(SAFE 1)	290	3.68	1.18	
b) Addicted people mostly gather in areas with dense planting	(SAFE 2)	290	3.76	1.16	
c) High dense landscape has great potential for sexual attack	(SAFE 3)	290	3.38	1.26	
2. Undesirable activities	-	**287**	**3.50**	**0.93**	**0.75**
d) Darkness of planting areas makes me scared to go there	(SAFE 4)	291	3.57	1.25	
e) Crowded planting area offers safe and comfort place for drinkers	(SAFE 5)	294	3.49	1.17	
f) Dense planting areas have great potential to be used by loiters	(SAFE 6)	290	3.43	1.28	

Table 4. Mean ranking for perceived safety in landscape scenes by the public.

Scene number	Mean	Std. deviation	Scene number	Mean	Std. deviation
P1	4.24	0.93	**P6**	3.61	1.19
P2	4.21	0.95	**P7**	3.49	1.26
P3	4.20	0.87	**P8**	3.08	1.23
P4	4.15	1.07	**P9**	3.01	1.19
P5	3.66	1.16	**P10**	2.94	1.20

of dangerous animals like snakes' (mean = 3.16, sd = 1.23). Based on a result from reliability test, the safety items were grouped into two: undesirable effect (α = 0.70) and design issue (α = 0.750); so the groups have an internal consistency above 0.70 (Table 3). The mean value for these two dimensions 'criminal activities' and 'undesirable activities' shows slightly difference in which criminal activities have a mean of 3.60 (sd = 0.94) in comparison to undesirable activities with the mean of 3.50 (sd = 0.93).

It is argued that dense planting areas are suitable venue for anti-social and criminal activities. High dense planting areas do not look well maintained so less people might use the place, which makes a good place used for undesirable and criminal activity (Donovan and Jeffrey, 2012).

Preferences for landscape content

The participants also were asked to rate 10 landscape scenes in order to determine suitability of each landscape pattern for perceived safety by using 5 points Likert scale (1 = strongly disagree to 5 = strongly agree). From Table 4, the result reveals that the highest mean score is for the scene number 1 (mean = 4.24,) followed by scene number 2 (mean = 4.21), scene number 3 (mean = 4.20), scene number 4 (mean = 4.15), and scene number 5 (mean = 1.16). Meanwhile, scene number 10 (mean = 2.94) is the least preferred.

Looking at Figure 1 depicts that the scenes number 2, 4, and 5 include water pool and the water looks calm and resembles a mirror that reflects the surrounding. The water is also clean and no litter can be seen inside. In addition, the water view is expansive and not blocked in all directions; therefore, a person can view water ward without any obstacle. The scenes number 8, 9, and 10 contain trees and shrubs; no ground cover such as grass or lawn and water features. Meanwhile, the trees are crowded with high elevation and without big and broad crown. By looking at the mean rank, it can be argued that crowdedness of the trees planted plays a predominant role in perceived safety. The scenes with crowded planting pattern received fewer mean score for safety perception. A water feature, the second important element might also decrease safety feeling in the place and can be dangerous especially for children; nevertheless water attracts more people to visit park, which enhances social safety. The effect of ground cover such as grass and lawn similar to water feature might enhance perceived safety in parks.

As Table 5 shows the scenes were grouped into 3 groups according to alpha score in which all are greater than 0.70 and they are water, tree and shrub (mean = 4.00, sd = 0.72); tree, shrub, and grass (mean= 3.88, sd= 0.75) and the last group is tree and shrubs without grass (mean = 3.00, sd = 0.98). Based on the least preferred group, it seemed that people do not prefer scenes without water bodies, grass, and ground cover and the scenes with clean green cover and low dense plants are perceived safer than the scenes that lack them.

Regression result

Stepwise regression analysis was held to test the effect

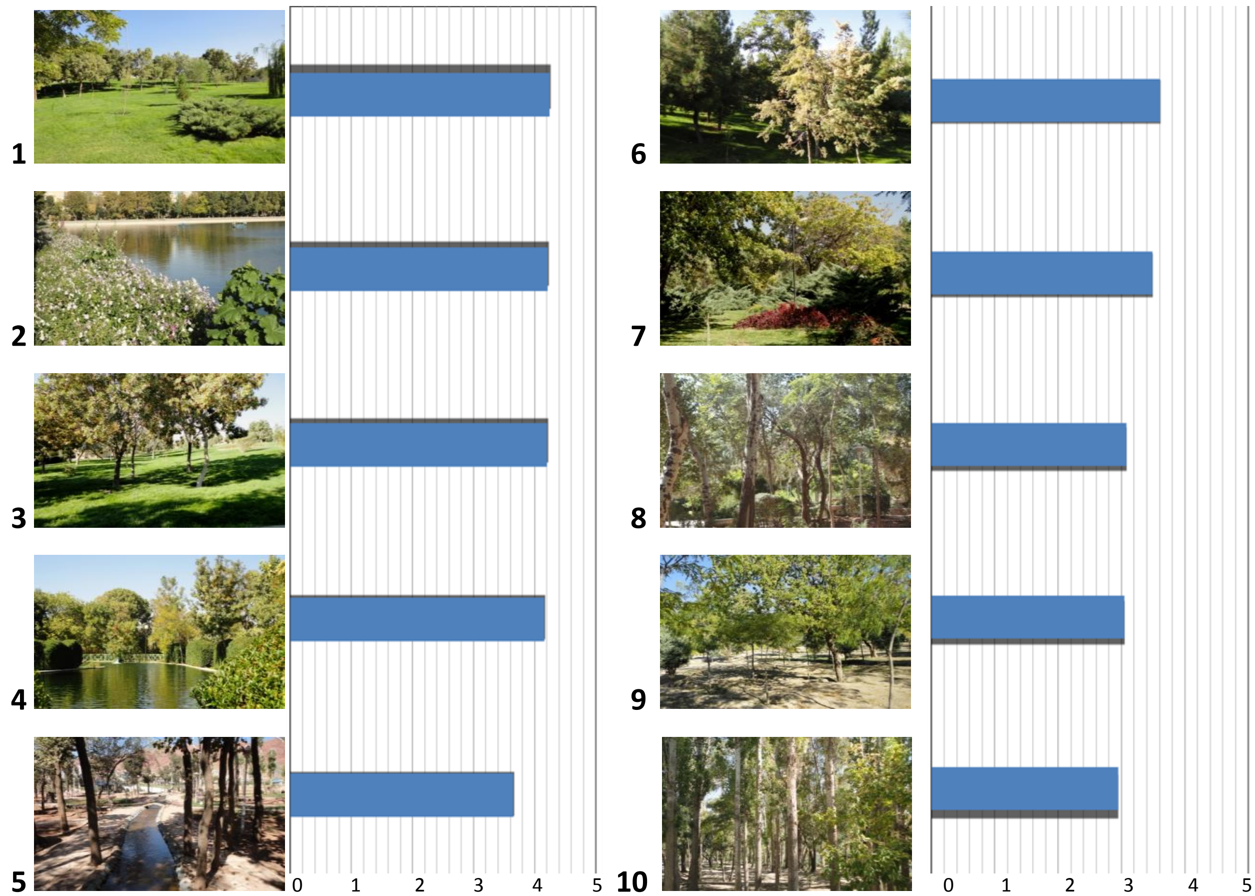

Figure 1. Rating of appropriateness of scenes for perceived safety among urban park users in Tabriz, Iran, ten Scenes Varying in Planting Pattern (number 1 has highest rank and number 10 has the lowest rank). Scale from 1 (strongly disagree) to +5 (strongly agree).

Table 1. Mean analysis for landscape scene groups of urban park.

Dimension	N	Mean	Std. Deviation	Alpha
Water, tree, and grass (scenes 2, 4, and 5)	284	4.00	0.72	.710
Tree and shrubs without grass (scenes 8, 9, and10)	282	3.88	0.75	.750
Tree and shrubs with grass(scenes 1, 3, 6, and 7)	284	3.00	0.98	.720

of perceived safety on landscape characteristics and roles of plants for safety. 4 out of 7 perceived safety items showed correlation with 7 scenes out of 10 scenes (Table 5). The results indicate that scene number 5 correlates positively with hiding criminal people (β = 0.19), gathering addicted people (β = 0.16), presence of loiter (β= .14); scene number 7 with gathering addicted people (β = 0.17) and presence of loiter (β = 0.17) as well (Table 6). Moreover, scene numbers 6, 8, and 9 show significant negative correlations with perceived safety alternatives. For instance, scene number 8 has negative correlation with hiding criminal people (β = -0.21), scary place (β = -0.22), gathering addicted people (β = -0.25), and presence of loiters (β = -0.20). In addition, the scene with deeper water pool was perceived to be unsafe place for the participants (scenes number 4, Figure 1).

Scene number 6 (Figure 1) shows significant negative effect (β = - .019) on the presence of loiters as safety item, scene number 9 discloses significant negative effect (β = - 0.13) on hiding criminal people. However, the R square scores of the models are not very high. As it is revealed, the scenes with water features (scenes number 2, 5, and 7, Figure 1) contribute positive effect on perceived safety. These scenes have large landscape view and water features while scene number 7 is more attractive because of colorful content. In addition, scene number 8 is correlated negatively with perceived safety dimensions.

Table 6. Stepwise regression results.

Variable	Antisocial behavior			
	Criminal people can easily vanish (SAF 1)	**Gathering addicted people (SAF 2)**	**Scar y place (SAF 4)**	**Presence of loiters (SAF 6)**
Scene 2			+.22	
Scene 4			-.19	
Scene 5	+.19	+.16		+.14
Scene 6				-.19
Scene 7		+.17		+.17
Scene 8	-.21	-.25	-.22	-.20
Scene 9	-.13			
R square	0.10	0.11	0.10	0.10

SAF 1 = Hiding criminal people, SAF 2 = gathering addicted people, SAF 4 = scary place, SAF 6 = presence of loiters.

Conclusion

The majority of the participants are males, married with university level of education. Similarly, more than 40% of them are 19-29 years old group with moderate income level. The participants exposed that high dense planting areas fit for criminal activity and gathering of drug addicted people. Lack of accommodations such as lighting system creates scary setting for people in urban parks as well. A safer scene is a landscape with vast and open view. Moreover, water features also showed positive effect on perceived safety. It can be regarded that water features draw more people into the place (Hami, 2009) and it can increase social surveillance and support. On the other hand, the landscape scenes with the most densely planted setting were perceived the least safe environment. They contained blocked visual views. A scene with blocked view seems to play important role in reducing perceived safety; perhaps it acts as a refuge zone, which allows criminals to hide. Similarly, the landscape scenes without lawn correlated with unsafe feeling in urban parks in Tabriz. In one study, the "fear-maps" sketched by college students showed that fear correlated with the presence of trees, shrubs, and walls that conceal view and limit escape alternatives (Fisher and Nasar, 1995). This result confirms expanding RA theory in landscape preference studies that plants' condition might decrease or increase the cost of criminal activity.

Implication of the findings

The findings expand application of routine theory in designing park landscapes in Iranian social context. The study claims that a landscape design should grant an adequate vision to drop more eyes in the areas. Due to increment confusion of landscape areas, irregular and disorganized plants pattern should not be made in the park sites. Vegetations such as shrubs and bushes should not be planted in spaces between trees. Meanwhile, in landscape areas without ground cover and lawn, the trees need to be planted far from each other in comparison to the landscape with lawn and ground cover. The landscape scene with more varieties looks disorderly and complicated for the participants. Therefore, it is recommended to plant fewer varieties with high number of repetition rather than more varieties with low number of repetition.

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Full Length Research Paper

Characterization of groundwater quality in Oran Sebkha basin

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Growing populations and increasing industrialization causes increase in living standard, which result in decrease in the quality of water and may put stresses on natural waters by impairing both the quality of the water and the hydrological budget. This research aimed at determining the origin of the chemical elements of groundwater from the Oran Sebkha basin. It applied the inverse geochemical modeling to derive the sources of variation in the hydrochemistry. Fifty five (55) water samples were selected from different point in Oran Sebkha basin for sampling purpose in July 2011. Physico-chemical parameters such as pH and electric conductivity were measured *in situ*. Moreover, chloride, sulfate, alkalinity, calcium, magnesium, sodium, potassium, were measured in the laboratory. Inverse geochemical models of the statistical groups were developed using PHREEQC to elucidate the chemical reactions controlling water chemistry. The inverse geochemical modeling demonstrated that relatively few phases are required to derive water chemistry in the area. In a broad sense, the reactions responsible for the hydrochemical evolution in the area fall into three categories: (1) dissolution of evaporite minerals; (2) precipitation of carbonate minerals; and (3) weathering reactions of silicate minerals. The high values of the physico-chemical parameters of water obtained in the present study sites indicate a variation in the physico-chemical parameters and demonstrated that relatively few phases are required to derive water chemistry in the area. Range of values were found as pH (5.1-7.6), conductivity (720-15820 µS cm^{-1}), chloride (994-7810 mg l^{-1}), sulfate (6.1-112.4 mg l^{-1}), alkalinity (421-19962 mg l^{-1}), calcium (80-680 mg l^{-1}), magnesium (212.4-4525 mg l^{-1}), sodium (124.2-4687.4 mg l^{-1}) and potassium (0.9-42.5 mg l^{-1}).

Key words: Physico-chemical parameters, water, Sebkha.

INTRODUCTION

The availability of good quality water is an indispensable feature for preventing diseases and improving quality of life (Oluduro and Aderiye, 2007). Natural water contains some types of impurities whose nature and amount vary with source of water (Drever, 1988).

Water quality characteristic of aquatic environment arise from a multitude of physical, chemical and biological interactions (Deuzane, 1979). The water bodies, rivers, lakes, dams and estuaries are continuously subject to dynamic change with respect to the geological age, geochemical characteristics and anthropogenic influences.

This is demonstrated by continuous circulation, transformation and accumulation of energy and matter through the medium of living things and their activities. The dynamic balance in the aquatic ecosystem is upset by human activities, resulting in pollution which is manifested dramatically as fish kill, offensive taste, odor, color and unchecked aquatic weeds. The objective of the monitoring

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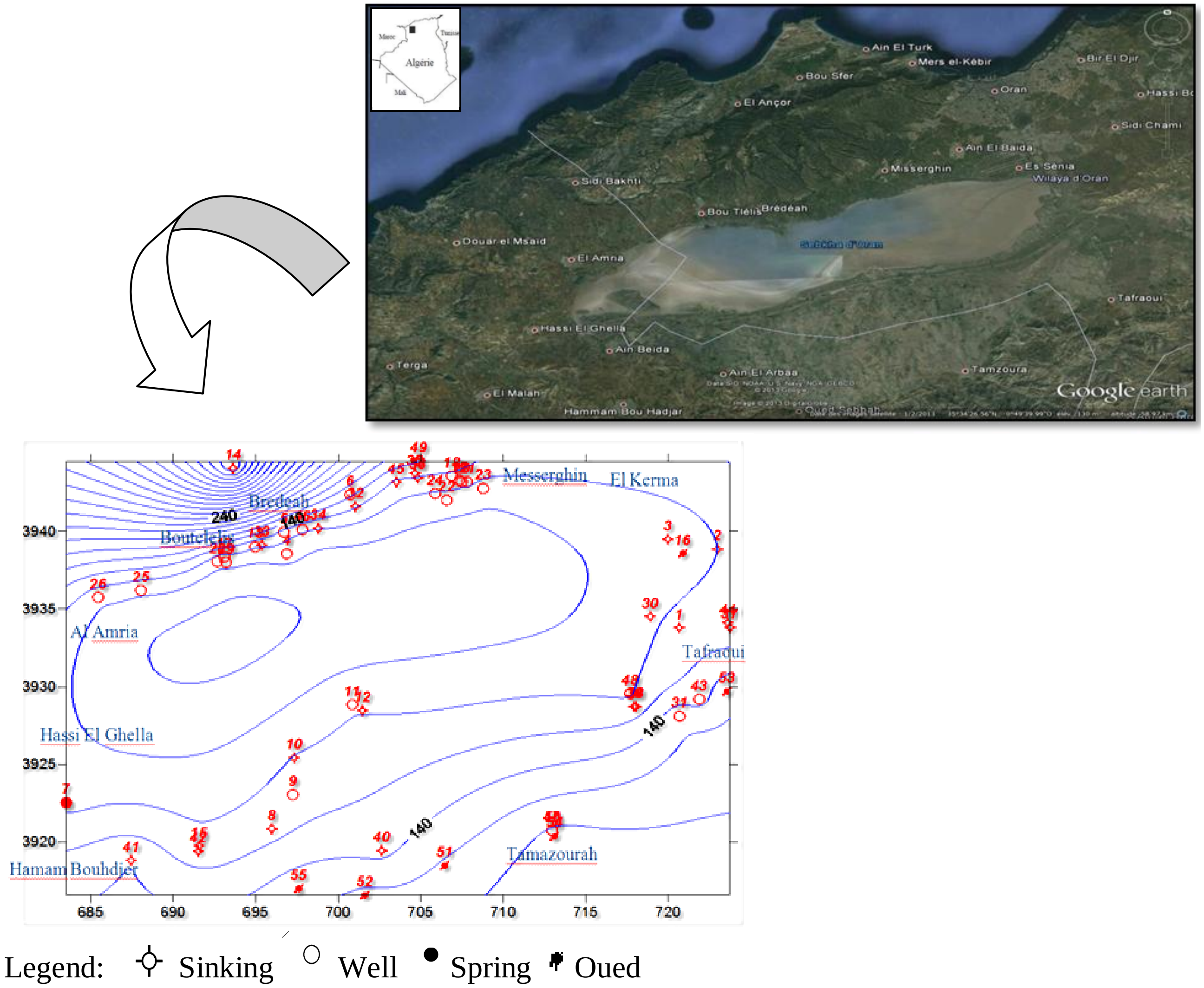

Figure 1. Localization of sampling points in the study area.

studies undertaken for water body is to assess variation in water quality.

The soundness or validity of the results in the inverse modeling depends on a valid conceptualization of the groundwater system, validity of the basic hydrochemical concepts and principles, accuracy of input data into the model, and level of understanding of the geochemical processes in the area (Güler and Thyne, 2004).

Variation in groundwater chemistry is mainly a function of the interaction between the groundwater and the mineral composition of the aquifer materials through which it moves. Hydrochemical processes, including dissolution, precipitation, ion exchange, sorption and desorption, together with the residence time occurring along the flow path, control the variation in chemical composition of groundwater (Apodaca et al., 2002). The zone of study covers: the great Oran Sebkha basin (with an area of 1878 km²); the Sebkha itself (with an area of 298 km²) and the stretches (over 40 km long and 6 to 13 km wide). The zone is located in the Central Coastal Oran basin and is bounded by: the Djebel Murdjadjo (530 m) in the north, the Mount Tessala (1061 m) in the south, the plain oued Tlelat in the east, and oued Mellah in the west (Figure 1).

The integrated geological study (sedimentology, geomorphology, tectonic, hydrogeology) determined factors which conditioned its setting up, since the lower-middle Miocene (Burdigalian-Langhian-Serravallian); that emerged in the beginning of the Tortonian age, then it met, and until the Pleistocene under a marine regime that evolved toward a continental regime since the superior Pleistocene. The southward swing of the northern area (Murdjadjo south side) at the Soltanian age would have been the main reason of the Sebkha of Oran endoreism and its subsequently closing (full) with the setting up of the wind accumulations.

Table 1. The physico-chemical parameters of water samples from Oran Sebkha basin.

Parameter	Average	Minimum	Maximum	Standard deviation	Median
pH	6.9	5.1	7.6	0.4	6.9
EC (µS m^{-1})	5905.3	720	15820	3303.7	5710
Cl^-(mg L^{-1})	2472.7	994	7810	1180.8	2307.5
SO_4^{-2}(mg L^{-1})	26.1	6.1	112.4	20.3	22
HCO_3^-(mg L^{-1})	4764	421	19962	4128	3288
Na^+(mg L^{-1})	863.7	124.2	4687.4	717.7	733.7
K^+(mg L^{-1})	8.6	0.9	42.5	8.4	6.2
Ca^{2+} (mg L^{-1})	304.4	80	680	131.9	280
Mg^{2+} (mg L^{-1})	1258.8	212.4	4525	920.2	956.4

MATERIALS AND METHODS

In order to characterize the groundwater quality in the dry season, a sampling network was chosen to allow the acquisition of representative data on the spatial and temporal variability (Figure 1). This network covers the entire basin upstream to downstream and consists of a set of points of water wells, boreholes and springs.

Water withdrawals were made at low waters. The samples were collected during the period of 04 to 20 July 2011 where comprehensive analyses were performed. The parameters that were measurement are: pH and electrical conductivity (EC) measured in the field using a multi-parameter HANNA (pH meter HANNA instrument HI 9811).

Subsequently, the samples were analyzed in the laboratory for their chemical constituents such as calcium, magnesium, sodium, potassium, chloride, bicarbonate and sulfate. This was achieved using standard methods as suggested by Rodier (1996). Ca^{2+}, Mg^{2+}, HCO_3^- and Cl^- were analyzed by volumetric titrations. Concentrations of Ca^{2+} and Mg^{2+} were estimated titrimetrically using 0.05 N EDTA and those of HCO_3^- and Cl by H_2SO_4 and $AgNO_3$ titration, respectively. Concentrations of Na^+ and K^+ were measured using an Ionogram (Model: Ionogram Easy lyte Na/K/Cl, 800 ml, MEDICA 001384-001 R2 Analyser, 12160/12014-05) and that of sulfate by Spectrometer method (Model: Spectrometer UV Optizen 2120 UV). The results were tabled for interpretation.

In literature, many different methodologies have been applied to study, evaluate and characterize the sources of variation in groundwater geochemistry. Among these methods is the inverse geochemical modeling in PHREEQC (Parkhurst and Appelo, 1999) based on a geochemical mole-balance model, which calculates the phase mole transfers (the moles of minerals and gases that must enter or leave a solution).

RESULTS AND DISCUSSION

The physico-chemical parameters obtained from analysis of water samples from Oran sebkha basin are presented in Table 1. The groundwater samples of the study area have pH values ranging from 5.1 to 7.6, which indicate that the groundwater is slightly alkaline. The electrical conductivity (EC) values ranged from 720 to 15820 µS cm^{-1} which is the characteristic of mixed water (Ca-Mg-Cl-HCO_3). The gradual increase of conductivity denotes a significantly lateral input of wastewater with higher conductivity (Trinh, 2003). The order of abundance of the major cations is Mg ≥ Na ≥ Ca ≥ K and all samples exceeded the desirable limit of Ca, Mg and Cl for drinking water, respectively :75, 50 and 200 mg l^{-1}, but the sulfate concentrations are all below health guidelines (WHO, 1993) (Table 1).

In all water samples, a critical look at the results revealed that the values of these physico-chemical parameters are higher in the basin based on geological position; discharges of industrial wastewater and contamination of the groundwater by seawater were excluded as the source of high concentrations. The quantity of waste in different phases of a natural aquatic system is reflected by the level of hardness, alkalinity, and other physico-chemical parameters. Since the higher values of all these physico-chemical parameters than those obtained could be as a result of washing away of sulfate based fertilizers into the river (Ipinmoroti and Oshodi, 1993; Vogel, 1970).

Inferring the sources of solutes in groundwater using simple massbalance approaches does not provide unequivocal results, a reasonable way of constraining the processes that might influence the major-ion chemistry. The controls on the hydro chemical evolution of groundwater largely depend on the chemistry of the recharging water, water aquifer matrix interaction (cation exchange), or both, as well as groundwater residence time within the aquifer (Garrels and MacKenzie, 1971).

Three general processes that contribute to the generation of solutes in groundwater are: evaporate dissolution, carbonate dissolution and silicate weathering (Garrels and MacKenzie, 1971). The chemistry of the evolving water depends not only on the bulk chemistry of the matrix, but also on the rate of weathering. Meybeck (1987) reported that weathering rates of evaporates and carbonates are up to 80 and ~12 times, respectively, faster than silicate weathering rates. Hence, even relatively minor proportions of carbonates and evaporates can significantly influence water chemistry.

The study of the Ca^{2+}/Mg^{2+} (méq L^{-1}) ratio of groundwater from the area of study suggests the dissolution dolomite present in the alluvium (Figure 2). That is, if the ratio $Ca^{2+}/Mg^{2+} = 1$, dissolution of dolomite should occur, whereas a higher ratio is indicative of greater calcite con-

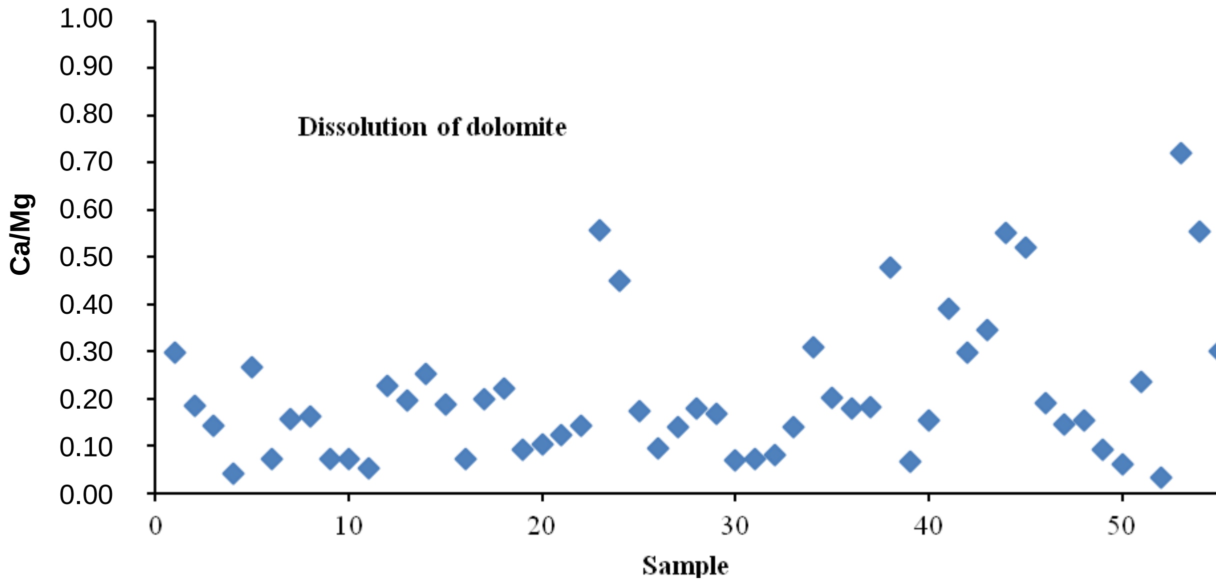

Figure 2. Sample number versus Ca^{2+}/ Mg^{2+}.

Table 2. Saturation indices of the water samples from Oran Sebkha basin calculated by PHREEQC.

Phase	Stoichiometry	Average
Anhydrite	$CaSO_4$	-2.19
Aragonite	$CaCO_3$	0.84
Calcite	$CaCO_3$	0.98
Dolomite	$CaMg(CO_3)_2$	2.87
Gypsum	$CaSO_4{:}2H_2O$	-1.98

tribution (Maya and Loucks, 1995). The points are located below the line (Ca^{2+}/Mg^{2+} =1) indicating the dissolution of dolomite. The samples have a ratio between 0.03 and 0.72 indicating the dissolution of dolomite. Dissolved carbonates (calcite and dolomite) occur predominantly in the form of HCO_3^-, due to the pH range. The solubility of calcite and dolomite is largely controlled by CO_2 fugacity and pH, according to the reactions:

$$CaCO_3 + CO_2(g) + H_2O = Ca^{2+} + 2HCO_3^- \qquad (1)$$

$$Ca1\text{-}xMgxCO_3 + CO_2\,(g) + H_2O = (1\text{-}x)\ Ca^{2+} + xMg^{2+} + 2HCO_3^- \qquad (2)$$

The plot of Ca^{2+}+ Mg^{2+} versus SO_4^{-2} + HCO_3^- will be above the 1:1 line if the dissolutions of calcite, dolomite, anhydrite and gypsum are the dominant reactions in a system (Maya and Loucks, 1995). Ion exchange tends to shift the points to left due to an excess of Ca^{2+}+ Mg^{2+} (Cerling et al., 1989; Fisher and Mulican, 1997; McLean and Jankowski, 2000). If reverse ion exchange is the process, it will shift the points to the right due to a large excess of SO_4^{2-}+ HCO_3^- over Ca^{2+}+ Mg^{2+}. The plot of Ca^{2+}+ Mg^{2+} versus SO_4^{2-}+ HCO_3^- (Figure 2) shows that the all samples are located in the right side due to an excess of SO_4^{-2}+ HCO_3^- (Belkhiri et al., 2010).

A Na (méq L^{-1})-normalized Ca^{2+} (méq L^{-1}) versus HCO_3^- (méq L^{-1}) and plot Mg^{2+} (méq L^{-1}) (Figures 3, 4 and 5) (Gaillardet et al., 1999) shows that the three group samples range from being influenced by silicate weathering to carbonate dissolution. The relation between Na-normalized Ca^{2+}, HCO_3^- and Mg^{2+} shows that although most of the Mg may have been derived from carbonate dissolution, some have a silicate source (Belkhiri et al., 2010).

The saturation indices of some of the common mineral phases is presented in Table 2, which clearly shows that the groundwater is generally supersaturated with respect to most of the carbonate and silicate phases and is most probably responsible for the composition of the groundwater (Belkhiri et al., 2010). The results of saturation calculations show that all the points are under saturated with anhydrite and gypsum, halite mineral phases are minor or absent in the area, suggesting that their soluble components Na^+, Cl^-, Ca^{2+} and SO_4^{2-} concentrations are not limited by mineral equilibrium. In contrast, aragonite, calcite and dolomite reach saturation as groundwater chemistry evolves along the groundwater flow paths. The groundwater in the studied area evolves from less saline Ca-g-HCO_3 water to blended Mg-Ca-HCO_3-Cl water to brackish Mg-Ca-Cl-HCO_3 water along the topographic flow path inverse geochemical modeling along groundwater flow paths indicating the dissolution of evaporite minerals, precipitation of carbonate minerals and weathering reactions of silicate minerals (Table 1 and Figure 6)

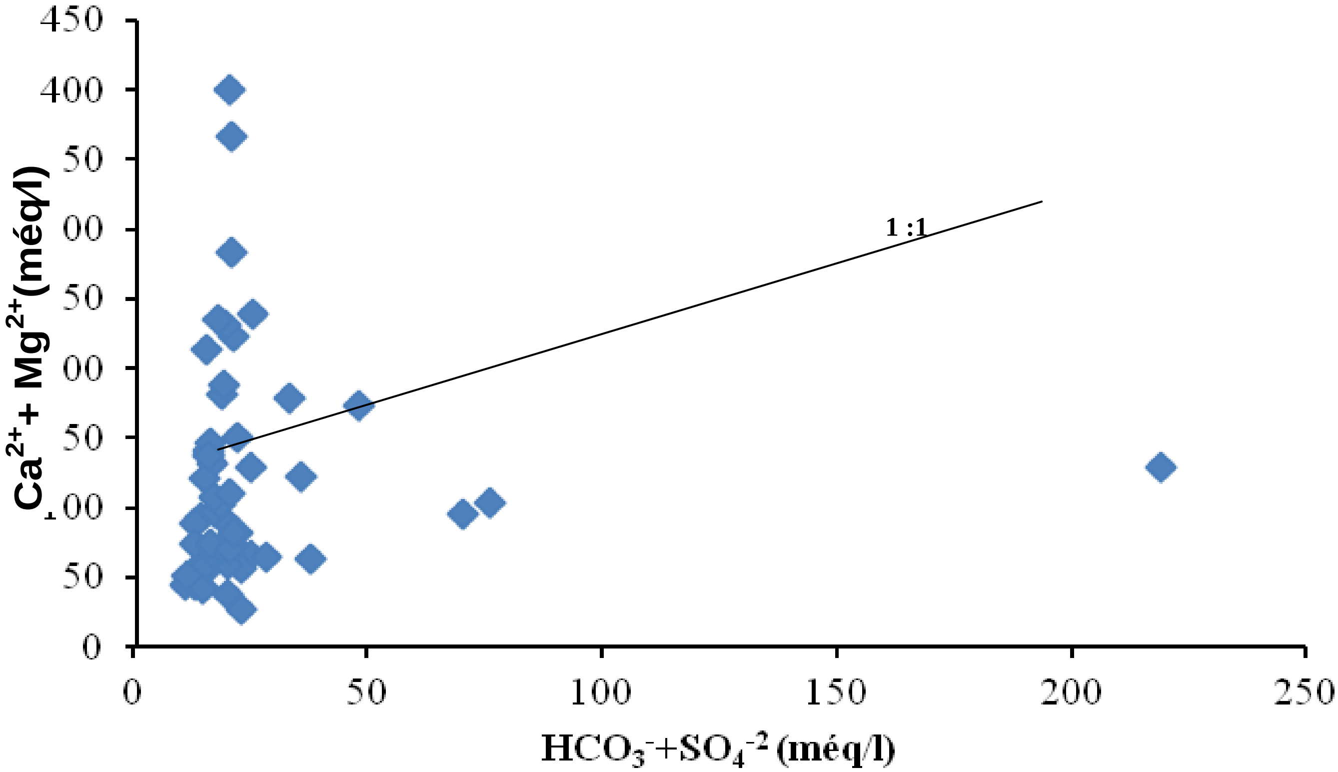

Figure 3. Ca^{2+}+ Mg^{2+}versus SO_4^{-2}+ HCO_3^-.

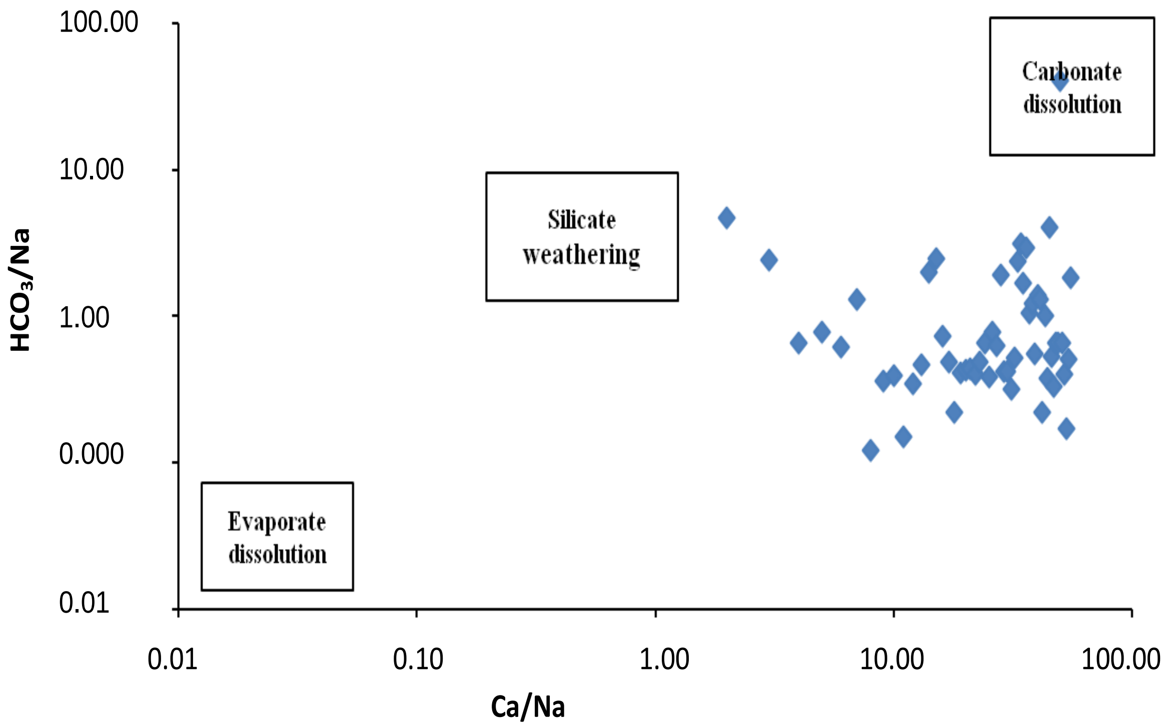

Figure 4. Na-normalized Ca^{2+} and HCO_3^- (HCO_3/ Na) (méq L^{-1}/ méq L^{-1}).

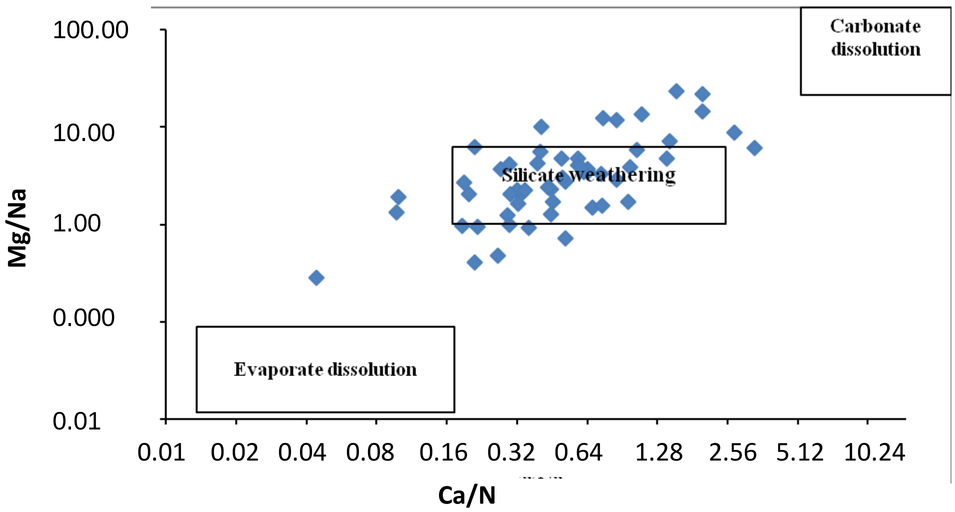

Figure 5. Na-normalized Ca^{2+} and Mg^{2+}.

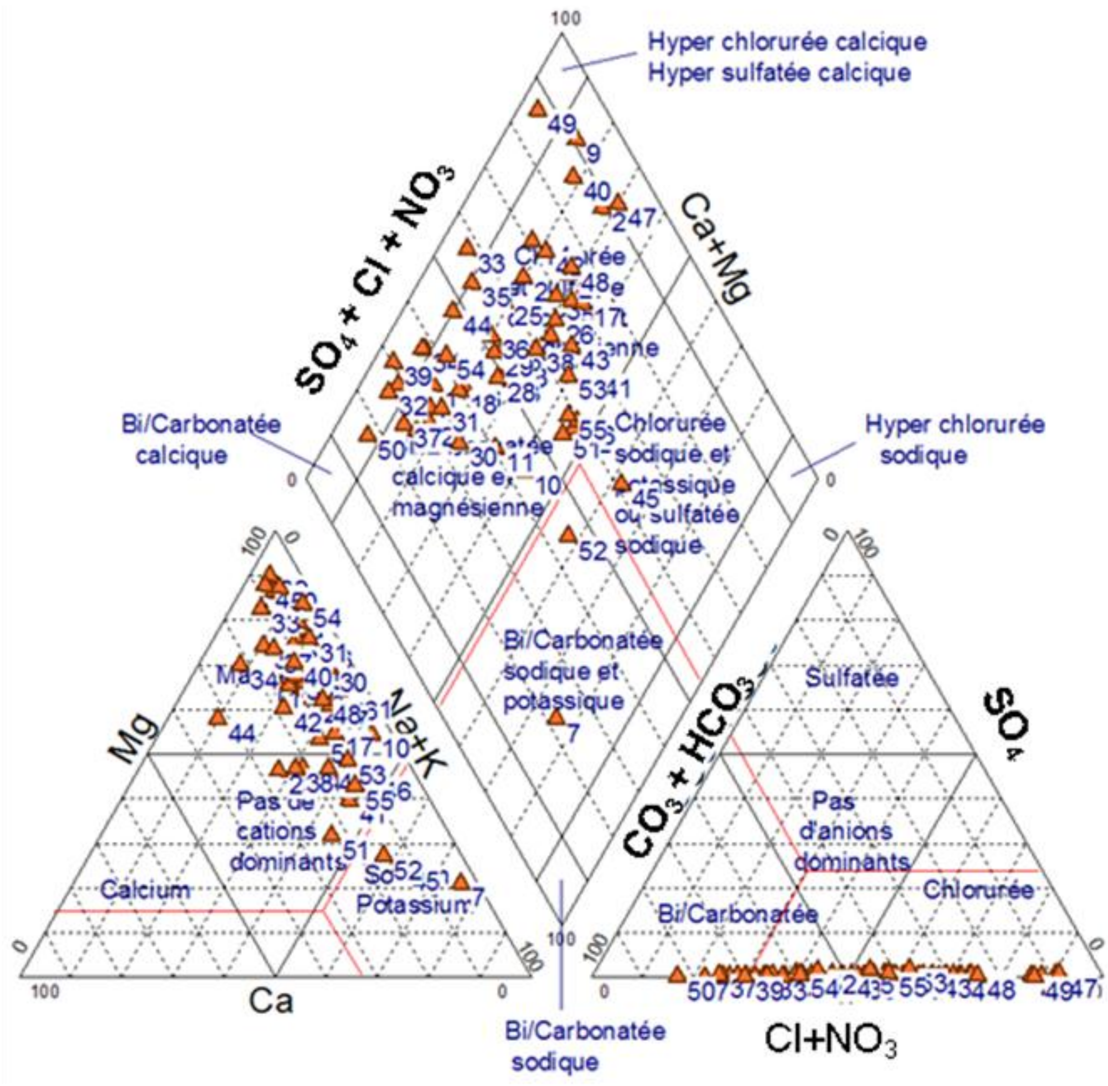

Figure 6. Piper diagram showing groundwater classification (Piper, 1994).

(Belkhiri et al., 2010).

Conclusion

In conclusion, the water quality is a significant aspect of determination of the water body status. The parameters examined in the scope of this thesis were subjected to variety of spatial trends. The results of this study show that the groundwater in the studied area evolves from less saline Ca-Mg-HCO_3 water to blended Mg-Ca-HCO_3-Cl water to brackish Mg-Ca-Cl-HCO_3 water along the topographic flow path. The analysis indicates that the water of Oran sebkha basin is characterized by moderate alkalinity in the investigated period.

In addition to this, it important that bacteriological assessment of water from these different wells be carried out to sure if the water is safe for drinking and other domestic applications.

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Full Length Research Paper

A multi-method analysis of forest fragmentation and loss: The case of ward 11, Chiredzi District of Zimbabwe

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Forest fragmentation and loss seriously affect biodiversity. There is need to monitor and assess forest fragmentation and loss in communal areas for effective biodiversity management. In this study, we analysed the extent of forest fragmentation and loss in ward 11, Chiredzi district of Zimbabwe over a 14 year period (1989 to 2003). A multi-method design was adopted for triangulation and verification purposes. This involved the use of GIS and remote sensing techniques for analysis of satellite images of 1989 and 2003. Fragstats was used to compute the density, size and variation of patches between the two years. A patch area method for determining optimum quadrat size was proposed from for observations and measurements were done. Questionnaire surveys were used to complement data produced through GIS analysis. The non aligned block sampling design in which sample locations were randomly nested was used. Questionnaire surveys were used to collect qualitative data. Results show that there is ecologically significant fragmentation and loss of forest. Forest patches increased by 58.04% between 1989 and 2003. A loss of 32.47% of forest area was estimated. People's perceptions confirm the conclusion that the forest has been significantly fragmented and lost due to collaborative effects of climatic changes and human activities.

Key words: Forest fragmentation and loss, multi-method design, remote sensing, geographic information system, Fragstats, patch area method.

INTRODUCTION

Forest fragmentation is a process during which a large expanse of forest habitat is transformed into a number of smaller patches of smaller total area, isolated from each other by a matrix of habitats unlike the original (Haila, 1999; Fahrig, 2003). By this definition, a landscape can be qualitatively categorized as either continuous or fragmented, where the fragmented landscape represents the endpoint of the process of fragmentation. Fragmentation and loss are recognized as major threats for the conservation of biodiversity and ecological functions of forests (Harris, 1984; Forman, 1995; Rochelle et al., 1999; Loyn and McAlpine, 2001).

The harmful consequences of forest fragmentation for certain species is derived from three main causes: reduction of the size (area) of the remaining forest patches, increased isolation of the fragments and loss of overall connectivity, and increased edge effect and disturbances from the surroundings (Saunders et al., 1991; Forman, 1995; Haila, 1999; Santos and Tellerı´a, 1999). It affects the abundance, richness and dispersal ability of forest-dwelling species (Lida and Nakashizuka, 1995, Gill and Williams, 1996, Gibson et al., 1988; Merriam, 1998; Haila, 1999; Rochelle et al., 1999; Santos and Tellerı´a, 1999; Soledad Garcı´a-Gigorro and

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Santiago Saura, 2004).

The most obvious effect of the process of fragmentation is the removal of forest habitat. This has led many researchers to measure the degree of habitat fragmentation as simply the amount of habitat remaining on the landscape (Carlson and Hartman, 2001; Fuller, 2001; Golden and Crist, 2000; Hargis et al., 1999; Robinson et al., 1999; Summerville and Crist, 2001; Virgos, 2001; Robinson et al., 1995). When ecologists think of fragmentation, the word invokes more than habitat removal: it does not cause only loss of the amount of habitat, but by creating small, isolated patches it also changes the properties of the remaining habitat" (van den Berg et al., 2001).

Over time, many species of plants and animals have evolved to depend on one another. For example, some plants can only be pollinated by a certain kind of bird or insect, (Soper, 2000). The complex relationships between species are often disrupted when organisms are transported to new places or a new element is introduced, (Soper, 2000; Wo Okot-Uma, 2000). This supports Jacobs (1979)'s view that habitat fragmentation results in the split of a species group into smaller groups which are more vulnerable to environmental changes.

Existing forests serve a multitude of functions vital for mankind in addition to providing wood as a renewable resource. Thus, there is a paramount need to conserve forest resources and to implement measures to increase forest biomass at the same time. The global total area of forests (excluding other wooded lands) at present amounts to about 4 billion ha, roughly half of which is tropical forests, and of the remainder, temperate and boreal forests account for one third and two thirds, respectively. During the course of human history, roughly 2 billion ha have been lost due to various human activities, mostly in the temperate zones.

Clearing natural habitats for agriculture, forestry, urban development and water projects reduce their effectiveness in providing shelter for species which live there (Forman, 1997; Jackson and Jackson, 1998; Green et al., 2000). For a particular species, certain conditions of external parameters, for example temperature, humidity and resources like food and space must exist for the species to survive, grow, reproduce and maintain a viable population (Jackson and Jackson, 1998).

There is prevalence of the slash and burn type of agriculture which, in the 1980s, cost the world 100 000 km^2 per year of tropical rainforest, (Munowenyu, 1996). In some areas especially in Africa, large sections of tropical rainforests are cleared for raising cash crops like sugarcane, banana, pineapple, soya bean and palm oil for export (Miller and Spoolman, 2009). This has significantly contributed to the fragmentation and loss of forest habitat posing a deluge of impacts on vegetative and animal species diversity.

Specifically, in Zimbabwe it is estimated that 70 000 hectares of woodland are cleared annually for agricultural activities (Chenje et al., 1998). The profitability of wood as a burning fuel, and as a useful industrial raw material has overridden environmental reason, threatening ecological systems, pollution, and destroying forest health and biodiversity (Gogo, 2012).

Over 46 015 hectares of forests have been destroyed and 1,38 million cubic metres of firewood burnt to cure part of the 127 million kilogrammes of tobacco delivered to the auction floors (Manica Post, 2011). Farmers often remove trees from grazing lands as well as arable lands. Woodland areas are converted to agriculture either as informal annexation of woodlands by individual farmers or through government resettlement schemes (Chenje et al., 1998).

Wild animals are reported to have migrated due to these environmental changes. While habitat fragmentation and loss are clearly visible in this area, no study has been carried out to measure their extent and related impacts on flora and fauna species diversity. This study seeks to assess the extent of habitat fragmentation and loss and their impacts on flora and fauna species, diversity.

Given the impending repercussions of natural phenolmena and human activities that are the driving forces behind habitat fragmentation and loss, there is need to come up with strategies and habitat management policies that minimise their impacts. The starting point is research related to forest fragmentation and loss and their impact on various ecosystem functions. Currently, there is paucity of quantitative and qualitative data to demonstrate the extent to which fragmentation and loss have affected vegetative and animal species diversity.

This study aimed to assess forest fragmentation and loss in Chikombedzi ward 11 providing quantitative and qualitative data to demonstrate the changes that have taken place over time.

MATERIALS AND METHODS

Study area

The study was carried out in Chikombedzi area ward 11 in Chiredzi district which is in the south eastern part of Zimbabwe (Figure 1).

The area is generally hot and dry. The total human population of the ward is approximately 15 000. The majority of the population is peasant farmers. Ward 11 is separated from ward 10 by a railway line to the north of the ward. To the south, the ward is separated from ward 13 by Mwenezi River. To the east, the ward shares the boundary with ward 12, which are small scale farms of the colonial African purchase area and to the west, it shares boundary with former large scale cattle ranches which are currently occupied under the Land Reform Program.

The study area falls in a region which might be affected in the near future by intensive human activities and this justifies the necessity of similar studies. The dominant type of vegetation is *spiciformis* and *Julbernardia globiflora*, Miombo woodland, (Campbell et al., 1988), make part of woody vegetation. *Parinari* tree bush Savannah with continuous or discontinuous grass cover pattern, topography, soil type and human disturbance. *Brachystegia* depending on the soil moisture regime (Zhou, 2004).

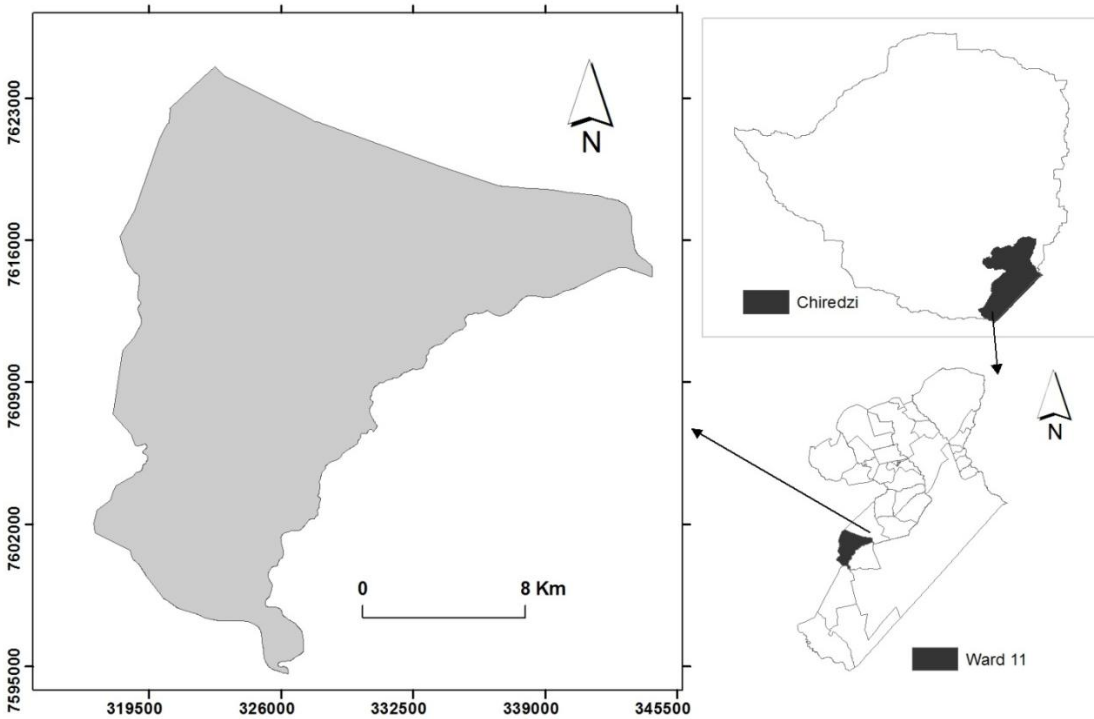

Figure 1. Map of the study area.

Vegetation species composition and variants is mostly determined by rainfall *curatellifolia* can also be found in pure stand or in combination with *Burkea African* and *Terminalia serice* and they are mainly found in well drained middle slopes and on upland soils. However, few vegetation of this type remains in its pristine state due to clearing of land for agriculture. Woody tree species are dominated by the drought tolerant Mopane (*Colophospermum mopane*), baobab (*Adansonia digitata*), *Commiphora* spp., *Kirkia/cuminate* and *Acacia* tree species (Zhou, 2004; Chenje et al., 1998).

In ward 11 of Chikombedzi, there has been significant logging of trees, proliferation of veld fires and other various human activities that have led to loss of natural vegetation exposing soil to erosion resulting in the siltation of water bodies. Infrastructural development such as roads, urban areas, schools and clinics as well as population growth have exacerbated habitat exploitation resulting in significantly visible fragmentation and loss. The dominance of farmers could only mean an increase in land clearance for crop production, which contributes to the problem of fragmentation and loss.

Ground sampling design

A nested non-aligned block sampling design, adopted by Chapungu and Yekeye (2013) in a study estimating species diversity in a communal landscape, was used in which sample locations were randomly nested as shown in Figure 2.

This design was used because it allows multi-scale assessment of variables in which small and large variations over large areas will be captured (Urban, 2002; Chapungu and Yekeye, 2013). A grid of 12500 x 12500 m was drawn within the ward boundaries on satellite images using the Integrated Land and Water Information System (ILWIS), Geographic Information System (ITC, 2005). The grid was further subdivided into 25 sub-cells (grids of 2500 x 2500 m) from which three of them were randomly selected. The three selected cells of 2500 m were further divided into 25 micro cells (grids of 500 x 500 m) where three locations were randomly selected. The centre of the three selected 500 x 500 m grids were used for quadrat identification using a hand held Global Positioning System (GPS) receiver at less than 0.5 m error from the identified points.

Determination of optimum quadrat size

The size of the quadrat was determined using the proposed patch area method (Figure 3). This method involves plotting the number of patches identified in quadrats of successively larger size, so that the area enclosed by each one includes the area enclosed by the smaller one. In this study, 100 x 100 m up to 800 x 800 m plots were developed within each sampling unit to determine the cumulative frequency of identified forest patches. The data for each quadrat was recorded. The mean cumulative frequency (patch number) was then plotted against each plot size shown in Figure 5.

The quadrat with the optimum number of patches was the 500 x 500 m quadrat. Thus, it was the one adopted for this research.

Image processing

Landsat satellite images for 1989 and 2003 were downloaded and used to calculate percentage for each land cover type within Chikombedzi area, ward 11. The images were processed with Arc View GIS software. Supervised classification system was done using the maximum likelihood classifier. The land cover classes identified were used to determine the extent of habitat fragmentation and loss within the ward. Fragstats was used to compute the number, size and density of patches from the satellite

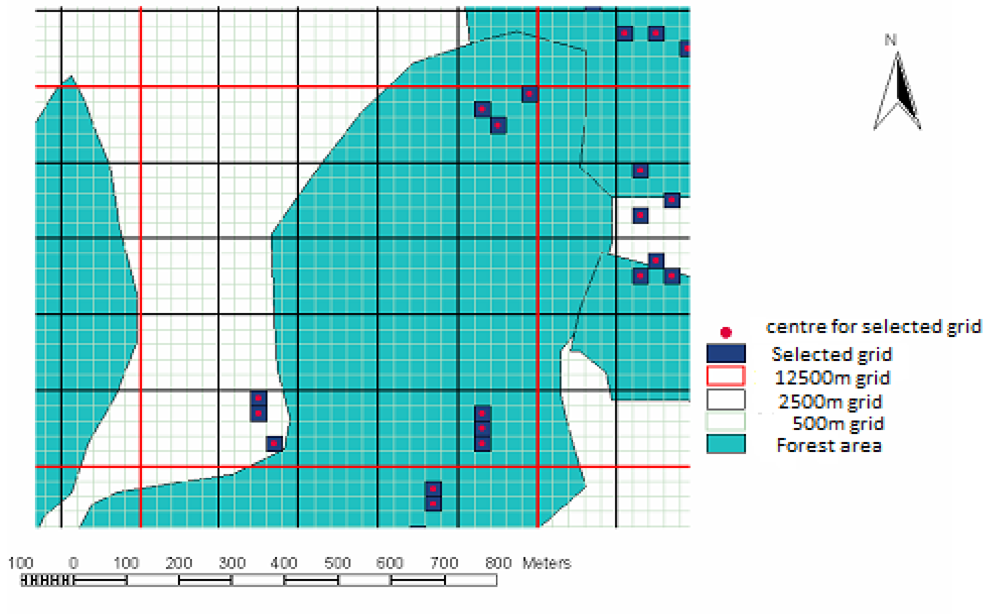

Figure 2. Non-aligned block sampling design using grids of 12500, 2500 and 500 m.

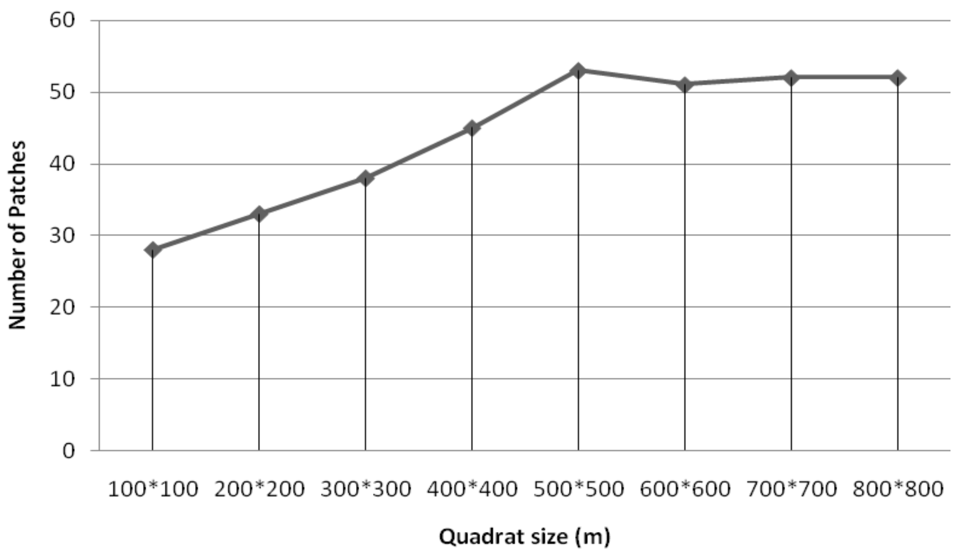

Figure 3. Determination of optimal quadrat size.

images. This facilitated comparison of patch size and number between the two years.

Observations and species physical counting

Direct observations were also used to collect data on the general state of the habitats, human interaction with ecosystem as well as the species available in the sampled areas. Species within the quadrats were also physically counted to establish species richness of the area.

Questionnaire survey

A total of 50 questionnaires were distributed to collect data on vegetative and animal species affected through habitat fragmentation and loss. Factors affecting habitat fragmentation and loss were also inferred through this method. Questionnaires were distributed in Chikombedzi, Pfumari, Chanienga, Chomupani, D16, D14, Mupakati, Gurungweni Chamagutise and Chagwaliva areas. People residing in the area for at least twenty years were targeted because they had stayed in the area long enough to notice the changes occurring in the area.

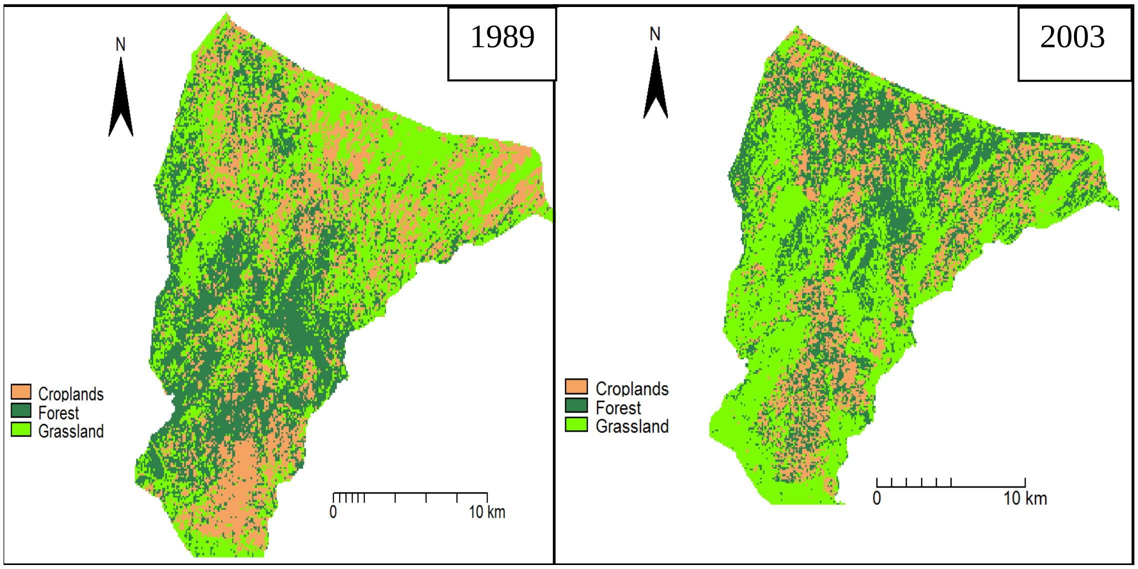

Figure 4. Habitat changes in Chikombedzi ward 11.

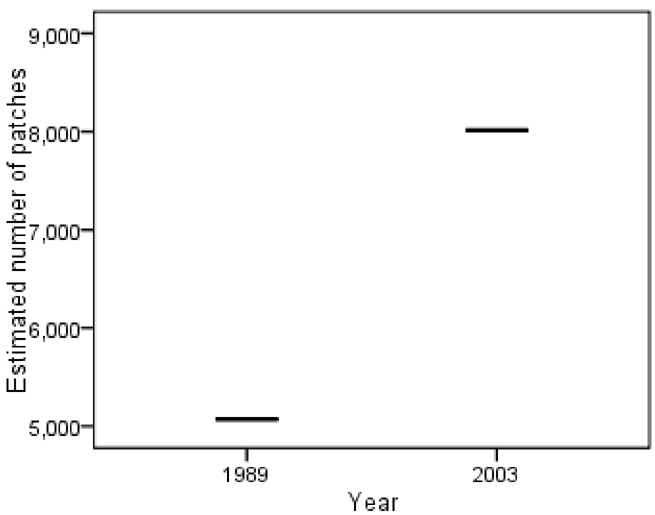

Figure 5. The number of forest patches in 1989 and 2003 (p>0.05).

Interviews

Interviews were also used to collect data from the individuals who could not participate in the questionnaire survey. Most of these individuals were elderly people who had a lot of information about the environmental changes occurring in the ward.

RESULTS AND DISCUSSIONS

Habitat fragmentation and loss

Land cover and land use maps for 1989 and 2003 were analysed and compared to assess the extent of habitat fragmentation. Satellite data from Landsat thematic maper imagery shows habitat changes between 1989 and 2003 (Figure 4).

Figure 4 shows differences in habitat coverage between the two years. There is a decrease in forest cover and an increase in forest patches, an indication that there is fragmentation and loss. The number of patches were also analysed to ascertain whether fragmentation is increasing or not. According to Weins (1994), an increase in the number of forest patches is an indicator of fragmentation processes taking place. Figure 5 shows the differences in estimated number of patches between the two years.

It is shown that there is a significant change ($p>0.05$) in the estimated number of patches between the two years. In 1989, 5070 forest patches were observed in the ward. The number increased to about 8013 in 2003. The estimations confirm the views of the respondents in the area who attested to the view that there is an increase in forest fragmentation and habitat loss. Figure 6 shows the views of the respondents which confirm findings drawn from image analysis.

It is shown that the greater percentage (92%) of the respondents concurs with the fact that fragmentation and loss of forest is taking place in the area. The respondents revealed that construction of roads and clearance of forests for fields as well as human settlement and grazing are the prime causes of the fragmentation and loss in habitats.

A decrease in forest patch size is an indicator that fragmentation and loss is taking place (Sole et al., 2004). Analysis of patch size in ward 11 shows that fragmentation and loss are taking place. The mean patch size has changed between the two years. Figure 7 shows the statistical differences in patch size between the two years.

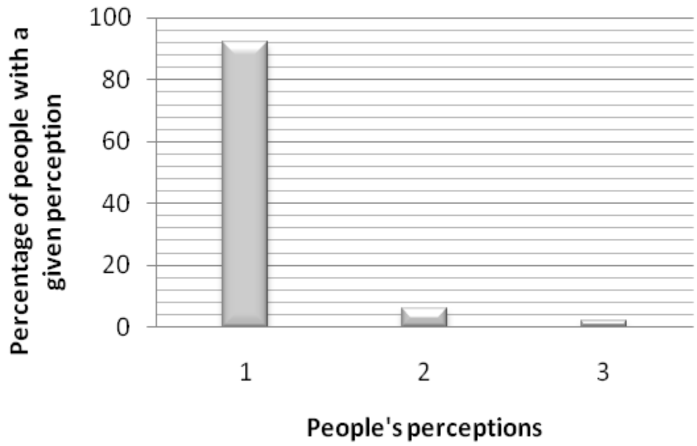

Figure 6. Perceptions about habitat fragmentation and loss in Chikombedzi area. 1) Habitat has been fragmented and lost 2) Habitat has been fragmented and not lost 3) Habitat has been lost but not fragmented.

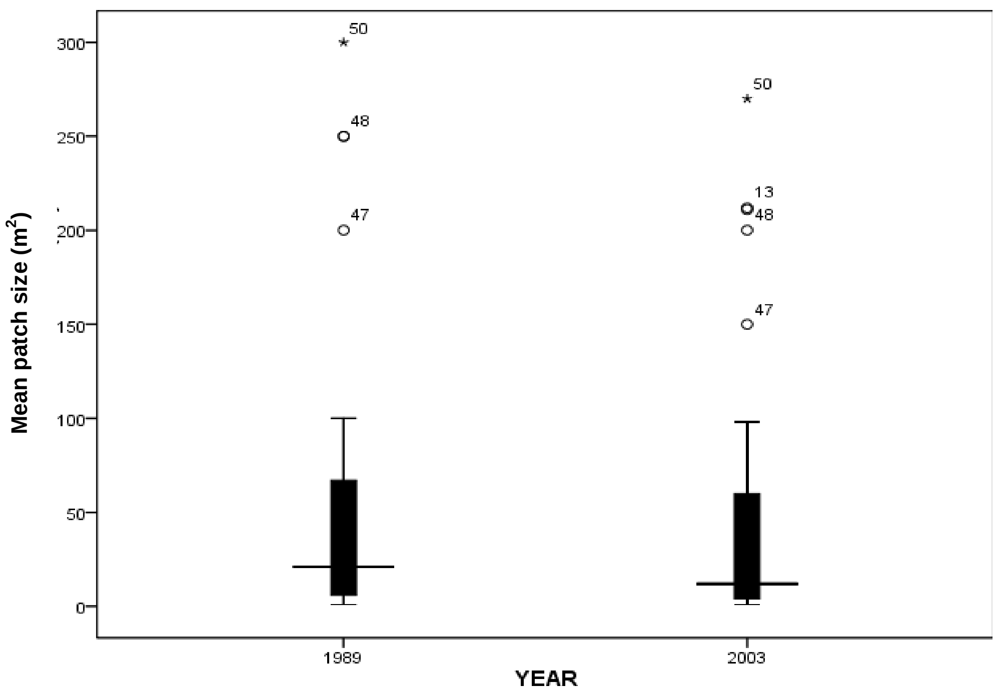

Figure 7. Forest patch size in 1989 and 2003 in ward 11, Chikombedzi area.

As shown in Figure 7, there is a significant ($p=0.002$, $\alpha=0.05$) difference between mean forest patch size in 1989 and 2003. In 1989 the mean patch size was 49.2 m^2 while that of 2003 was 42.74 m^2. Respondents also highlighted that there are significant changes in the size of forest patches in the area owing to multifarious human activities including veld fires, expansion of crop land, fuel wood harvesting and construction.

The total area for three main land uses in the area was also calculated and compared between the two years. Table 1 shows the differences in calculated croplands, forest and grassland area between the two years. In 1989 the area covered by forest habitat was 32.47% and in 2003 the habitat had changed to 31.69%. This shows that forest has been reduced in size over the 14 year period.

Some ecological changes are statistically insignificant but environmentally significant. The differences observed as shown in Table 1 are statistically insignificant but

Table 1. Cropland, forest and grassland area changes between 1989 and 2003.

Land cover type	1989		2003		Changes between 1989 and 2003	
	Area (km^2)	Percentage land cover	Area (km^2)	Percentage land cover	Difference in area	Percentage difference
Croplands	95.64	27.3	68.07	19.04	27.57	-8.26
Forest	113.75	32.47	113.29	31.69	0.46	-0.78
Grassland	140.91	40.23	176.19	49.27	-35.28	9.04

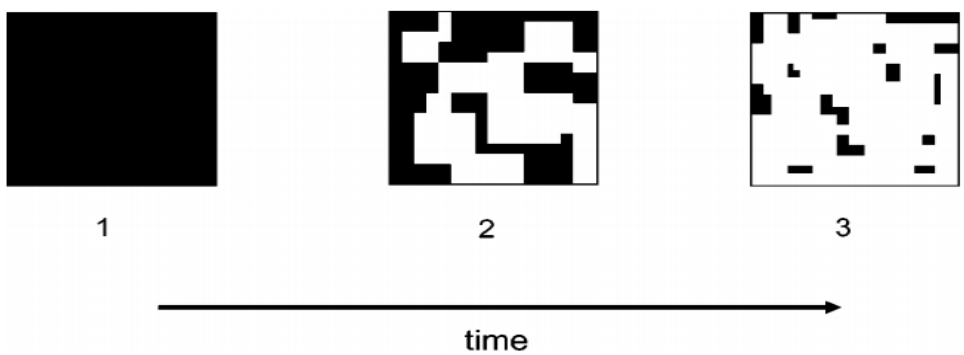

Figure 8. The process of fragmentation and loss of habitat.

environmentally significant because the slight change in land cover results in significant changes in species composition, richness and other ecosystem interactions.

DISCUSSION

In this paper, we analysed images and it was shown that there is a decline in forest area. Forest area declined from 32.47% of the total land area of the ward in 1989 to 31.69% in 2003. There is also evidence of an increase in forest patches, an indicator of fragmentation occurrence. This decrease in forest cover and increase in forest fragmentation has been confirmed by people resident in the ward for more than 25 years. The decrease in land under forests implies a change in species evenness and richness (Mcletchie, 2002; Alonso, 2004). As the area under forests decreases, the number of small vegetative species increases (Chapungu and Yekeye, 2013). However, although there is an increase in species richness, the size of the species in height and diameter at breast height has significantly decreased. This is mainly because deforestation, which has been highlighted as the key factor of fragmentation and loss, mainly affects species of larger sizes as they are targeted due to their socio economic benefits. This encourages growth of small graminae and herbaceous species which are smaller in size both in height and diameter.

The changes in forest cover confirm the views of the respondents that the rate of deforestation is increasing as the forests are a source of fuel wood for the inhabitants in the area. Moreover, agricultural land clearing activities have significantly changed land use patterns where woodland area has been transformed into shrubland mostly used for grazing purposes. This confirms Lord and Norton (1990)'s contention that agricultural activities play a critical role in habitat fragmentation, which consequently contribute to the changes in species evenness and richness.

Agricultural activities have influenced fragmentation and loss of forest habitat. However, due to scarcity and unreliability of rainfall, crop production has declined and most land has been left fallow resulting in growth of grasses and bushes. There is also evidence that some vegetative species have gone extinct. Local people confirmed that there are some vegetative species which became extinct in the area due to the fragmentation and loss process. When native vegetation is cleared (usually for agriculture or other kinds of intensive exploitation) habitats which were once continuous become divided into separate fragments (Figure 8) (Hanski, 1999; Pimm, 1991). After intensive clearing, the separate fragments tend to be very small islands isolated from each other by cropland and pasture.

Fragmentation and loss of habitat are recognized as the greatest existing threat to biodiversity. Such forest fragmentation and loss as illustrated in Figure 8 shows that Chikombedzi district could be facing serious challenges with regards the loss of forests due to a combination of natural disasters in the form of droughts and human activities in the form of expansion of agricultural area, settlement and other developmental activities.

Conclusions

In this study, we concluded that using a multi-method design provides a confirmatory dimension to research results. This is useful in verifying results obtained from satellite image analysis or from other qualitative methods. Using this design, we conclude that there is a decrease in forest cover and an increase in forest patches, an indication that there is habitat fragmentation and loss. The key factor of this fragmentation and loss is deforestation which is perpetuated for several reasons including human settlement, agriculture and infrastructural development. Natural phenomena such as droughts have exacerbated the ecological impact. The vegetative species mostly affected are *Mopani* and *Mutsviri*. These tree species are mainly prone to deforestation because of their socio economic value and multi-purpose functions.

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Full Length Research Paper

Comparison of plant nutrient levels between compost from *Sky loo* and *Fossa alterna* toilets

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Recent scholars have highlighted the benefit of harvesting compost from eco-san toilets for application as plant nutrients. However, levels of nutrients in eco-san compost may vary depending on the type of toilet and also the type of top soil in a particular geographical region. This study compared levels of nitrogen, phosphorous, potassium, calcium and sodium between compost from *Sky loo* and *Fossa alterna* toilets. Samples were collected from Zimora and Ng'ombe villages in Chikhwawa district, southern Malawi. Statistical analysis using SPSS showed significantly higher levels of nitrogen, calcium and moisture in compost from *Fossa alterna* toilets than in *Sky loo* ($p < 0.05$). However, there were no significant differences in the levels of potassium in the two types of eco-san compost studied. This study has revealed that compost from *Fossa alterna* is generally a richer source of plant nutrients than that from *Sky loo* thereby presenting poor, local communities in sub-Saharan Africa with a cheaper alternative to commercial fertilizer.

Key words: Eco-san toilets, compost, Malawi, plant nutrients, soil quality.

INTRODUCTION

With a Human Development Index rank of 171 out of 187 countries, Malawians living in rural areas face numerous challenges that include lack of access to safe drinking water, rising poverty, rapid population growth and poor sanitation (United Nations Development Programme, 2012). The growing numbers of poor households means that the majority of smallholder farmers cannot afford commercial fertilizers due to high prices. Such poor communities suffer from periodic famine due to persistent drought, and depreciating soil quality among many other external factorsg (Sugden, 2009). Eco-san compost has the potential of improving soil quality thereby increasing food security for poor households. Eco-san technology provides a safe way of recycling human excreta through composting. However, meaningful and comprehensive knowledge on variations of plant nutrient composition between compost from different eco-toilets is still scare.

There are three types of eco-san latrines, namely: Arborloo, Fossa alterna and Sky loo. Arborloo, sometimes known as "fertility pit", does not provide mechanism for harvesting manure; instead, a tree seedling (preferably a fruit tree) is planted on the spot when the pit

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becomes full. Sky loo, which is also known as “dry toilet”, has a permanent super structure and it is a urine diversion system. The urine and stool are collected separately. Fossa alterna is a kind of toilet in which urine and faeces are mixed in one vault (Snel and Smet, 2006).

Although, eco-sans toilets provide an environmentally friendly waste management technology for disposing of faeces and urine and their recovery through composting for possible use as manure, it faces some resistance due to socio-cultural issues. Adoption of eco-san technology has made little progress in Malawi despite a decade of advocacy and promotion by non-governmental organizations such as Water for People (Malawi). Such negative attitude stems from a general reluctance of people to use of their excreta as a valuable resource. Traditionally, issues of human excreta are considered a taboo in most parts of the world and are not usually discussed in public. For this reason, sharing of information and willingness to learn practical and environmental benefits of recycling nutrients in excreta back to soil seem remote.

Across the world, eco-san is increasingly being seen as an alternative for providing safe sanitation, reducing health risks associated with poor sanitation, protecting water resources, soil fertility and optimizing resources management at the same time (Water for People, 2009). Eco-san technology can improve social and economic conditions especially for impoverished communities. Similar technologies or ‘dry box toilets’ have been used successfully for many years in a number of countries, such as Vietnam, China, Mexico, El Salvador, Guatemala, Ethiopia, Zimbabwe and Sweden (Esrey and Anderson, 2001). In Asia, containers of untreated human excrement are set outside residences during the night and taken to crop fields. The contents of these containers are called ‘night soil’ because the boxes are collected at night for application (Nawab et al., 2006).

Soil is the primary natural resource base for agriculture, but most of the soils in Malawi have low levels of nitrogen. This means that they cannot support crop production without supplementation of key nutrients such as nitrogen, phosphorous and potassium from external sources. Nitrogen, potassium, phosphorous, calcium, magnesium and sulphur are collectively known as macrontrients. These macronutrients are vital for the rapid growth of plants, increased seed and fruit production and improving the quality of leaf and forage crops. Ferrallitic soils are widely prevalent in Malawi. These soils have levels of both nitrogen (0.05 - 0.12 %) and organic matter (0.4 - 1.6 %) in low amounts; indicating poor soil fertility. Available phosphorous is between 0 - 22 ppm while potassium ranges from 0.11 - 0.36 mE/100g). Enhancement of soil productivity is very important to the sustainability of agriculture and to meeting basic food needs of the growing population.

Commercial inorganic fertilizers in Malawi costed about US$40 for a 50 kg bag in 2012. This is a huge expense in a country where almost seventy percent of the population live on less than 1US$ per day (United Nations Development Programme, 2012). Conversely, human excreta are a freely available resource in all societies. They can be utilized as soil amendments to boost crop production. Eco-san technologies are important in econo-mic emancipation of poor masses because compost from eco-san toilets is an alternative to commercial fertilizers and have potential to reduce reliance on inorganic fertilizers. Compost has the ability to improve the soil structure and water holding capacity and is comparatively better off than commercial fertilizers (Centre for Community Organisation and Development, 2011).

The concept of eco-san technology was first introduced in Malawi in 2001 by Water Aid in Salima district and the Church of Central Africa Presbyterian (CCAP) at Embangweni, in Mzimba district, before being taken up by Community Water Sanitation and Health (COMWASH) in Phalombe and Thyolo districts (Morgan, 2010). Despite attaining a decade since its inception, it is still not widely used. Recent reports indicate that 50% of the communities in Ng’ombe and Zimora villages in Chikhwawa district have adopted eco-san toilets as a result of promotion activities by Water for people in Malawi (Water for People, 2012). However, this progress is minimal and there remains a lot of work to be done before a real paradigm shift in sanitary provision can occur whereby people do not simply equate sanitation to toilets but rather to total and ecologically sound sanitation with an agronomic and economic perspective. This study was therefore conducted to compare levels of essential plant nutrient between compost from *Sky loo* and *Fossa alterna* toilets in Chikhwawa district, southern Malawi.

MATERIALS AND METHODS

This study was conducted between May and August 2012. Three *Sky loos* and three *Fossa alternae* which had been in use for at least one year were identified in the area as sampling points. Samples were collected from well decomposed and harvested compost (approximately 500 g of compost was collected in triplicates into sealed plastic zipper bags) and were transported to Polytechnic Chemistry Laboratory in Blantyre City, Malawi. Samples were air-dried by thin spreading on clean sheets of paper in the laboratory for five days. Dry samples were sieved over 2 mm mesh and then stored in air tight polyethylene zipper bags for further analysis. The standard analytical methods used were from American Public Health Association series of Standard Methods of Examination of Water and Effluent (APHA, 1998) and AOAC Official Methods of Analysis (AOAC International, 1998).

Data analysis

The data collected were subjected to student’s independent t-test (two tailed) using SPSS to validate the hypothesis that the two

Table 1. Comparison of plant nutrient levels in *Fossa alterna* and *Sky loo* compost.

Compost type	mc (%)	N (%)	P (%)	K (%)	Na (%)	Ca (%)	S
Sky loo	5.03 ± 0.21	0.06 ± 0.00	0.05 ± 0.01	0.04 ± 0.00	0.01 ± 0.00	0.16 ± 0.02	BDL*
Fossa alterna	11.39 ± 0.44	1.88 ± 0.08	0.06 ± 0.00	0.05 ± 0.00	0.01 ± 0.00	0.10 ± 0.03	BDL*

*BDL = below detection limit.

Table 2. Nutrient levels in natural topsoil, compost from *Fossa alterna* and *Sky loo for studies done in Zimbabwe.* Source: Morgan, 2002.

Source	N (mg/kg)	P (mg/kg)	K (mEq/100g)
Natural dry land topsoil	38	44	0.94
Fossa alterna compost	275	292	4.51
Sky loo compost	232	297	3.06

Table 3. Chemical properties of natural soils in Chikhwawa district, Malawi. Source: Ministry of Agriculture and Food Security, 2001.

Agro-ecological zone	N (%)	P (ppm)	K(mEq/100g)
Chikhwawa Escarpment	>0.12	6 - 18	>0.2

types of eco-san compost had the same level of nutrient content.

Null hypothesis (H_0): $\mu_{FA} = \mu_{SL}$
Alternative hypothesis (H_a): $\mu_{FA} \neq \mu_{SL}$

Where μ_{FA} represented *Fossa alterna* compost mean values and μ_{SL} represented *Sky loo* compost mean values. The test was carried out at 95% confidence level (p-value = 0.05). If p-value computed was less than 0.05, the null hypothesis was rejected and alternative hypothesis accepted instead. With a p-value < 0.05, it meant there was a significant difference in the means of nutrient levels of *Fossa alterna* compost and *Sky loo* compost.

RESULTS AND DISCUSSION

Results obtained from the analysis of the two types of eco-san compoat are summarised in Table 1. There was a significant difference in levels of nitrogen for *Fossa alterna* and *Sky loo* (1.88% ± 0.08; 0.06% ± 0.00 respectively with p ≤ 0.05). There was a lower amount of nitrogen in *Sky loo* compost than *Fossa alterna* compost probably because of the urine diversion design in the *Sky loo* latrine. Urine has a high content of readily available nitrogen. Nitrogenous wastes in the body, which result from ingestion of proteins, are excreted as urea after they have been converted from amines and ammonia (Chasseaud, 1970). Moisture content was also significantly different (11.39% ± 0.44, for *Fossa alterna* and 5.03% ± 0.21 for *Sky loo*; with p ≤ 0.05). High amounts of water in compost from *Fossa alterna* result from urine inclusion because its principal component is water.

Levels of calcium were also significantly different such that *Fossa alterna* compost (0.10% ± 0.03) had lower level as compared to the *Sky loo* compost (0.16% ± 0.01) and p = 0.04. In humid soils, presence of ammonium sulphate may lead to loss of calcium from the soil because clay particles act like ion exchange resins. Calcium ions are exchanged for ammonium ions and are easily leached from the soil (Gardiner and Miller, 2004). This might explain why levels of calcium were lower in *Fossa alterna* compost than *Sky loo* compost.

However, there was no significant difference in levels of phosphorous for *Fossa alterna* compost (0.60% ± 0.00) and *Sky loo* compost (0.05% ± 0.01); *p* = 0.17. No significant difference was observed in levels of potassium for compost from *Fossa alterna* (1.88% ± 0.01) and compost from *Sky loo* (0.04% ± 0.03); *p* = 0.34. There was also no was no significant difference in levels of sodium for *Fossa alterna* (0.007% ± 0.00 and *Sky loo* (0.007% ± 0.00); with *p* = 0.94.

The results obtained in this study are comparable to findings in Zimbabwe (Table 2) which were reported by Morgan (2002) to compare major nutrient levels in samples of naturally occurring topsoil and compost from *Fossa altena* and *Sky loo-toilets*.

The natural soils which are found in the study area (Chikhwawa district, southern Malawi) are classified as eutric cambisols and haplic luviso (Food and Agriculture Organisation, 1999). Table 3 shows major natural occurring plant nutrient levels of these soils.

The levels of plant nutrients in eco-san compost from Chikhwawa district in Malawi are however lower those of eco-san compost from Zimbabwe. This phenomenon underlines the fact that amounts of nutrients in excreta differ from person to person and from region to region (Vinneras, 2002).

It is also important to note that eco-san compost can be a source of microorganisms such as salmonella, especially if the compost is harvested within a period shorter than 4 weeks. Studies done by Lemunier et al. (2005) indicated that compost may support long-term survival of *Escherichia coli and Listeria monocytogenes* but proper long-term (over 12 months) composting may prevent the presence of such microorganisms in compost and therefore pose low health risks to consumers of food plants grown using eco-san compost.

Conclusion

The findings from this study show that *Fossa alterna* produces compost richer in nitrogen than the *Sky loo* therefore more valuable nitrogen based organic fertilizer. The levels of other nutrients such as potassium and phosphorous did not vary between *Fossa alterna* compost and *Sky loo* compost.

The study has increased an understanding on the variations in nutrient levels of human compost depending on the type of eco-san technology used. It also contributes to the existing knowledge on the key factors which influence adoption of eco-san technology to improve soil productivity. Nitrogen is an essential plant nutrient which influences production of most cereals such as maize. Therefore, *Fossa alterna* compost can serve as good alternative for the relatively expensive inorganic fertilizers. However, nitrogen is highly labile and a single analysis is not sufficient to predict its sustainable supply to the crop over the growing season. it is therefore recommended that further extensive studies on crop productivity should be based on long term data of crop response to the two types of eco-san compost.

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Full Length Research Paper

Monitoring the land-use and vegetation cover changes in the Kainji Lake Basin, Nigeria (1975-2006)

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This paper demonstrates the use of remotely sensed data and geographic information system (GIS) techniques for monitoring the land-use and vegetation cover changes in the Kainji Lake Basin between 1975 and 2006- a period of thirty one (31) years. Since 1968 when Kainji Lake was constructed, various activities such as agriculture, deforestation, irrigation, fishing and construction of roads and bridges have taken place. It is all these activities coupled with other natural factors that cause environmental degradation and the damage of the ecosystem of the lake basin. Landsat TM image of 1975, Landsat MSS image of 1986 and Landsat ETM+ images of 2001 and 2006 were acquired, classified and analysed with the use of Ilwis 3.3 and Idrisi 32 to study the landuse and vegetation changes in the Lake Basin between 1975 and 2006. Area calculations of Idrisi 32 were used to derive the trends, rates and magnitudes of changes, while map overlay was employed for assessing the nature and location where the changes have taken place. Map overlay technique was also used to create a matrix to discuss the location of the changes within the study periods. The study reveals that the Lake Reservoir and settlements around the lake were gradually increasing; intensive agriculture was capturing the basin at alarming rate, while the lake surface itself is recently been occupied by weeds. The woodland vegetation in which the first and the most popular National Park in the country where it is located is also discovered to be changing to other land-use types. Various conservation and control measures were suggested for the sustainable utilization of the Lake Basin.

Key words: Remote sensing, geographic information system (GIS), image classification and land-use and land-cover, change detection.

INTRODUCTION

The Kainji Lake basin is one of the most important inland basins in Nigeria, it is the home of the first and the largest hydro-electricity station in the country, the woodland vegetation of the basin is also the home of the first National Parks in Nigeria. Agboarumi (1997) described the basin as blessed, mighty, great and the central hub upon which the entire social economic activities of the nation depends. It is the realization of this fact that the government of Nigeria in conjunction with the Global Environmental Facility (GEF) financed the sustainable management of the protected areas in the country with the main objective of strengthening the capacity of the relevant institutions at all levels in maintaining the biodiversity of this areas, Kainji Lake basin being among these protected areas (Papka, 2004).

Rivers, lakes, streams and water bodies have complex ecosystem ranging from mountain torrent to quiet, still lowland water which may be deep or shallow, large or small (Haslam 1978). The most important physical variable which affect the land-use and vegetation aquatic

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ecosystem include water movement and the quantity of flow, the soil or substance of the bed of the water course, the width and the depth of the channel, the general position of the channel in the river or lake system, the drainage orders, the slope (gradient of the channel and human intervention). Ikusemoran and Adesina (2009), reported that generally whenever a dam is constructed along a river channel, riparian communities around such locations are often affected directly and indirectly. For instance, the places that are inhabited by man are usually flooded, since the surface area of the river channel increases because of the dam construction. Also, the backward effect of the lake water creates some disturbances to the human population around the river channels. Moreover, human activities are also subjected to changes.

According to Ikusemoran and Adesina (2009), the impoundment of Kainji Lake on River Niger has converted the river to a lake ecosystem and has also changed the land cover around the formed lake. The forest formation has changed overtime, which could be due to the change in the orientation of the riparian communities through temporal displacement that took place after the creation of the lake reservoir. Any nation with sustainable utilization of her resources in mind must have adequate information on many complex interrelated aspects of its activities in order to make decisions. Land-use is only one of such aspects. The knowledge about land-use and land-cover has become increasingly important as every nation plans to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of important wetlands, and loss of fish and wildlife habitat. Land-use data analysis are needed in the analysis of environmental processes and problems that must be understood if living conditions and standards are to be improved or maintained at current levels.

One of the prime prerequisites for better use of land is information on existing land-use patterns and changes in land-use through time. The knowledge on land-use such as agricultural, recreational as well as information on their changing proportions is needed by legislators, state and local government officers in determining better land-use policies, identification of future development on pressure points and areas, and implementation of effective plans for regional development. In this dynamic situation, accurate and meaningful current data on land-use are essential for inventory of water resources, flood control, water supply planning and wastewater treatment. Many federal agencies use current and comprehensive inventories of existing and changing uses of land to improve the management of public lands. Federal agencies also need land-use data to access the environmental impact resulting from the development of energy resources, to manage wildlife resources and minimize man-ecosystem conflicts, to make national summaries of land-use patterns and changes for national policy formulation and to prepare environmental impact statements and assess future impacts on environmental quality.

Remote sensing and/or GIS have been applied to land-use and land-cover changes of Lake Reservoir within and outside Nigeria. Okhimanhe (1993) used the combination of Spot HRV imagery of 1986 and aerial photographs of 1974 to study the environmental impact assessment of Burumburum/Tiga dam in Kano State, Nigeria.

The study reveals that the construction of the dam contributed to the depletion of the vegetation that could have minimized desertification. Adeniyi and Omojola (1999) also used aerial photographs, Landsat MSS, Spot XS/panchromatic image transparency and topographical maps to study landuse and landcover changes in Sokoto and Guronyo dams, Nigeria between 1962 and 1986. Their studies revealed that settlement covered most part of the area after the construction of the dam.

Therefore, because of the central role of provision of electricity as well as conservation of flora and fauna, by the Kainji Lake, proper monitoring of the Lake Basin becomes important for sustainable utilization and development.

Objectives of the study

1. To create land-use/land-cover maps of the Kainji Lake basin from 1975-2006 using remotely sensed data and GIS techniques and using the maps to assess the trends, magnitudes, nature and locations of the land-use and vegetation cover changes of the lake basin within the study period.
2. To assess the actual land areas which have been lost or gained by the principal features in the lake basin, that is, the lake reservoir, intensive agriculture and the woodlands vegetation within the study period.
3. To evaluate the environmental and social economic implications of the land-use and land-cover changes in the lake basin.

The study area

According to National Electric Power Authority (NEPA) Diary (1995), the genesis of Kainji Lake power station dates back to 1951 when the demand for electricity was rising faster than supply due to the growth of industries and rapid urbanization in Nigeria. In order to meet the increasing demand for electricity, and consequent upon the realization that bulk supply of electricity could be cheaper through the utilization of hydro power technology, the former Electricity Corporation of Nigeria (ECN) began the exploitation of water resources of River Niger upstream of Jebba. Nedeco and Balfour (1961) reported that the reason for the choice of Kainji as the best site for the Lake were many among which are; rock foundation which was tested and was found to be capable of

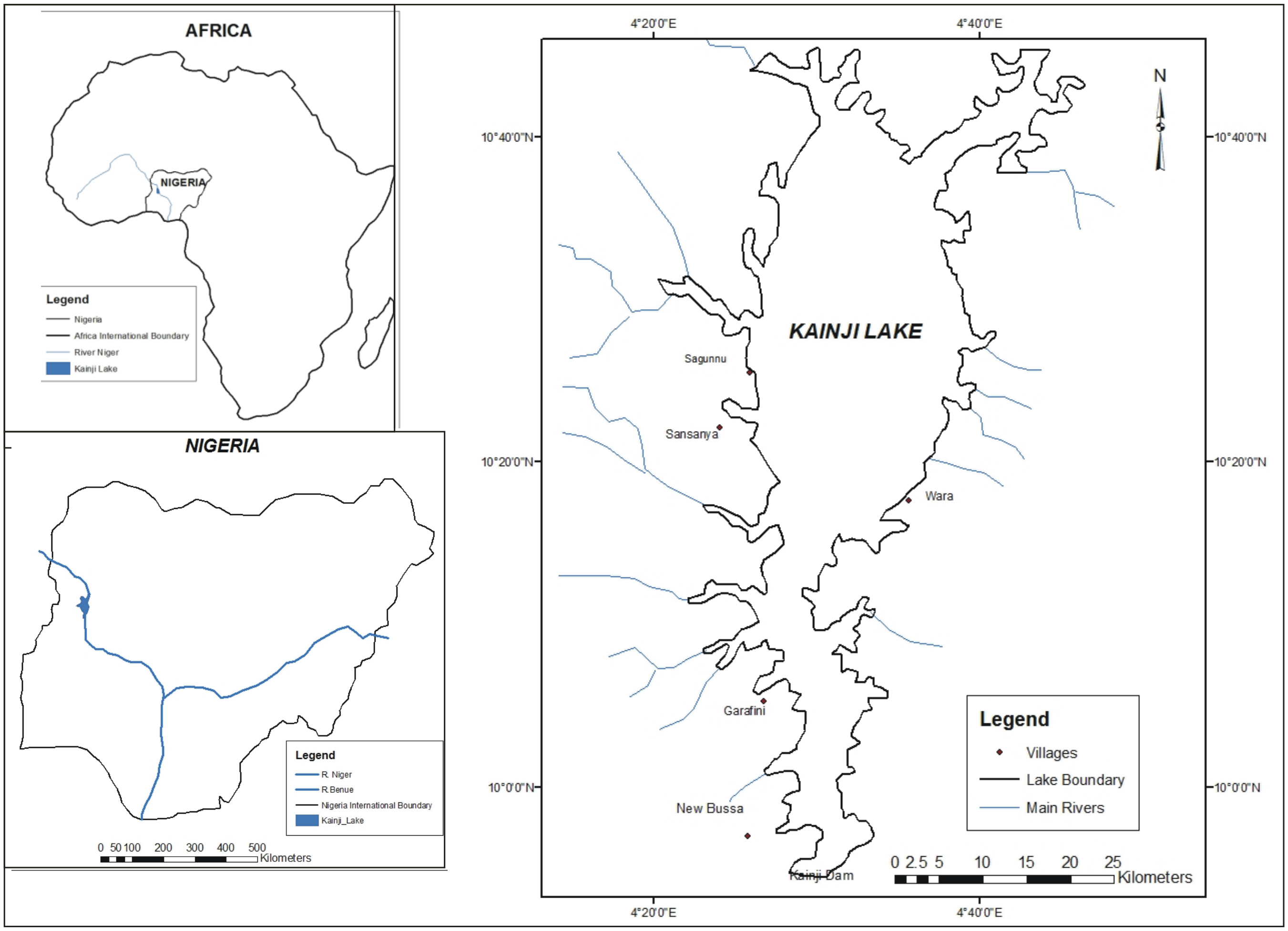


Figure 1. The study area.

holding the enormous height of the dam, it is also the point where the river valley is not too wide, the physical features of upstream of the dam valley also allows for a large reservoir. Agboarumi (1997) observed that the Kainji dam is today a pride of nature, providing cheap and abundant means of electricity for the continuously growing population and industries, sources of revenue, fishing, irrigation, cattle crossing, tourism, employment, international recognition, man-power training and many more.

The lake is located between latitudes 9° 50″ to 10° 42″N and longitudes 4° 20″ to 4° 42″E (Figure 1). Olokoh (1995) reported that construction of the Kainji dam which began in March 1964, was completed in December, 1968 and was officially commissioned on 15th February, 1969. The impounding of the lake started exactly on the 2nd August, 1968 and the water level rose to 140.2 m on the 19th of October the same year - a period of seventy eight days. The lake that was formed sunk most parts of Kainji Island on which the dam was constructed. NEPA Diary (1995) stated that the lake covers an area of 1250 km^2 with a maximum depth of 54.9 m. The lake extends to about 136.8 km upstream of Jebba beyond Yelwa in the North. The lake gets its water from two sources: the river Niger with its headwater in Guinea, and local rivers around the lake basin which flow directly into the lake or into River Niger before entering into the lake.

According to Nedeco and Balfour (1961), the soil depth of the area increases with slope and a gentle undulating topography for the area with red to brown well drained soils differing in texture from sandy loam to clay loam. Most of the basin area have dry season of five months starting from early November to middle of March. Rainfall increases from the month of April, reaching the peak in August and starts declining in September. Rainfall decreases with decrease in latitudes within the basin and also increases with increasing altitude (Olokoh 1995).

METHODOLOGY

Sources of data

The first four data sets (Table 1) which cover a total period of 31 years (1975-2006) were the main images that were acquired

Table 1. Sources of data

Data type	Source	Date
Landsat TM	http:glcffap.umd.edu:8080/esdi/index.jsp	08/12/1975
Landsat MSS	http:glcffap.umd.edu:8080/esdi/index.jsp	21/10/1986
Landsat ETM+	http:glcffap.umd.edu:8080/esdi/index.jsp	22/10/2001
Landsat ETM+	http:glcffap.umd.edu:8080/esdi/index.jsp	05/11/2006
Landuse/Landcover/ Vegetation Maps	Forestry Monitoring and Evaluation Unit (FOMECU) Abuja	Nov.1978 & Nov. 1995

for the monitoring of the Lake Basin. The first two data sets have large gap of more than ten years each, while the last two have close gaps of five years each. This was designed to reflect the impact of dam in the past years of low population and the recent years when the population of the country has been increasing tremendously. All the four images were acquired between late October and early December which is the transition period between the dry and wet season, the climatic conditions during this period is the same all over the lake basin (Olokor, 1995), hence the vegetation cover and other land-use types appear the same on the image regardless of the year when they were obtained. The fifth data sets (Table 1) were acquired from Forest Monitoring, Evaluation and Coordinating Unit (FOMECU) which was established in 1987 as an organ of the Department of Forestry in the Federal Ministry of Agriculture and Natural Resources with its primary mandate of coordination and monitoring of the implementation of Forestry II programs which contains aforestation, reforestation and desertification control projects (Federal Republic of Nigeria, 1999). The maps were used as complimentary and guide during the classification and ground truthing of the imageries.

Image classification

Three bands of infrared, red and green were selected from each of the four imageries to perform colour composition operations using Ilwis 3.3 Academic software. The Imageries were then “submap” individually through the use of the coordinates of the four corners of the lake basin. Colour separation was then performed in order to generate “map lists” while, the sample set module of the Ilwis was also used to create the “domains” which were used for the image classifications. The Maximum Likelihood Classification techniques of the Ilwis 3.3 were used to classify each of the four images. Accuracy assessment was conducted as error matrix commonly referred to as confusion matrix. The following overall accuracy results were obtained for the four images: 90.88% (1975), 87.44% (1986), 82.04% (2001) and 89.63% (2006). Each of the images was filtered through the filtering module of the Ilwis 3.3. The results of the filtered images are shown in Figure 2a-d. The processes of ground-truthing was carried out with the use of Germin 76 Global Positioning System which was used to take the coordinates of settlements, intensive agricultural area, extensive agricultural area around the dam site through Kainji town (see location in Figure 1), as well as some areas within the settlement of Kainji town (Figure 1), the recorded coordinates was linked with the classified image and while other landuse types were found to be correct, the differences between intensive and extensive agriculture on the image was initially difficult until several readings were made to determine the actual positions of each class. The acquired tailor-made map of 1995 processed from satellite images by FOMECU Nigeria, were also used as guide during the ground-truthing. In fact, it was the map in conjunction with the sampled coordinates of freshwater marsh and freshwater swamps taken at the off shore of the Lake at Gaski that was used to ground-truth the two features, that is, freshwater marsh and freshwater swamp. The lake itself was conspicuous on all the images.

Change detection techniques

Three main change detection methods which have been previously applied by several researchers (Adeniyi and Omojola, 1999; Ikusemoran, 2009a) were employed in this paper, they are:

Change detection by area calculation

There are three steps in calculating change detection by area calculation

1. The first step is the calculation of the magnitude of change, which is derived by subtracting observed change of each period of years from the previous period of years.
2. The second step was the calculation of the trends, that is, the percentage change of each of the land-use, by subtracting the percentage of the previous land-use from the recent land-use divided by the previous land-use and multiplied by 100 (B-A/Ax100).
3. The last is the calculation of the annual rate of change by dividing the percentage change by 100 and multiplied by the number of the study years, that is, thirty-one (31) years (1975-2006).

Change detection by nature

The nature of change was derived by map overlay. Each of the four classified images in Figure 2a-d was exported using the TIF. (Geo Tiff) TIFF of Ilwis 3.3 to Idrisi 32 for map overlay and analysis. The output images were overlain to generate the matrix tables (Tables 4a-c) using the addition module of the Idrisi. The area of the features in each image were then calculated through the area module of the Idrsi to generate the magnitude, trends and the percentage change of each of the features in each image.

In generating the matrix table (Table 4a-c) the first image was assigned values from 1 to the maximum class, that is, 10 (as in 2001 and 2006) and nine and eight in 1986 and 1975, respectively. While the second image was assigned 20, 30, 40 and so on until the maximum class of that image (for example 110 in 2001/2006 and 100 in 1986) was reached. (Table 4a-c) The essence of using these figures was that, since the addition of the overlay module was used, when two of these numbers in rows and columns were added, no two additions would produce the same result.

In the matrix tables (Table 4) all the numbers in red colour are the pixel values of each class when the maps were overlain. Those in blue colour were the pixel numbers of each class before they were overlain. The black numbers represents the areas of each of the overlain classes. The purple colour figures are the totals of each

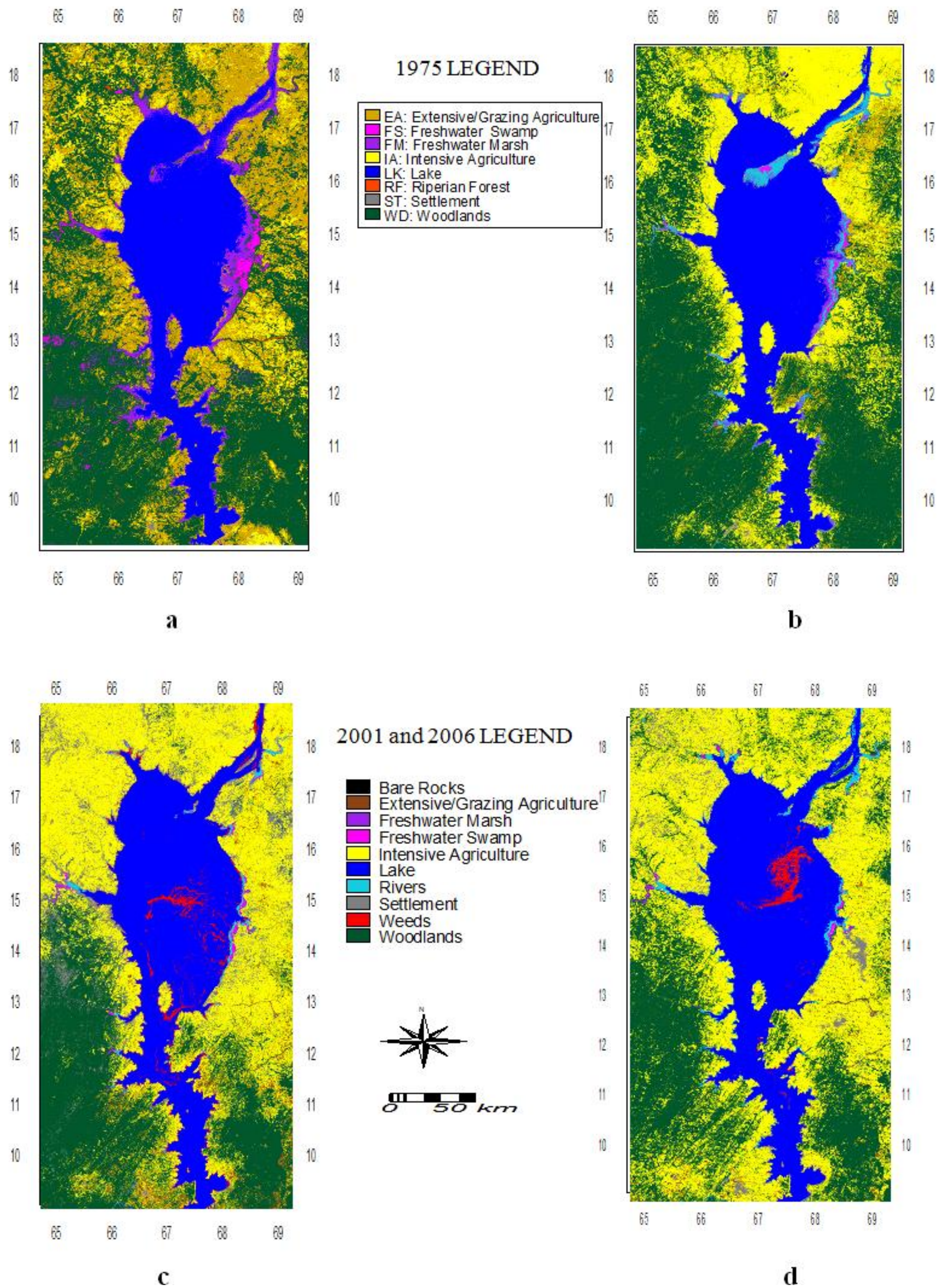


Figure 2. Classified Kainji Lake Basin. **a,**1975; b, 1986; **c,** 2001; **d,** 2006.

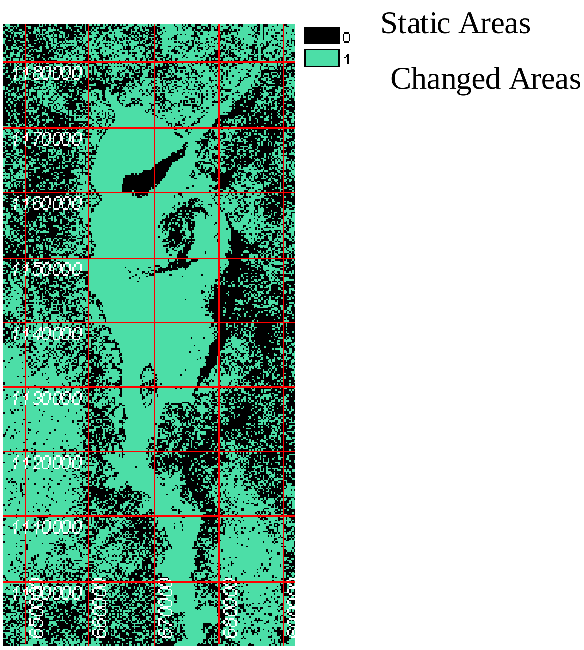


Figure 3. Changed and static areas (1975-2006).

of the classes. Finally, the green colour represents the total area of the study area in square kilometres.

There are three important classes of information that could be generated from the change detection by nature through the matrix table; the first information is that it shows the areas that have not recorded any change at all throughout the study period. This is represented by all the figures (bold) in the diagonals, that is, all the classes with the values in the diagonal have not recorded any change.

The second information that could be extracted were the areas or classes that have changed from their initial land-use or land-cover to another land-use or land-cover type, that is, the areas that have lost to other land-use/land-cover type. These areas were represented by all the classes with values along the columns in the matrix tables. The third was the areas that have gained from other land-use/land-cover type, that is, the areas with all the values along the rows of the matrix tables.

Change detection by location

The reclass module of the idrisi software was used to create the map that shows the areas that have experienced changes (changed areas) and the areas that have not (static areas) within the study periods. All the classes with the values in the diagonals, (the static areas) were assigned “1” while the values of the other classes, that is, those at the rows and columns were assigned “0” (changed areas). The output map shows the static (1) and the changed areas (0) (Figure 3). The area of the output map was also automatically calculated in Idrisi environment.

Mapping and calculations of the extent of changes of each class

The logic expression of the image calculator and the area module of the Idrisi were used to map and calculate the extent to which each of the features in the basin has changed respectively.

However, only three features of major concern were selected for this purpose: the lake reservoir, the woodland vegetation and the intensive agriculture areas. The result was to produce the following:

1. Areas that were not Lake Reservoir in 1775 but have changed to lake reservoir in 2006 so as to know whether the lake is expanding or not as has been the fear of Nigerians.
2. Areas that were of woodland vegetation type in 1975 but have changed to other land-use types in 2006. This was done to determine the land areas of the woodlands (home of National Park) that have been lost within the study periods to other landuse types.
3. Areas that were not intensive agriculture in 1975 but have changed to intensive agriculture in 2006 so as to assess the rate of land captured by intensive agriculture within the study periods.

RESULTS

The result of the trends of changes of the landuse and landcover of Kainji Lake is presented in Table 2, while the magnitudes, percentage changes and annual rate of changes are presented in Table 3a-c. The spatial locations of the changes in the lake area between 1975 and 2006 are presented in Table 4a-c, while Table 5 shows the extent of changes in the Lake area within the study period. Moreover, Figure 2a-d represents each of the four classified images of 1975, 1986, 2001 and 2006, respectively, while Figure 3 shows the parts of the lake that have not been subjected to changes (static) between 1975 and 2006. Figure 4a represents the total areas captured by the reserviour between 1975 and 2006, Figure 4b shows the area that was captured by intensive agriculture within the study period, while Figure 4c shows the areas that have been lost by woodland vegetation between the same period.

DISCUSSION

Trends, magnitudes, percentage changes and annual rate of changes

Table 2 shows the trends in terms of the area coverage and the percentage of each class of the basin area from 1975 to 2006. It was revealed that the Lake Reservoir that covered 910.6224 km^2 in 1975 has increased to 1094.2302 km^2 (addition of 1053.3750 km^2 lake reservoir and 40.8602 km^2 weed coverage) in 2006. The woodland vegetation of the Basin area which is the home of the first National Park in the country has also reduced in size from 41.41% in 1975 to 24.38% in 2006. Moreover, intensive agriculture that covered only 5.59% in 1975 has increased to 40.95% in 2006. There was the presence of riparian forest in 1975 which had disappeared in the lake basin before 1986. Human settlement area that covered only about 12 km^2 in 1975 has risen to 175 km^2 in 2006. Finally, between 1975 and 1986, there were no weeds on the lake, but the weeds has not only appeared on the lake but was rapidly capturing the lake surface which has been a great concern to the country as noted by Ayeni et

Table 2. The trends of the landuse/landcover changes of the lake basin (1975-2006).

Landuse/Landcover	1975		1986		2001		2006	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Lake Reservior	910.6224	21.07	955.8086	22.12	1010.4105	23.38	1053.3760	24.38
Woodlands	1789.2332	41.41	1925.3175	44.55	1366.9067	31.63	1146.5369	26.53
Intensive Agriculture	241.4720	5.59	1031.4233	23.87	1549.6968	35.86	1769.5118	40.95
Extensive/ Grazing	1131.4632	26.18	200.4712	4.64	119.1034	2.76	59.8514	1.39
Settlement	12.3040	0.28	69.9070	1.62	140.7425	3.26	175.5531	4.06
Freshwater Swamp	187.6231	4.34	40.9016	0.95	9.0850	0.21	7.4500	0.17
Freshwater Marsh	41.8048	0.97	12.0611	0.28	8.3117	0.19	6.1934	0.14
Riparian Forest	6.6992	0.15	-	-	-	-	-	-
Rivers	-	-	84.4552	1.95	51.5014	1.19	61.4718	1.42
Bare Surface	-	-	0.8732	0.02	0.3219	0.01	0.4142	0.01
Weeds	-	-	-	-	62.1358	1.51	40.8602	0.95

Table 3a. The magnitudes, percentage and annual rate of changes of the lake basin (1975-1986).

Landuse/Landcover	1975	1986	Magnitude of change	Percentage change	Annual rate of change	Remark
LakeReservoir	910.6224	955.8086	45.1862	2.03	+4.97	Increase
Woodlands Vegetation	1789.2332	1925.3175	136.0343	6.11	+7.61	Increase
Intensive Agriculture	241.4720	1031.4233	789.9513	35.45	+327.14.	Increase
Extensive/Grazing	1131.4632	200.4712	930.992	41.78	-82.28	Decrease
Settlement	12.3042	69.9070	57.603	2.59	+468.16	Increase
Freshwater Marsh	187.6231	40.9016	146.7215	6.58	-78.20	Decrease
Freshwater Swamp	41.8084	12.0611	29.7437	1.33	-71.15	Decrease
Riparian Forest	6.6962	-	6.6962	0.30	-100	Decrease
Rivers/Freshwater	-	84.4552	84.4552	3.79	+8445.52	Increase
Bare Surface	-	0.8732	0.8732	0.04	+87.32	Increase
Total	4321.2189	4321.2187	2228.3066	100	9009.09	

Table 3b. The magnitudes, percentage and annual rate of changes of the lake basin (1986-2001).

Landuse/Landcover	1986	2001	Magnitude of change	Percentage change	Annual rate of change	Remarks
LakeReservoir	955.8086	1010.4105	54.6019	3.85	+5.71	Increase
Woodlands Vegetation	1925.3175	1366.9067	558.4108	39.39	-29.00	Decrease
Intensive Agriculture	1031.4233	1549.6968	518.2735	36.55	+50.25	Increase
Extensive/Grazing	200.4712	119.1034	81.3678	5.74	-40.59	Decrease
Settlement	69.9070	140.7425	70.8355	5.00	+101.33	Increase
Freshwater Marsh	40.9016	9.0850	31.8166	2.24	-77.79	Decrease
Freshwater Swamp	12.0611	8.3117	3.7494	0.26	-31.09	Decrease
Rivers/Freshwater	84.4552	51.5015	32.9538	2.32	-39.02	Decrease
Bare Surface	0.8732	0.3249	0.5513	0.04	-63.14	Decrease
Weeds	-	65.1359	65.1358	4.59	+651.36	Increase
Total	**4321.2187**	**4321.2189**	**1419.6964**	**99.98**	**528.02**	

al. (1994), Obot et al. (1995) Adesina et al. (1998) and Mbagwu et al. (2002).

In Tables 3a-c, the total land area that was subjected to changes (magnitude) in the lake basin was revealed to

Table 3c. The magnitudes, percentage and annual rate of changes of the lake basin (2001-2006).

Landuse/Landcover	2001	2006	Magnitude of change	Percentage change	Annual rate of change	Remark
LakeReservoir	1010.4105	1053.3760	42.9655	6.98	+4.25	Increase
Woodlands Vegetation	1366.9067	1146.5369	220.3698	35.81	-16.12	Decrease
Intensive Agriculture	1509.6969	1769.5118	219.8149	35.72	+14.18	Increase
Extensive/Grazing	119.1034	59.8514	59.252	9.63	-49.75	Decrease
Settlement	140.7425	175.5531	34.8106	5.66	+24.74	Increase
Freshwater Marsh	9.0850	7.4500	1.635	0.27	-18.00	Decrease
Freshwater Swamp	8.3117	6.1934	2.1183	0.34	-25.49	Decrease
Rivers/Freshwater	51.5015	61.4718	9.9703	1.62	+19.36	Increase
Bare Surface	0.3219	0.4142	0.0928	0.02	+28.67	Increase
Weeds	65.1359	40.8602	24.2757	3.95	-37.27	Decrease
Total	4321.2189	4321.2188	615.3044	100	-55.45	

Table 4a. The matrix table created from the 1975 and 1986 overlay.

	1986									
Landuse/ Landcover 1975 ↓	**Lake 20**	**Woodlands 30**	**Intensive Agric. 40**	**Extensive/ Grazing 50**	**Settlement 60**	**Freshwater Marsh 70**	**Freshwater Swamp 80**	**Rivers 90**	**Bare Surface 100**	**Total**
Lake 1	21 **860.0672**	31 1.6351	41 12.9424	51 0.5239	61 8.6951	71 6.0439	81 1.5352	91 19.1756	101 0.0041	910.6225
Woodlands 2	22 8.2687	32 **1338.4333**	42 296.5595	52 95.1436	62 8.6927	72 8.5479	82 3.5479	92 21.1956	102 0.4240	1789.2332
Intensive Agric 3	23 0.1316	33 83.2523	43 **136.7763**	53 16.0322	63 4.7008	73 0.1218	83 0.0097	93 0.3095	103 0.1381	241.472
Extensive/ Grazing 4	24 19.7831	34 457.7723	44 539.6454	54 **78.1327**	64 24.9840	74 4.2408	84 0.1852	94 6.4411	104 0.2786	1131.4632
Settlement 5	25 0.3891	35 1.8113	45 8.5847	55 0.3696	65 **1.0803**	75 0.0268	85 -	95 0.0162	105 0.0260	12.304
Freshwater Marsh 6	26 67.0398	36 18.8986	46 31.9482	56 3.5179	66 12.7686	76 20.1308	86 2.1308	96 30..5991	106 0.0016	187.6232

Table 4a. Contd

Freshwater Swamp 7	27 0.1291	37 18.8344	47 3.7298	57 6.2600	67 0.6141	77 1.6245	87 **4.0335**	97 6.5743	107 -	41.8047
Riparian Vegetation 8	28 -	38 4.6802	48 1.2371	58 0.4914	68 0.0967	78 0.0203	88 0.0260	98 **0.1438**	108 0.0008	6.6963
Total	955.8036	1925.3175	1031.4235	200.4113	69.9074	40.9016	12.0611	84.4552	1.2732	4321.22

Table 4c. The matrix table created from the 2001 and 2006 overlay.

	2006										
Landuse/ Landcover 2001 ↓	**Lake 20**	**Woodlands 30**	**Intensive Agriculture 40**	**Extensive/ Grazing 50**	**Settlement 60**	**Freshwater Marsh 70**	**Freshwater Swamp 80**	**Rivers 90**	**Bare Surface 100**	**Weeds 110**	Total
Lake 1	21 **964.4217**	31 0.1129	41 1.3394	51 0.0227	61 5.2975	71 0.0008	81 0.0812	91 6.8546	101 0.0008	111 32.2788	1010.4104
Woodlands 2	22 1.2444	32 **867.8331**	42 453.8906	52 16.1589	62 18.9546	72 1.9039	82 1.2874	92 5.4015	102 0.0252	112 0.2071	1365.9147
Intensive Agric 3	23 4.4503	33 235.0917	43 **1146.0406**	53 32.2625	63 115.9486	73 2.2954	83 0.8878	93 11.6915	103 0.2729	113 0.7554	1550.0967
Extensive/ Grazing 4	24 0.2087	34 21.8463	44 80.8440	54 **10.0093**	64 5.2309	74 0.1340	84 0.1470	94 0.5515	104 0.0536	114 0.0780	119.1033
Settlement 5	25 7.6693	35 16.7632	45 80.0991	55 1.2070	65 **24.1368**	75 0.8090	85 0.3736	95 9.1102	105 0.0487	115 0.5255	141.2872
Freshwater Marsh 6	26 0.3078	36 2.5781	46 1.0194	56 0.0439	66 0.2372	76 **1.1469**	86 1.3118	96 2.4254	106 -	116 0.0146	9.0852
Freshwater Swamp 7	27 1.2371	37 0.4776	47 0.1949	57 0.0114	67 0.0796	77 0.6100	87 **1.5287**	97 4.1668	107 -	117 0.0057	8.3119
Rivers 8	28 24.6737	38 1.5985	48 3.1328	58 0.0707	68 1.9267	78 0.5483	88 0.5491	98 18.4202	108 0.0008	118 0.5808	50.5022

Table 4c. Contd.

Bare Surface 9	29	39	49	59	69	79	89	99	109	119	0.3211
	0.0016	0.0065	0.1746	0.0089	0.1178	-	-	0.0041	**0.0106**	0.0008	
Weeds	30	40	50	60	70	80	90	100	110	120	65.1358
10	49.1614	0.2291	2.7763	0.0560	3.6234	0.0016	0.0268	2.8461	0.0016	**6.4135**	
Total	1053.376	1146.537	1769.5117	59.8513	175.5531	7.4499	6.1934	61.4719	0.4142	40.8602	4321.22

Table 5. The extent of changes of the lake reservoir, woodlands and intensive agriculture (1975-2006).

Land-use/ Land-cover class		Area (km^2)	Area (%)
1	LakeReservoir in 2006 but notLake Reservoir in 1975	205.2586	4.75
2	Intensive Agriculture in 2006 but not Intensive Agriculture in 1975	1587.7759	36.75
3	Woodlands in 1975 but not woodland in 2006	943.2975	21.83

be 2228.3066 km^2 between 1975 and 1986 which decreased to 1419.6964 km^2 before 2001 and reduced drastically to 615.3044 km^2 in 2006. This means that some parts of the lake have been subjected to changes. This was also revealed in Figure 3.

Extensive agriculture/grazing land and intensive agriculture had the highest percentage changes of 41.78 and 35.45%, respectively, between 1975 and 1986, though, while extensive agriculture changes positively, intensive agriculture recorded negative changes.

From 1986 through 2001 to 2006, extensive agriculture/grazing land reduced drastically which is a result of the policy of the Federal Government against grazing in the basin area in order to protect the National Park.

This policy has always resulted in communal classes between the communities, the park rangers and the nomads (Mayowa and Omojola, 2005; Ikusemoran, 2009b; Henry et al., 2013; Wahab and Adewumi, 2013).

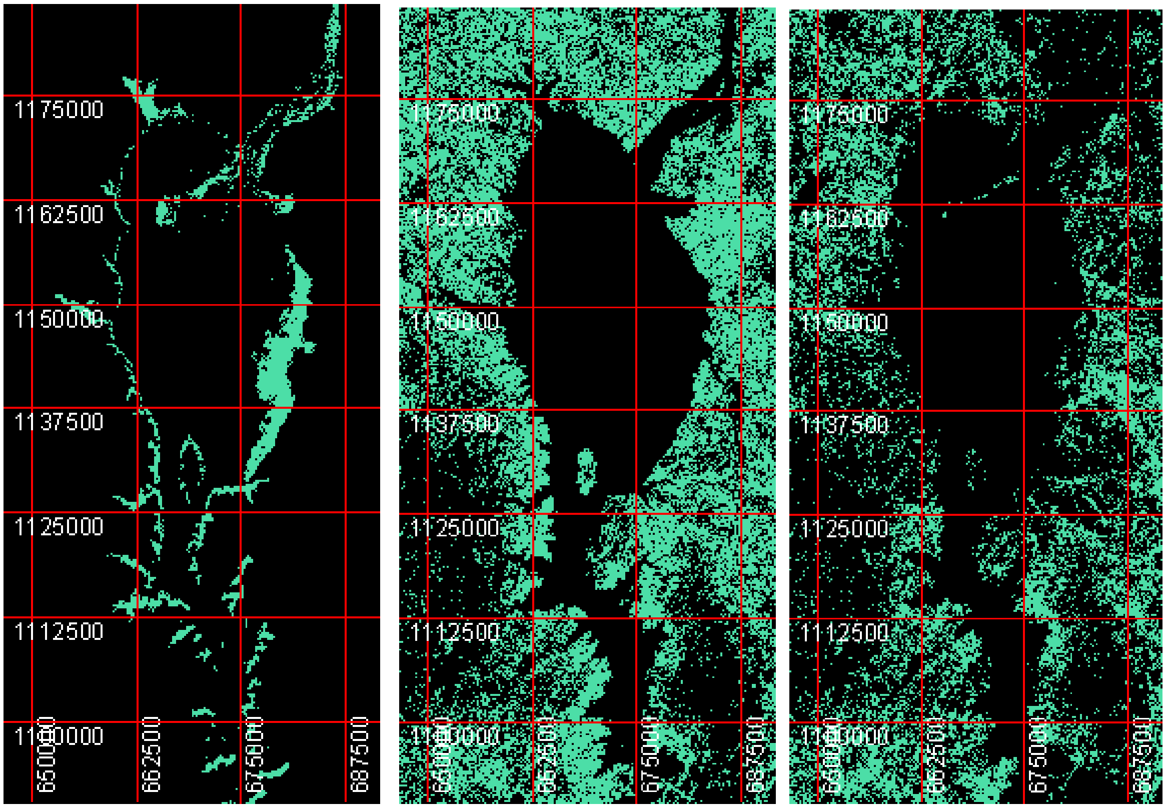
The nature of the changes of the lake basin

The matrix tables (Table 4a-c) show the nature of the land-use and land-cover changes in the basin area. Between 1975 and 1986 (Table 4a), the reservoir had static area of 860.0672 km^2 but gained heavily from freshwater marsh (67. 0398 km^2), extensive agriculture (19.7831 km^2) and woodlands (8.2687 km^2). Within this period, parts of the lake were also lost to other classes especially 19.1756 and 12.9424 km^2 to rivers/-freshwater and intensive agriculture, respectively. Woodland vegetation, though gained 457.7723 km^2 from extensive agriculture and a sizeable areas from other classes but also lost 296.5595 km^2 to intensive agriculture, 95.1436 km^2 to extensive agriculture and little losses to other classes.

However, the gain was more than the losses which might be due to the then few population in the basin area coupled with the strict protection of the Kainji Lake National Park that was just established and shouldered the responsibility of the protection of the basin.

Riparian forest that was found especially along the main rivers had disappeared before 1986 as it was mostly captured by woodlands. In Table 4b, the Lake basin, though, was still capturing much of the freshwater marsh (29.8412 km^2) but the rivers/freshwater class was the worst victim as the lake gained a total land area of 48.2208 km^2 from the class.

Weeds that suddenly appeared on the lake after 1986 as reported by Daddy et al. (1995) and water hyacinth *(Eichhorinia crassipes)* was first reported in 1989 on Kainji Lake and since then the plant continued to increase and spread to every part of the lake. Hence the dominance of the weeds on the lake as 42.7381 km^2 of the surface of the lake was captured by the weeds between 1986 and 2001. Intensive agriculture gained much from woodlands, and extensive agriculture during this period (644.2672 and 132.0717km^2 respectively) but also lost some parts to other land-use



a b c

Figure 4. a. Area captured by the reservoir between 1975 and 2006; **b.** Area captured by intensive agriculture between 1975 and 2006; **c.** Area loss by woodlands between 1975 and 2006.

types as 155.4621, 78.0515 and 31.1660km^2 to woodlands, settlement and extensive agriculture, respectively.

Table 4c shows the nature of the changes of the lake basin between 2001 and 2006. Due to the control measures especially by the National Institute of Freshwater Fisheries Research (formerly Kainji Lake Research Institute). Daddy et al. (1995) reported that the institute evolved mechanical, biological and manual control measures in controlling the water hyacinth on the lake. They reported that 45% of the estimated coverage by the weeds has been effectively removed. It was these efforts that made the lake to regain 49.1614 km^2 from the weed coverage area within this period

The spatial location of the changes in the lake basin

Spatial location procedures show the actual points or areas where changes have really taken place within the study period. The spatial locations of changes between 1975 and 2006 were derived by the overlay of 1975 and 2006 images and creating a matrix table from them in the same way it is shown in Figure 4a-c. The result of the reclass processes using the figures in the diagonal as 1 and other figures in the rows and columns as 0 gives an output map as shown in Figure 3.

The area module of the Idrisi was used to calculate the area of the output map. Out of the total basin area of 4321.22 km^2, it was revealed that 1638.9273 km^2 representing 37.93% has been subjected to changes, while 2682.2915 km^2 (62.07%) of the lake area has not been subjected to any change (Figure 3). The large static area is due to the large area coverage of the lake and the protected woodland area by the National Parks of Nigeria.

The extent of changes of each land-use/land-cover

It is important to know the extent of changes of each land-use type so as to assess the area coverage of the areas in any desired unit and percentages for proper land-use planning. The image calculator of the Idrisi software was used to determine the extent of the changes on the Lake Reservoir, woodland vegetation and intensive agriculture. These three classes are of great concern to the country as the lake has been a subject of discussion as having the possibility of dam collapse, some environmentalists (Ikusemoran, 2009a; Mbagwu et al., 2002) have also been emphasizing the loss of the woodland vegetation in the basin area which may affect the ecosystem of the lake basin, no wonder Wahab and Adewumi (2013) noted the presence of 14 sawmills within 40 km buffer around the park boundary between Wuromakoto and Gidan Aboki. Finally, human activities especially intensive agriculture was singled out to be the main activity responsible for the degradation of the lake basin (Ikusemoran, 2009a). The result of the image calculator on the different images as used is presented in Figure 4a to c. The values of the area of each class were also used to create Table 5.

A total area of 205.2558 km^2 representing 4.75% (Table 5) of the lake basin has been captured by the reservoir between 1975 and 2006. This means that the lake is actually expanding as has earlier been reported by Abiodun (2009) and Ikusemoran (2009a). The woodland vegetation has also lost a total area of 943.2975 km^2 (21.83%) between 1975 and 2006. Intensive agriculture is the degrading factor of the basin as 1587.7759 km^2 (36.75%) of the basin area have been lost to intensive agriculture between 1975 and 2006 (Table 5). This conforms to the earlier reports of Henry et al. (2013) that increased human and cattle population is continuously putting more pressure on the Kainji Lake Area and has ultimately cause fragmentation and degradation of wildlife habitats.

Implications of the land-use changes on the lake basin

1. Communal classes: Communal classes among the farmers, communities and the nomadic have recently become a problem especially in the savanna belt of Nigeria because of classes on land for their desired interests. For instance, extensive/grazing land has reduced drastically from 1131.4632 km^2 in 1975 to 200.4712 km^2 in 2006 and yet more animals are being reared in this belt since it is the main occupation of the people in the area, hence there is much pressure on the land and government efforts in controlling the parks have been faced with stiff opposition by the nomads who have no other occupation and no other home than the savanna where pastures are available for their animals. Henry et al. (2013) have reported on this syndrome that the effects of all these pressure on land culminate in increased man and animal conflicts lead to revenge killings and poaching.
2. Dam collapse: The area coverage of the lake reservoir has been increasing. The lake that covered 910.6224 km^2 in 1975 has increased to 1075.5464 km^2 (weed area coverage inclusive) a difference of 164.924 km^2. Many individuals, organizations and NGOs have been reporting that if the lake is actually increasing in size, then dam failure is inevitable unless solid maintenance is put in place, but how effective the maintenance will be in a country where maintenance culture is not valued remains a great question that calls for immediate answer.
3. Loss of Agricultural Land: With the increasing settlement area (12.3040 to 175.5531 km^2 between 1975 and 2006), and with the high rate of increase of intensive agriculture, (241.4720 km^2 in 1975 to 1769.5118 km^2 in 2006) (Table 2), if unchecked, there would soon be no land to use for agriculture. At present from Figure 4b, the only places that are yet to be utilized for agriculture are the lake reservoir and some parts of the preserved woodland areas.
4. Reduction or loss of park land: The reduction of the size of the woodland vegetation area as reflected in Table 3a-c coupled with the increasing capturing of the woodland area especially by intensive agriculture (Table 4a-c). According to Amusa et al. (2010), reduction of the park land could be attributed to the fact that the primary occupation of the Kainji Lake area is agriculture, which in effects reduced the park land area. This means that sooner or later the woodland vegetation which is the home of the first national park in Nigeria will become a history. Moreover, due to poaching and other human interference, many animals, plants and other micro organisms in the basin may become extinct.
5. Land exposure/desiccation: Continuous usage of land for agriculture may lead to agricultural land been converted to open, non-cultivated type such as open grassland or sandy bare surfaces as noted in Table 3a-c where bare surface that was not present in the basin in 1975 has been appearing though at a slow rate since 1986. Adeniyi and Omojola (1997) asserted that land exposure and desiccation are noted for increasing the local rainfall run-off and reducing infiltration. This factor affects the total water balance of a drainage basin, reduce soil matter by exposure to agents of erosion and consequently hamper land cultivation. Ogunwusi (2012) also reported that over 90% of the natural vegetation in Nigeria had been cleared and over 350,000 ha of forest and natural vegetation are lost annually.
6. Flooding: The expansion of the lake water has resulted into serious flooding especially at the western bank (where much land has been captured by the lake (Figure 4a) and the downstream which is the receiving end (Abiodun, 2009). The sudden appearance of weeds on the lake has also been attributed to another possible cause of flood of the lake (Olokor et al., 1998; Mbagwu, 2002).

In the work of Okhimanhe (1993) highest susceptibility of the flood in the Kainji Lake occurs within the first 3 km from the reservoirs including the river channels and surface waterbody lying between 69 and 162 m above sea level, while the lowest is at 15 km away from the reservoir and greater than 193 m above sea level. The serious flood at the downstream of this lake in this year (2012) has caused many displaced settlements, destructions of farmlands and properties (Adedeji et al., 2012; Nkeki et al., 2013)

7. Reduction in fish catch: The degradation of the lake area coupled with other factors such as excessive water (floods) and weed encroachment no doubt have collectively impart negatively on the annual fish catch in the lake area as Omojowo et al. (2010) reported that total fish catch reduced from 38,346 mt in 1996 to 13, 361 mt in 2001.

Conclusion

In this paper, the use of remotely sensed data and GIS techniques for environmental monitoring has been demonstrated. The Kainji Lake basin which is the home of the Kainji dam (the first and the largest hydro-electricity dam in Nigeria which provides electricity to the entire country and other neighbouring countries such as Niger Republic), the home of the first National Parks in Nigeria, and the base of various research institutions such as National Institute of Freshwater Fisheries Research, College of Wildlife, Fisheries College and many more is so important to the country that all hands must be on deck to see to its sustainable utilization. The lake water has been revealed to be expanding- causing fear of dam collapse, the woodland vegetation is rapidly decreasing- putting the existence of the National Park in suspense, water hyacinth has recently captured some parts of the lake, and despite numerous efforts by the government and research institute, the weeds as at 2006, still covered more than 40 km^2 of the lake surface, intensive agriculture that was very minimal in 1975 was discovered to have captured more than 40% of the lake basin. The lake basin therefore, needs nothing but proper monitoring if only the survival of the lake is in the interest of the country. Human interventions especially agricultural practices was discovered to be the major cause of the changes in the basin, this calls for further studies in the preservation of the basin from human interference. Dam collapse, communal classes, flooding, land desiccation and reduction in park and agricultural lands have also all been discussed as the possible implications of the changes on the lake basin. Remote sensing and GIS techniques can be used to monitor land-use and land-cover changes to guarantee quality environment which would provide for future needs of the nation.

Recommendations

The Kainji Lake basin is so much important to Nigeria that its sustainable utilization should not be com-promised. The basin which is the central hob of Nigeria's economy should be well protected from environmental degradation. The lake water is rapidly expanding which may cause serious problems to the inhabitants especially at the downstream, hence, the government should do all they can to resettle the people at the sides and the downstream of the lake. Furthermore, government should discourage new settlement in the basin area so as to reduce pressure on the land area. To complement the efforts of the National Parks in the protection of the basin, Kainji Lake Basin Management Authority should be established to be solely responsible for the protection of the Lake Basin. The protection of the woodland vegetation of the basin should be of primary concern to the country as the depletion of the vegetation may lead to the end of the first and the most popular national park in the country. There should be proper land-use and land-cover planning of the basin area to reduce land degradation or loss of wetlands, provision of modern irrigation facilities for efficient utilization of the lake water instead of bastardizing the basin land surface, provision of improved seedlings that would yield better output from minimal land area, extensive training on lake basin, wetlands and general environmental management and finally ensuring public awareness and action to guarantee quality environment and making the lake basin a recreation and eco-tourism site. Remote Sensing and GIS techniques, though, still very new in most parts of Nigeria, is second to none in environmental monitoring, hence, the techniques is recommended for use in environmental monitoring and management of our already fragile environment.

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Assessment of environmental responses to land use/land cover dynamics in the Lower Ogun River Basin, Southwestern Nigeria

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This study investigates the pattern of land use/land cover change in the Lower Ogun River Basin between 1984 and 2012. Two sets of topographical maps, a Landsat-5 TM image of 1984, Landsat-7 ETM+ of 2000 and a Google Earth image of 2012 were used for the study. The topographical maps and satellite images were digitally processed using ILWIS 3.2™ software and exported to ArcGIS 9.3™ for further processing and analysis. The processed images were subsequently classified using the maximum likelihood classification algorithm, resulting in the identification of seven land use classes. Furthermore, change detection analysis was carried out using Cross Module in ILWIS™. The result of the change detection analysis indicated that between 1984 and 2000, 80.08% of the land cover in the study area has been converted to other land uses while only 19.92% remained unchanged. Also, within the same period, light forests, non-forested wetlands and forested wetlands decreased at average annual rates of 8.26, 4.66 and 2.81%, respectively, while water bodies also decreased at an annual rate of 0.17%. On the other hand, farmland, shrubs and urban/built-up areas expanded at average annual rates of 7.23, 6.74 and 4.65%, respectively. The result further indicates that between 2000 and 2012, 49.86% of the land cover has been converted to other land uses, while 50.14% remained unchanged, and that farmlands, shrubs, urban/built-up areas and forested wetlands expanded at average annual rates of 6.01, 1.95, 0.89 and 0.17%, respectively, just as light forests, non-forested wetlands and water bodies decreased annually by 8.26, 2.70 and 1.40%, respectively. Five randomly collected soil samples were analyzed for their physicochemical properties. Findings show the growing impact of urban agriculture on wetland ecosystem within the study area, manifesting in soil degradation and biodiversity loss. The implication of these findings is that the area is susceptible to devastating flooding which can culminate in the loss of lives and properties. This study recommends the development of effective land management information system and policies that will ensure sustainable management of fragile ecosystem.

Key words: Change detection, river basin, urban agriculture, land use/land cover, wetlands.

INTRODUCTION

FAO (1995) stated that land use concerns the function or purpose for which the land is used by the local human population and can be defined as the human activities which are directly related to land, making use of its resources or having an impact on them. Land use and land cover change has emerged as one of the key independent themes in the global change, climate change, earth systems and sustainability research programs (Gutman et al., 2004). The environmental impacts of land use change have been documented in urban, suburban, rural and open space areas. For example, Awoniran (2012) observes that land use changes (land conversion) occur at the periphery of large urban concentration where urbanization and industrialization pressures frequently result in loss of prime agricultural lands and tree cover. These often result in unprecedented changes in the hydrological balance of the area, increase in the risk of floods and landslides, air and water pollution among others. Other local impacts are soil erosion, sedimentation, soil and groundwater contamination and salinization, extinction of indigenous species, marine and aquatic pollution of local water bodies, coastal erosion and land pollution.

Though humans have been modifying land to obtain food and other essentials for long, current rates, extent and intensities of landuse/landcover change (LULCC) are far greater than ever in history; driving unprecedented changes in ecosystem and environmental processes at local, regional and global scales (Lambin et al., 2007). Various estimates indicate that 50% of the ice-free land surfaces has been affected or modified in some ways by human activities (Vitousek et al., 1997), while 10 to 55% of the net primary productivity has been captured by human land use activities (Rojstaczer et al., 2001). The intergovernmental panel on climate change (IPCC) estimates that the cutting down of forests contributes close to 20% of the overall greenhouse gases that are entering the atmosphere, making the goal of reducing deforestation an urgent and immediate one (United Nations Development Programme, 2009). These anthropogenic-cally induced land use change has, to a greater or lesser extent, resulted in major environmental problems such as desertification, eutrophication, acidification, climate change, flooding, greenhouse effect and biodiversity loss.

The Lower Ogun River Basin, because of its proximity to the urban periphery of Lagos, is presently under intense pressure occasioned by increasing urbanization rate. Increasing population pressure, increasing demand for food, high cost of land and urban agricultural activities are having serious environmental impact on the basin (Tejuoso, 2006). The consequence of this is: land degradation, flooding and threatened food security.

The use of remotely sensed data with the integration of Geographic Information System technology provides a strong and analytical framework for assessing land use/land cover inventory, annual rate of change and evaluating the emerging environmental response at the periphery of a fast growing city. The importance of geospatial information to be generated from such an endeavor cannot be over emphasized as Adeniyi and Omojola (1999) submitted that information based on urban land use changes can shed more light on the growth process, since physical changes in the distribution of urban land uses are direct indications of social and economic changes.

This study assesses land use/land cover change, evaluate the proportion of changes and analyze the environmental impacts of the change on the Lower Ogun River Basin within 28 years using Remote Sensing and GIS technology. This is considered germane in addressing emerging environmental problems and ensuring sustainable land use management which may be anchored on accurate and up to date land use data and map that serves as bedrock for evolving a sound land use planning and policy for the area under study.

The study area

The study area is located partly in Ifo South Local Government Area of Ogun State and Kosofe Local Government Area of Lagos State, and lies between Latitudes 06° 35ˈN and 06° 45ˈN and Longitudes 3°17ˈE and 3°25ˈE (Figure 1). It is approximately 161.4 km^2. It is located within the sub-equatorial zone, which is characterized by rainfall throughout the year with two maxima (May to July and September to October). December and January have very little rain, and the annual rainfall is between 1500 to 2000 mm. The effective temperature (ET) is between 32 and 36°C. However, the highest diurnal range of temperature in the dry season (mid November-mid March) is 20°C while the mean range is about 10°C during the warm and wet season (May to October). The highest air temperature occurs in April/May and the lowest occurs in December through February. (The mean annual temperature is about 27°C while the annual range does not exceed 6°C (Ekanade, 1985). It lies within the rainforest belt (dry lowland rainforest). The vegetation of the region is swamp and marsh forest, part of which had given way to the construction of houses, markets and other infrastructures. Tree species here consist of typical colonizer or invaded species. These are plants with numerous and easily dispersed seeds and capacity for fast and vigorous establishment in cleared or open location. The river channels are characterized by vegetation of the wet southern segment of the rainforest belt. The characteristic vegetation include tall trees like *Tarriefa utilis*, *Geophila* sp., epiphytic ferns (*placycerina* sp.), *Tuchomanes* sp. *Nephrolepis* sp. Mosses and Lierworts (Ogunbajo, 2005).

Generally, the relief of the area may be described as belonging to the belt of coastal plains. The land rises from the sandy beaches along the Atlantic Ocean to a belt of fresh water swamps with an intricate network of lagoons and creeks. The coastal belt is about 10 km wide and is generally less than 20 m in height. Further inlands, it gives way to a sandy plain which in turn leads up to a plain of eroded sandstones standing less than 20 m above

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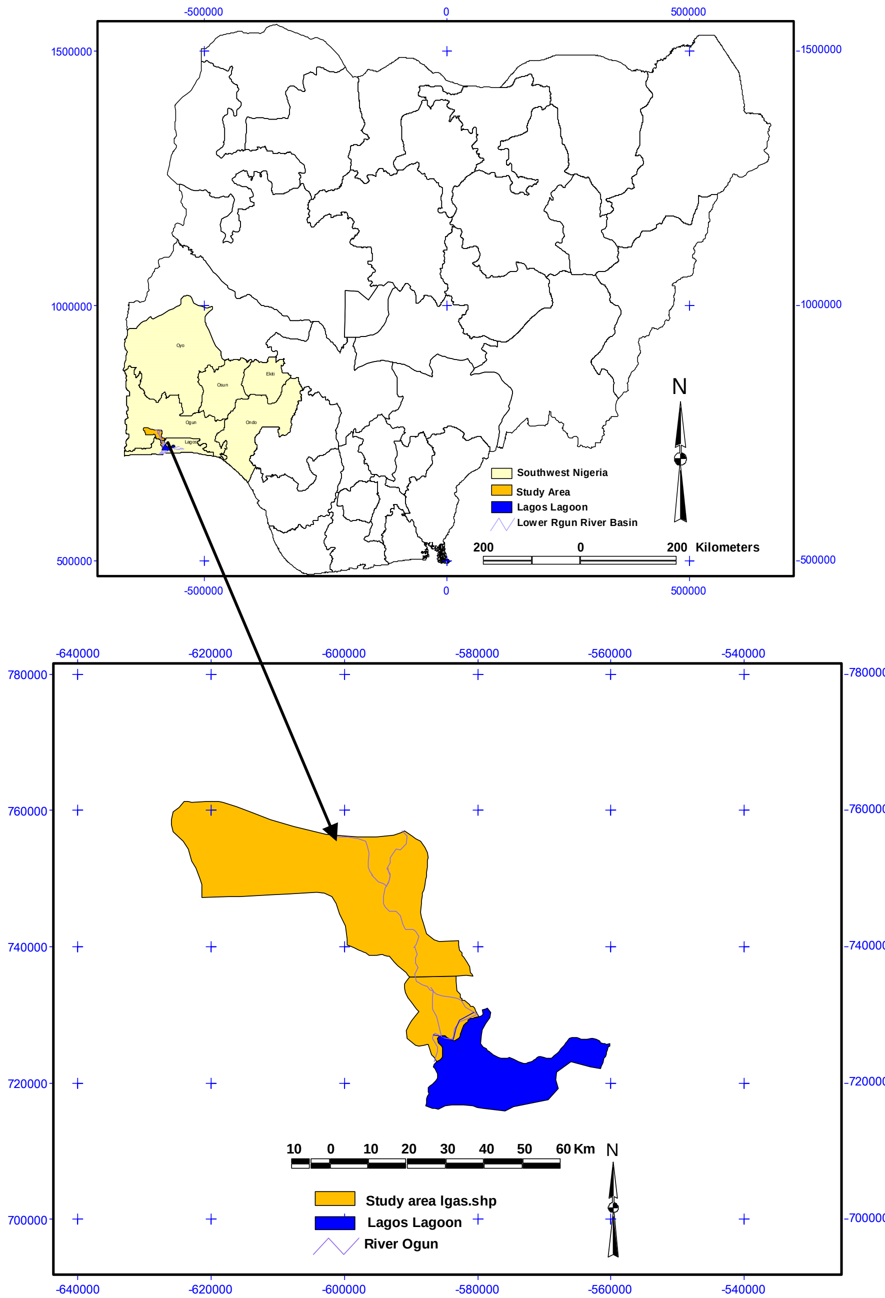

Figure 1. Lower Ogun River Basin in SW, Nigeria.

sea level. Taking its source from the northeastern portion of the study area, River Adiyan is the only major tributary to River Ogun and discharges into River Ogun, north of Iseri-Oke. The drainage is dendritic and the Adiyan River flows throughout the year and forms a major valley in the vicinity. Farming, hunting and fishing have been the chief occupations of the local people for many decades. Crops grown in the area include cocoa, vegetables, sugar cane and maize. However, sand mining along the channel of River Ogun that traverses the study area is a major human activity.

Conceptual framework

The analysis of land use change is embedded within the broader discourse on global environmental change, a variety of theoretical approaches which are called “man-environment” theories. More balanced theoretical frame-works for the study of nature-society relationship are offered by ecologically sensitive approaches known as "human ecology" or "cultural ecology" (Briassoulis, 2000). These approaches draw upon ecology and systems theories to provide comprehensive descriptions of the complex interactions between people and their bio-physical environment (Sack, 1990, Butzer, 1990).

Land use change research has evolved out of global efforts to identify, predict and manage ecologically damaging land use changes such as deforestation. Indeed, the international global environmental change research community has chosen land use/cover change as a major area of research not only because it provides broad scale data on changing carbon storage and sequestration by plants, but also because it provides an entry into understanding the human dimensions of environmental change (Turner et al., 1995; Lambin et al., 1999; Sherbinin, 2002). Political and cultural ecology, intensification theory, economic theories and other concepts have informed LULC research associated with the International Geosphere-Biosphere Progamme (IGBP).

The early interests of social scientists in explanation and ecologists in prediction are evidently convergent in the spatially explicit model. Ecologists have provided strong motivation with their focus on the landscape as a biogeographic unit of analysis subject to fragmentation processes. On their part, social scientists have filled the explanation gaps on the human side of the equation. Now, social scientists and ecologists are even found to publish jointly on the topic (Turner et al., 1996; Wear and Bolstad, 1998). The spatially explicit model is increasingly used to predict landscape change and is often evaluated both in terms of conventional inference on variable coefficients and goodness-of-fit and with respect to ability to predict actual landscape change (Nelson and Hellerstein, 1997; Wear and Bolstad, 1998; Mertens and Lambin, 2000).

MATERIALS AND METHODS

Research locale

The main data used for this study included a Landsat TM satellite image of December 1984, and ETM+ of February 2000 obtained from the Global Land Cover Facility and 2012 Google Earth® image. Two sets of topographical maps on a scale of 1:50000, Lagos NE Sheet 279 and Lagos SE Sheet 279, published in 1964 were obtained from the Federal Survey, and used as base map and supportive ground-truth information required for classification and accuracy estimation of the classified TM and ETM+ images was collected through a field survey carried out in 2012.

Digital image processing

Preprocessing operations in the form of linear contrast stretch and spatial filtering were performed on the images which were also geo-rectified to Universal Transverse Mercator (UTM) coordinate system. Subsets of the satellite images and topographical maps were geo-referenced using georeferenced tie points and affine transformation method. The supervised Maximum Likelihood Classification method was used for all the images. Training areas corresponding to each classification item (land use class) were chosen from among the training samples collected from the field and the topographical map of the study area.

Thereafter, seven land use/land cover classes were identified on the two images for change detection analysis. These include urban, light forest, forested wetland, non-forested wetland, farmland, shrub and water body. Change detection analysis was performed using the cross algorithm of the ILWIS software. Choice of the emerging land use classes was guided by i) the objective of the research ii) expectation of certain degree of accuracy in image classification and iii) the ease of identifying classes on the topographical map. The classified images were further subjected to majority filtering operation to smoothen and eliminate noise (salt and pepper) from the images. The evolving land use/land cover types were quantified using cross tabulation statistics to carry out land use/land cover change. The classified images were subsequently vectorized and exported to ArcGIS 9.3™ for the graphical illustration of land use/land cover change in the study area.

Soil sampling and analysis

Two study sites were selected on the classified images for soil quality analysis. That is, forested wetland which was relatively less disturbed and non-forested wetland which was under cultivation. Five composite soil samples, replicated thrice, each to the depth of 0-20 cm to give a total of 30 soil samples were randomly collected using soil auger and analyzed for their physicochemical properties to determine the impact of land use change on soil quality in the selected forested and non-forested wetlands. The coordinate of each soil samples were also taken using GPS.

The soil samples were air-dried for seven days, crushed and sieved through 2 mm opening. The hydrometer method (Bouyoucos, 1962) was used for particle size analysis. Soil pH was determined potentiometrically in H_2O at a ratio of 1:1 (soil to water) (Mclean, 1982). The Kjeldahl method was used to determine total nitrogen (Bremner and Mulvaney, 1982). The determination of soil organic carbon was based on the Walkley-Black chromic acid wet oxidation method (Nelson and Sommers, 1982), while available phosphorus was determined using Bray P1 method (Olsen and Sommers, 1982). Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were determined using 1 M NH_4OAc (Ammonium acetate) buffered at pH 7.0 as extractant (Thomas, 1982). The K^+ and Na^+ concentrations in soil extracts were read on Gallenkamp Flame photometer while Ca^{2+} and Mg^{2+} concentrations in soil extracts were read using Perkin-Elmer Model 403 atomic absorption spectrophotometer. Descriptive statistics was used to detect the changes that have taken place in the study area from 1984 to 2000. Test of significance for differences in means of soil physico-chemical properties under forested and non-forested wetland was done using least square difference (LSD) method.

Vegetation sampling

In this study, four corners of each of the two sites were marked with pegs at the defined dimension (100 m^2) and were gridded into 10 quadrants having dimensions of 10 by 10 m. For each 10 m^2 grid observations of height of trees and herbs were recorded. During the study, a tree was taken to be a woody specie of erect posture with a minimum breast circumference of 7 cm and a minimum height of 2 m (Salami and Aladenola, 2003). Shrubs on the other hand are woody plants not having a main trunk but several main branches. In general, shrubs are smaller than trees. The vegetation data recorded in the field were entered into a database using Microsoft Excel® software and analyzed using the tools in the spreadsheet.

Focus group discussion (FGD)

As an additional source of ground-truth information, four focus discussion and the in-depth interviews were based on convenience

Table 1. Landsat TM 1984 land use/land covers accuracy assessment.

LULC	FML	FWT	LF	NFWL	SRB	URB	WB	TR
FML	487	14	429	0	66	60	0	1056
FWT	85	2321	301	200	0	25	2	2934
LF	1051	464	3087	239	176	202	1	5220
NFWL	134	242	185	2235	0	138	12	2946
SRB	917	43	762	24	730	21	3	2500
URB	19	46	38	16	5	4461	134	4719
WB	0	0	0	0	0	94	2182	2276
RELIABILITY	0.18	0.74	0.64	0.82	0.75	0.89	0.93	
LULC	FML	FWT	LF	NFWL	SRB	URB	WB	TR

Average accuracy = 68.55%, average reliability = 70.9%, overall accuracy = 71.6%.

Table 2. ETM+2000 land use/land cover accuracy assessment.

LULC	FML	FWT	LF	NFWL	SRB	URB	WB	TR
FML	1127	181	62	43	554	15	0	1982
FWT	208	1308	378	140	629	55	0	2718
LF	60	114	1913	97	67	73	0	2324
NFWL	33	42	26	1723	432	509	3	2768
SRB	114	77	33	932	2276	401	0	3833
URB	9	4	1	255	71	6531	53	6924
WB	0	0	0	17	0	59	2077	2153
RELIABILITY	0.73	0.76	0.79	0.54	0.56	0.85	0.97	
LULC	FML	FWT	LF	NFWL	SRB	URB	WB	TR

Average Accuracy = 71.4%, average reliability = 74.4%, overall accuracy = 74.7%.

and purposeful sampling (Miles and Huberman, 1984). The focus group had three themes for discussion, that is, the history of land use in the study area, the major types of land use, and the impact of land use.

RESULTS AND DISCUSSION

Land use/land cover accuracy assessment

The general acceptance of the error matrix as the standard descriptive reporting tool for accuracy assessment of remotely sensed data has significantly improved the use of such data. An error matrix is a square array of numbers organized in rows and columns which express the number of sample units (i.e. pixels and clusters of pixels) assigned to a particular category relative to the actual category as indicated by reference data (Coppin and Bauer, 1996). For instance, Table 1 shows the producer's accuracy for the image classification of Landsat TM 1984 into seven classes of land use/land cover types: Farmlands (Fm) = 46%; forested wetlands (FW) = 79%; light forest (LF) = 59%; non forested wetlands (NFW) = 76%; scrubs (SS) = 29%; urban (U) = 95%; water body (WB) = 96%.

Also, the user's accuracy as shown in the same table indicates the probability that a pixel classified into a given category are the true representation of that category on the ground: Farmlands (Fm) = 18%; forested wetlands (FW) = 74%; light forest (LF) = 64%; non forested wetlands (NFW) = 82%; scrubs (SS) = 75%; urban (U) = 89%; water body (WB) = 93%; Overall accuracy = TD (sum of major diagonal) divided by TR (row totals) = 15503/21651 x 100 = 71.6%. The accuracy is essentially a measure of how many ground truth pixels were classified correctly. Thus, for the 1984 land use/land cover classification an average accuracy of 66.23% and overall accuracy of 71.23% was generated. This indicates that error is considered to be consistent with limits of the available technology.

Table 2 shows the producer's accuracy for the image classification of Landsat ETM+ 2000 into seven classes of land use/land cover types: Farmlands (Fm) = 57%; forested wetlands (FW) = 48% light forest (LF) = 82%; non forested wetlands (NFW) =62%; scrubs (SS)= 59%; urban (U) = 94%; water body (WB) = 96%. Also, the user's accuracy as shown in the same table indicates the probability that a pixel classified into a given category are the true representation of that category on the ground:

Table 3. Google Earth Image 2012 land use/land cover accuracy assessment.

LULC	FML	FWT	LF	NFWL	SRB	URB	WB	TR
FML	1213.7	147.2	0	0	634.88	70.8	0	2066.72
FWT	294.76	1274	278.8	84.08	709.88	110.8	0	2752.68
LF	146.76	80.28	1813	41.08	147.88	128.8	0	2358.68
NFWL	119.76	8.28	0	1667.08	512.88	564.8	0.96	2873.76
SRB	200.76	43.28	0	876.08	2356.88	456.8	0	3933.8
URB	95.76	0	0	199.08	151.88	6586.8	50.96	7084.48
WB	86.76	0	0	0	80.88	114.8	2074.96	2357.4
RELIABILITY	0.84	0.64	0.8	0.48	0.52	0.92	0.98	
LULC	FML	FWT	LF	NFWL	SRB	URB	WB	TR

Average accuracy = 73.68%, average reliability = 73.75%, overall accuracy = 77.34%.

Farmlands (Fm) = 73%; forested wetlands (FW) = 76%; light forest (LF) = 79%; non forested wetlands (NFW) = 54%; scrubs (SS) = 56%; Urban (U) = 85%; water body (WB) = 97%; overall accuracy = TD (sum of major diagonal) divided by TR (row totals) = 16955/22702 x 100 = 74.9%. Thus, 2000 land use/land cover average accuracy is 70.40% and overall accuracy is 74.9%. This indicates that error is considered to be consistent with limits of the available technology.

Table 3 shows the producer's accuracy for the image classification of Google Earth Image 2012 into seven classes of land use/land cover types: Farmlands (Fm) = 80%; forested wetlands (FW) = 66%; light forest (LF) = 62%; non forested wetlands (NFW) = 55%; scrubs (SS) = 59%; urban (U) = 96%; water body (WB) = 99%. Also, the user's accuracy as shown in the same table indicates the probability that a pixel classified into a given category are the true representation of that category on the ground: farmlands (Fm) = 84%; forested wetlands (FW) = 64%; light forest (LF) = 80%; non forested wetlands (NFW) = 48%; scrubs (SS) = 52%; urban (U) = 92%; water body (WB) = 98%; overall accuracy is estimated to be 77.34%. Thus, 2012 land use/land cover average accuracy is 73.68%. This indicates that error is considered to be consistent with limits of the available technology.

Changes in land use/land cover between 1984 and 2012

Figures 2, 3 and 4 show the spatial distribution of the static land use/land cover of the study area in 1984, 2000 and 2012, respectively. Table 4a and b below showed the entire study area covering 16140 ha. In 1984, light forest constituted the most extensive land use/land cover occupying 5350 ha (33.2%) and urban/built up area was 2690 ha (16.7%). The non-forested wetland, forested wetland, shrub, water body and farmland occupied {ha, (%)} 2380 (14.5), 2170 (13.5), 1720 (10.7), 1180 (7.3) and 650 (4.0) respectively of the study area.

However, in 2000 urban or built up area expanded quite rapidly, increasing to 4690 ha (29.1%) of the study area. The shrub and farmland areas increased to {ha, (%)} 3580 (22.2) and 1400 (8.7) respectively. During the same period, non-forested wetland, forested wetland, light forest and water body decreased to {ha, (%)} 1960 (12.1), 1790 (11.1), 1570 (9.7) and 1150(7.1) respectively. By 2012 urban built up, shrub, farmland and forested wetland has increased to {ha, (%)} 5191 (32.16), 4417 (27.37), 2409 (14.92) and 1827 (11.32), respectively. On the other hand, light forest, non forested wetland and water body had decreased to {ha, (%)} 14 (0.09), 1325 (8.21) and 957 (5.93) respectively.

Also, the pattern of land use/land cover change within the period under consideration indicated that between 1984 and 2000 farmland, shrub and urban/built up were expanding at the rates of 7.2, 6.7 and 4.7% per annum. Light forest, non-forested wetland and forested wetland were decreasing at the average rates of 8.3, 4.7 and 2.8% per annum, respectively, and water body decreased marginally at an annual rate of 0.2% per annum. The table also indicated that between 2000 and 2012 farmland, shrub and urban/built up increased by 72.1, 23.4 and 10.7% per annum, and forested wetland increased marginally by 2.1%. On the other hand light forest, non-forested wetland and water body were decreasing at the average annual rates of 8.26, 2.70 and 1.40% respectively.

Land use/land covers conversion pattern between 1984 and 2000

Table 5a show the pattern of land use change between 1984 and 2000. In Table 5a, while 19.92% of the land use/land cover in the study area remained unchanged, 80.08% have been lost to other land uses. The table also reveals that 12.00% of farmlands, 20.74% of forested wetland, 9.16% of light forest and 23.99% of non-forested wetland, as well as 24.59% of shrub, 35.76% of urban and 20.42% of water body respectively remained unchanged between 1984 and 2000. It was also observed

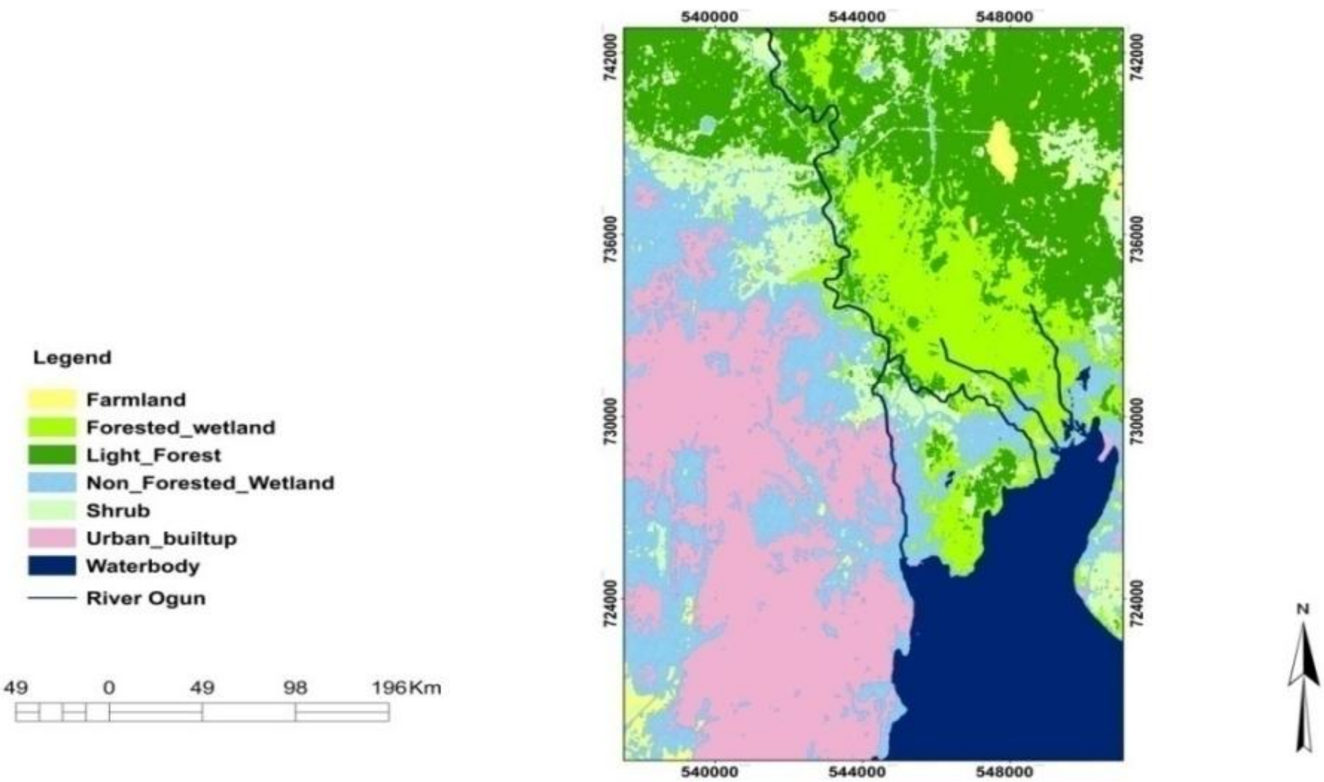

Figure 2. Land use/land cover map of Lower Ogun River Basin, SW Nigeria, in 1984.

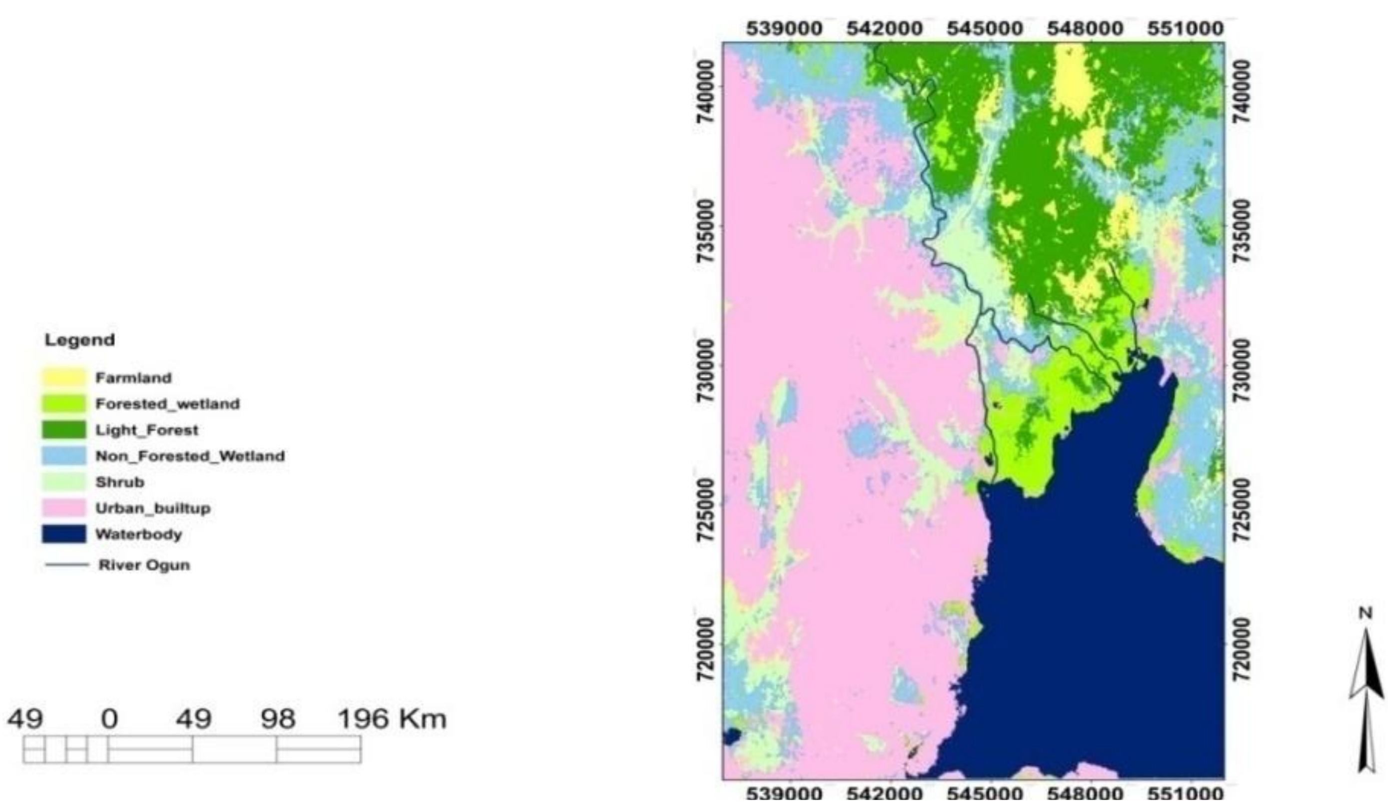

Figure 3. Land use/land cover map of Lower Ogun River Basin, SW Nigeria, in 2000.

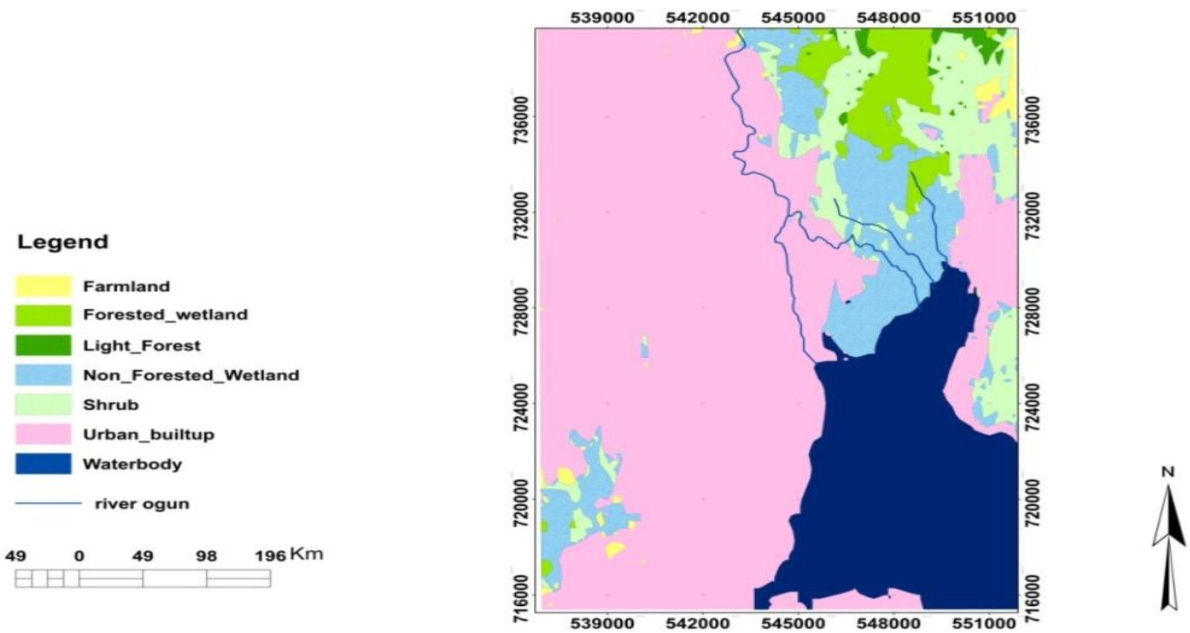

Figure 4. Land use/LAND COVER MAP of Lower Ogun River Basin, SW Nigeria, in 2012.

Table 4a. Extent and rate of change in land use/land cover from 1984 to 2000.

LULC	1984		2000		Change b/w 1984 & 2000		Av.Rate of Change	
	Area (ha)	Area (%)	Area (ha)	Area (%)	ha	%	ha	%
FML	650	4.0	1400	8.7	750	+115.4	47	+7.23
FWT	2170	13.5	1790	11.1	-980	-35.4	-61	-2.81
LF	5350	33.2	1570	9.7	-3780	-70.7	-442	-8.26
NFWL	2380	14.5	1960	12.1	-420	-17.7	-111	-4.66
SRB	1720	10.7	3580	22.2	+1860	+108.1	116	+6.74
URB	2690	16.7	4690	29.1	+2000	+74.3	125	+4.65
WB	1180	7.3	1150	7.1	-30	-2.5	-2.0	-0.17
Total	16140	100	16140	100	-	-	-	-

Authors' Image Analysis, 2013.

Table 4b. Extent and rate of change in land use/land cover from 2000 to 2012.

LULC	2000		2012		Change b/w2000 & 2012		Av.Rate of Change	
	Area (ha)	Area (%)	Area (ha)	Area (%)	ha	%	ha	%
FML	1400	8.7	2409	14.92	+1009	+72.1	+84.06	+6.01
FWT	1790	11.1	1827	11.32	+37	+2.1	+3.09	+0.17
LF	1570	9.7	14	0.09	-1556	-99.1	-129.68	-8.26
NFWL	1960	12.1	1325	8.21	-635	-32.4	-52.91	-2.70
SRB	3580	22.2	4417	27.37	+837	+23.4	+69.76	+1.95
URB	4690	29.1	5191	32.16	+501	+10.7	+41.75	+0.89
WB	1150	7.1	957	5.93	-193	-16.8	-16.08	-1.40
Total	16140	100	16140	100				

Authors' image analysis, 2013.

Table 5a. Land use/land cover change pattern between 1984 and 200

	Landuse/Landcover classes of 2000 (ha)								
1984 landuse/landcover classes (ha)	FML	FWT	LF	NFWL	SRB	URB	WB	Total area	FML
	FML	**78**	117.74	50.96	110.74	393.4	407.82	235.20	1400
		12.00%	8.41%	3.64%	7.91%	28.10%	29.13%	16.87%	100
	FWT	98.12	**450**	277.63	92.01	146.06	248.631	481.75	1790
		5.48%	**20.74%**	15.51%	5.14%	48.16%	13.89%	26.99%	100
	LF	93.62	144.44	**490**	154.80	346.50	346.19	311.017	1570
		5.96%	9.20%	**9.16%**	9.86%	22.07%	22.05%	19.81%	100
	NFWL	363.28	194.824	157.98	**571**	433.552	205.21	134.46	1960
		18.53%	9.94%	8.06%	**23.99%**	22.12%	10.47%	6.86%	100
	SRB	287.11	271.01	167.90	352.63	**423**	1113.74	157.16	3580
		8.02%	7.57%	4.69%	9.85%	**24.59%**	31.11%	4.39%	100
	URB	32.41	35.64	25.80	189.01	413.189	**962**	903.76	4690
		0.69%	0.76%	0.55%	4.03%	8.81%	**35.76%**	19.27%	100
	WB	0	0	0	0	0	202.75	**241**	1150
							17.63%	**20.41%**	10.0
	Total	952.329	1213.654	853.747	1291.577	2739.042	5614.572	3270.603	16140

Authors' image analysis, 2013.

that 88.00% of farmlands, 79.26% of forested wetland, 90.84% of light forest and 76.01% of non-forested wetland, as well as 75.41% of shrub, 64.24 and 79.58% of water body have been converted to other uses, within the same period.

Furthermore, the table also indicated that 5.48% of forested wetland, 5.96% of light forest, 18.53% of non-forested wetland, as well as 8.02% of shrub and 0.69% of urban have been changed to farmlands. While at the same time, 29.13% of farmland, 13.89% of forested wetland, 22.05% of light forest, as well as 10.47% of non-forested wetland, 31.11% of shrub and 17.63% of water body have been converted to urban land use. Thus, the conversion of light forest, forested and non-forested wetlands as well as shrub at the rates indicated above give an indication that farming and urbanization are the most important drivers of land use in the study area, and these also reflect the increasing scale of human activities in the study area.

Table 5b show the predominance of farmland and urban over other land use/land cover types with 80.7 and 53%, respectively. The table also reveal that 95.1 ha (10.5%) forested wetland, 35.8% light forest, 20.7% non-forested wetland, 15.2% shrub, 53% urban and 62.9% water body remain unchanged over the twelve years that constitute the latter part of the study period. According to the table, 13.7% of the farmland, 6.3% of forested wetland, 11% of the non-forested wetland and 1.9% of water body have been converted to urban. This suggests that environmentally fragile areas have been prone to urban encroachment without conscious effort to mitigate the devastating consequences such flooding, loss of biodiversity and destruction of ecosystem.

Table 6a and b present the results of the analyses on the proportions of LULC units gained and/or lost between 2000 and 2012 in the study area. From Table 6a, farmlands maintained 3360 ha equivalence of 41.5% but 805.5 ha (13.1%) of its total area over 12 years had been converted to other land use/land cover types. Nevertheless, farmlands had gained 2021.0 ha (20.3%) from other land use/land cover types, second highest to urban land use. This is further affirmed by the gained/lost analysis over the 12 years of the study which reveals that farmland record net gain of 1215.5 ha (60.1%). This suggests the growing interest of the urban dwellers in urban agriculture that constitutes one of the drivers of land use/land cover change in the study area. This is in line with the findings of Awoniran et al. (2011) who reported that urban agriculture and rapid urbanization are major drivers of land use/land cover change in the Lower Ogun River Basin.

This finding is further strengthened by the soil test carried out by the study which revealed the micro-variability of the soil, with significant ($p < 0.01$) differences in the properties compared. According to the results presented in Table 7, soils of the forested wetland areas are mainly clay while the non-forested areas are clay loam and sandy clay loam. The mean soil pH (1:1 soil-H_2O) ranged from 5.0 to 6.5, indicating slightly acidic soil condition. In the forested wetland areas, total nitrogen (TN; 0.98 to 2.63 g kg^{-1}), organic carbon (OC; 12.50 to 37.40 g kg^{-1}) and available phosphorus (24.05 to 44.80

Table 5b. Land use/land cover change pattern between 2000 and 2012.

2000 land use/land cover classes (ha)		2012 land use/land cover classes (ha)							
		FML	FWT	LF	NFWL	SRB	URB	WB	Total
	FML	**3360**	124.6	525.4	34.8	111.0	9.7	0	4165.5
		80.7%	3.0%	12.6%	0.8%	2.7%	0.2%	0	100
	FWT	174.0	**95.1**	160.5	114.5	179.3	143.9	39.1	906.4
		19.2%	**10.5%**	17.7%	12.6%	19.8%	15.9%	4.3%	100
	LF	517.6	262.2	**632.0**	92.7	225.0	33.1	3.2	1765.8
		29.3%	14.8%	**35.8%**	5.2%	12.7%	1.9%	0.2%	100
	NFWL	252.3	183.5	349.0	**267**	185.0	50.8	3.8	1291.4
		19.5%	14.2%	27.0%	**20.7%**	14.3%	3.9%	0.3%	100
	SRB	317.2	371.3	232.4	87.6	**241.0**	325.5	8.1	1583.1
		20.0%	23.5%	14.7%	5.5%	**15.2%**	20.6%	0.5%	100
	URB	752.0	346.8	258.5	604.2	516.2	**2909.1**	105.8	5492.6
		13.7%	6.3%	4.7%	11%	9.4%	**53.0%**	1.9%	100
		7.9	3.7	0	63.8	161.1	110.9	**587.8**	935.2
	WB	0.8%	0.4%	0	6.8%	17.2%	11.9%	**62.9%**	100
	Total	5381	1387.2	2157.8	12 64.6	1618.6	3583	747.8	16140

Authors' Image Analysis, 2013.

Table 6a. Proportion of LULC unit gained and/or lost between 1984 and 2000.

Land use classes	Proportion of LULC in 2000 and unchanged in 2012		Proportion of LULC in 2000 lost to other LULC by 2012		Proportion of LULC in 2000 gained from other LULC type by 2012		LULC in 2012 (unchanged + gained)		Difference of (2000-2012) LULC gained-lost	
	ha	%	ha	%	ha	%	ha	%	ha	%
FML	3360	41.5	805.5	13.1	2021.0	20.3	5381	100.00	+1215.5	+60.1
FWT	95.1	1.2	811.3	13.2	1292.1	13.0	1384.2	100.00	+480.8	+37.2
LF	632.0	7.8	1133.8	18.5	1525.8	15.3	2157.8	100.00	+392	+25.7
NFWL	267	3.3	1024.4	16.7	997.6	10.0	1264.6	100.00	-26.8	-2.7
SRB	241.0	3.0	1342.1	21.9	1377.6	13.8	1618.6	100.00	+35.5	+2.6
URB	2909.1	36.0	673.9	11.0	2583.5	25.9	3583	100.00	+1909.6	+73.9
WB	587.8	7.3	347.4	5.7	160.0	1.6	747.8	100.00	-187.4	-117.1
Total	8092	50.14	8048	49.86	8048	49.86	16140	100	-	-

Authors' image analysis, 2013.

mg kg^{-1}) values were obtained. Also, the cation exchangeable capacity (CEC) in the forested areas ranged from 9.55 to 12.37 cmol kg^{-1}. However, in the non-forested areas, TN, OC, available phosphorus and CEC values were low. Within each of the study area, soil properties varied significantly from one sample location to another. These results are in agreement with those reported by Adepetu et al. (1979) under continuous soil manipulation as a result of human activities. The soil physical properties such as soil texture known to be relatively 'stable' over-time (Mbagwu, 2008) changed from clay in the forested wetland to sandy clay loam in nearby non-forested wetland where anthropogenic activities are on-going.

Though, urban land use retained 2909.1 ha (36.0%) in 2012 and lost 673.9 ha (11.0%) to other LULC but still maintained its predominance by gaining 2583.5 (25.9%) from other land use/land cover types. The net gained analysis shows that this land use has gained 1909.6 ha, an equivalence of 73.9% over the twelve years of the latter study period. This revelation provides a strong signal about possible lost of farmlands that constitutes second largest land use in the area to urban land use in the nearest future. This may be attributed to the fact that

Table 6b. Proportion of LULC unit gained and/or lost between 2000 and 2012.

Land use classes	Proportion of LULC in 1984 and unchanged in 2000		Proportion of LULC in1984 lost to other LULC by 2000		Proportion of LULC in 1984 gained from other LULC type by 2000		LULC in 2000 (unchanged+gained)		Difference of (1984-2000) LULC gained-lost	
	ha	%	ha	%	ha	%	ha	%	ha	%
FML	78	12	572	88.0	1322	94.43	1400	100.00	750	53.57
FWL	450	20.74	1720	79.26	1340	74.86	1790	100.00	-380	21.23
LF	490	9.16	486	90.84	108	68.79	1570	100.00	-3780	-40.76
NF W	571	23.99	1809	76.01	1389	70.87	1960	100.00	-420	-21.43
SHR	423	24.59	1297	75.41	3157	88.18	3580	100.00	1867	52.15
URB	962	35.72	1728	64.24	3728	79.49	4690	100.00	2200	46.91
W B	241	20.42	939	79.58	909	79.04	1150	100.00	-30	-2.61
Total area	3215	19.92	12925	80.08	12925	80.08	16140	100.00	-	-

Authors' Image Analysis, 2013.

Table 7. Mean values of physico-chemical properties of soils of forested and non-forested wetland.

	pH	Sand	Silt (g kg-1)	Clay	P (mg kg-1)	OC	TN (g kg-1)	Mg	Ca	K (cmol kg-1)	Na	Exchangeable acidity	Textural Class
Non forested wetland													
1	5.1c	320	300	380	21.66d	20.30^{a}	1.93^{a}	1.23d	5.50d	0.17^{b}	0.50^{b}	2.00^{b}	CL
2	5.4b	440	250	310	29.57^{b}	15.60d	1.30^{c}	1.22d	6.52^{a}	0.23^{ab}	0.48^{b}	1.80^{b}	CL
3	5.3b	360	210	430	23.15^{c}	19.90^{b}	1.67^{b}	2.23^{b}	5.33d	0.27^{a}	0.48^{b}	1.22^{b}	C
4	5.0c	400	240	360	31.36^{a}	13.70e	1.07d	2.03^{c}	5.95^{c}	0.20^{b}	0.46^{b}	1.40^{a}	CL
5	5.9a	500	200	300	29.42^{b}	16.80^{c}	1.38^{c}	3.25^{a}	6.28^{b}	0.33^{a}	0.59^{a}	1.30^{b}	SCL
Forested wetland													
1	5.4c	120	270	610	44.80^{a}	22.50^{c}	1.72^{b}	2.22^{a}	8.70^{a}	0.93^{a}	0.52^{b}	1.00^{bc}	HC
2	6.2b	100	370	530	33.25^{b}	37.40^{a}	2.63^{a}	1.83^{b}	8.20^{b}	0.67^{a}	0.59^{a}	1.10^{b}	C
3	5.3c	120	380	500	31.63^{c}	18.70e	1.57^{c}	0.81^{c}	8.30^{b}	0.65^{a}	0.59^{a}	1.30^{a}	C
4	6.5a	40	400	560	33.15^{b}	19.50d	0.98e	1.83^{b}	7.45^{c}	0.56^{ab}	0.57^{a}	1.40^{a}	C
5	5.2c	100	320	580	24.05d	24.20^{b}	1.24d	1.83^{b}	6.90d	0.30^{b}	0.52^{b}	0.90^{c}	C

Means with the same alphabet(s) are not significantly different at p< 0.01. CL = Clay loam, C = clay, SCL = sandy clay loam, HC = heavy clay.

farmlands possess some characteristics that favour urban development and hence increases its vulnerability to urban encroachment. This implies a devastating decline in urban food production if the trend is not controlled to a sustainable level.

It is equally important to note from the table that a substantial loss in areas occupied by water body and non-forested wetland estimated at 117.1 and 2.7%, respectively, occurred over the study period. Keeping this trend going will not only amount to loss of vital parts of ecosystem that may trigger the conditions encouraging local climate modification but increase the vulnerability of the study area to destructive and pernicious effects of urban flooding that may culminate into loss of lives and properties magnitude of which may be horrified to imagine. Meanwhile, forested wetland, light forest and shrub, according to the table have net gain of 37.2, 25.7 and 2.6% over the study period but Table 5b reveals that these land covers are prone to conversion to other land uses particularly farmland and urban. This suggests that it requires conscious effort to stem down the inevitable conversion of these land covers to the sustainable path. The modification of these land covers through a programme of Lagos State Government; greenness and beautification of environment will go a long way to sustainably conserve the threatened land covers. The study has been able to identify two major processes of land use/land cover change in the study area, namely conversion and modification.

Table 6b shows that 19.3% of the area occupied by farmland over the study period has been converted to other LULC, in which light forest recorded 12.6% which happens to be the highest in the study period, followed by forested wetland 3.0%, shrub (2.7%), non-forested wetland (0.84%) and urban (0.23%). In spite of this loss, farmland has continued to increase in spatial extent by gaining 19.2% from forested wetland, light forest (29.3%), non-forested wetland (19.5%), shrub (20.0%), urban, that is undeveloped plots of land within urban (13.7%) and water body through reclamation of land (0.8%). Urban land use obviously is competing with farmland for available space in the process 33.1% of light forest, 20.6% of shrub, 11.9% of water body, 3.9% of non-forested wetland and 0.23% of farmlands that are previously non-forested wetland or forested wetland or shrub or light forest have been converted to urban use within the study period. This may partly provide clue to contemporary issue of building collapse in the Lagos mega city where large hectares of land have been reclaimed from water, non-forested wetland and shrub as revealed by this study and utilized for urban development without appropriate geotechnical analysis. The modification noticed is in the area of tree planting and beautification programme targeted at promoting green environment which, to a large extent, deserves encouragement.

Drivers of landuse/landcover change in the study area

Land use/land cover changes reflect the dynamics observed in the socio-economic condition of a given area. Similarly, changes in the socio-economic situations cause land use/land cover changes through their influence on land management techniques used and other various aspects of farming systems, institutional settings, environmental policy and others (Mengistu and Salami, 2007). As many researchers indicated in Nigeria, several factors have been modifying the original form of land cover. These include human activities such as agricultural colonization (Adejuwon, 1971); spread of rural settlements (Osunade, 1991); evolution of rural road networks and government policy (Ekanade et al., 1996) noted in Salami (2001).

The results obtained from the change detection analysis gave a clear indication that most of the light forests have disappeared, having been cleared for property development, road construction and provision of utilities such as the two waterworks in the study area.

Information obtained from field work also confirmed that the forested wetlands were being cleared for the cultivation of vegetables and sugarcane. Andreas and Hugh (2009) in a study of land use/land cover change in sub-Saharan Africa over a 25 year period concluded that land cover change in Africa is mainly driven by the expansion of croplands. The expansion of croplands may lead to a growth in agricultural output such as food and fiber production and impact positively on the socio-economic condition of the people. However, at the same time the land left available for future agricultural expansion is decreasing, and with population increase the agricultural zone itself is more crowded exacerbating potential friction amongst and in between agriculturalists and pastoralists alike. Such changes require rapid adjustments to land management so as to avoid crises in food security and conflict over dwindling access to natural resources, which are becoming more evident. The continued expansion of urban built up and farmlands have serious implications for the hydrology, microclimatology and soil health of the river basin, which would only be revealed by further studies.

Environmental consequences of land use/land cover change

From the results of the analyses carried out the dominant land use/land cover (drivers of land use/land cover) in the study area are urban and farmlands. Therefore, the analysis of land use impact that follows will examine the impacts of these two land use classes.

The results obtained from the various ecological approaches adopted in this study, that is, change detection analysis, focus group discussion, soil and vegetation sampling, were used to assess the biophysical status of the Lower Ogun River Basin ecosystem. This assessment focused primarily on: (a) soil quality (b) biodiversity (c) socio-economic impacts and (d) hydrological impact.

Soil quality has been viewed as the capacity of a soil to function within its ecosystem boundaries and interact positively with the environment external to that ecosystem (Olayinka, 2009). Soil quality has emerged as a unifying concept to address the larger issue of sustainability of ecosystem in general and agriculture in particular (Eswaran et al., 2005). From the point of view of land use and land management decision making soil quality is a measurable component of the environment which provides a quantitative basis for evaluating different land use options and impacts of technology. As indicated in Table 7, the impact of LULC is quite noticeable on the soil quality in the study area. Conversion of native forests to cultivation is usually accompanied by a decline in soil organic carbon and nutrients, and deterioration of soil structure. The result obtained from the soil analysis carried out indicated that the growth of urban agriculture in the study area engendered by rapid urbanization is having negative impact on the physical, chemical and organic properties of soil in the study area. The result of the vegetation profile conducted in the study area indicated that the combination of urban growth and the concomitant increase in population has resulted in the loss of biodiversity as manifested in almost complete degradation of the non-forested wetland.

Table 8. FGD findings on the impact of landuse change.

Impacts of land use	Maidan (forested wetland)			Isasi (non-forested wetland)		
	Sand Miner	Farmer	Fishermen	Sand miner	Farmer	Fishermen
Increased flooding	+	+	+	+	+	+
Pollution	+	+	+	+	+	-
Reduction in plant and animal species	+	+	+	+	+	+
Global Warming	-	-	-	-	+	+
Income Generation	+	+	+	+	+	+

+, Where the opinions were expressed by the respondents; -, where the opinions were not expressed at all.

Thus the original vegetation cover has given way to shrub and herbs while trees have completely disappeared, in contrast with the forested wetland. This development also has a serious implication on the microclimate of the study area and carbon emission. Information gathered from field work and focus group discussion also revealed that the dominant life form in the non-forested wetland was herb which covered 83% of the study site, while the remaining 17% was covered by shrub, there were no trees, as plant height ranged between 0.1 to 5 m. This result also indicated that this site has been seriously degraded. On the other hand, life forms in the forested wetland showed degradation from low shrub, medium shrub, tall herb and tall trees, which were the dominant life form, at 43%. This result also demonstrated the characteristic feature of tropical rainforest in which tree canopies occur in tree layers. Thus heights of plants ranged from <2 to >25 m.

A major source of hydrological impact of land use/land cover change in the study area are the two water works (Adiyan and Iju water works) sited within the study area. Ogunbajo (2005), in a study carried out on the impact of the two water works reported that, flooding of the immediate environment, change in the flow regime of river Ogun, silting of the river bed and pollution from sludge biomass were the observable impacts of the two waterworks. The waste water and high amount of silt contained therein are discharged into the downstream sector of river Adiyan resulting in the alteration of the morphology of the area which induces large scale erosion when it rains and consequently large flooding of the area.

Urban agriculture as with other urban activities has both positive and negative social, environmental, and economic impacts and externalities. Urban agriculture is an important source of income for some of the inhabitant of the communities within the study area. Findings from FGD, according to Table 8, confirmed the fact that in addition to income from sales of surpluses, farming households save on household expenditure by growing their own food.

Conclusion

Changes in the patterns of land use/land cover as demonstrated in this study are a reflection of increasing anthropogenic pressure on landscape which needs to be seriously addressed. Rapid population growth and its twin brother, urbanization remain the major causes of environmental degradation. More and more people, especially the urban poor, are getting engaged in urban agriculture using the mostly unprotected and uncontrolled wetlands in the Lower Ogun River Basin. Although this could lead to increased food production and food security there is need for further research into sustainable management and utilization of fragile ecosystem such as wetlands. There is a need for the control and planning of activities around the existing wetlands by government to avoid unsustainable encroachment of the fragile wetlands.

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Full Length Research Paper

Heavy metals concentration in various tissues of two freshwater fishes, *Labeo rohita* and *Channa striatus*

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Heavy metals like cadmium, zinc, copper, chromium, lead and mercury were measured in the various tissues of *Labeo rohita* and *Channa striatus* and in the water samples collected from the Kolleru Lake, Andhra Pradesh during 2009-2010. The concentrations of heavy metals in the different organs of fishes varied. In *L. rohita*, the concentrations of heavy metals were in the order of liver > kidney > gills > muscles and in C*. striatus,* it was liver > kidney > gills > muscle. The values of heavy metals concentration in the present study are within the maximum permissible levels for drinking water and fish.

Key words: Heavy metals, tissues, fish, Kolleru Lake.

INTRODUCTION

The contamination of aquatic systems with a wide range of pollutants has become a matter of concern since the last few decades (Canli et al., 1998; Dirilgen, 2001; Vutukuru, 2005; Amaraneni, 2006; Rao and Rao, 2007; Vinodhini and Narayanan, 2008; Gupta et al., 2009). The natural water bodies may extensively be contaminated with various heavy metals released from domestic, industrial effluents, idol immersion, draining of sewage, dumping of hospital, other wastes and anthropogenic activities, etc. (Conacher et al., 1993; Velez and Montora, 1998; Chandra Sekhar et al., 2004; Vinodhini and Narayanan, 2008; Malik et al., 2010; Laxmi Priya et al., 2011). Pollution of heavy metals in aquatic ecosystem is growing at an alarming rate and has become an important problem of many countries of the world. Heavy metal contamination may cause devastating effects on the ecological balance of the recipient environment and its diversity of aquatic organisms (Farombi et al., 2007; Vosyliene and Jankaite, 2006; Ashraj, 2005; Vinodhini and Narayanan, 2008). Fish occupies higher level in the food chain and is an important source of protein food for human beings. The heavy metals in aquatic ecosystem are transferred through food web into human beings. Some of heavy metals can cause health problems to fish consumers (Uysal et al., 2008; Taweel et al., 2011). Therefore, in the present study attempts have been made to assess the heavy metal concentration in water and fishes of Kolleru Lake, Andhra Pradesh.

MATERIALS AND METHODS

Study area

The study area, lake Kolleru (16° 32 and 16° 47' N and 81° 5 and 81° 21 E) is a natural wetland located between two major deltas, Godavari on the east and Krishna on the west of costal Andhra Pradesh, India. The freshwater enters the lake through a number of rivers, stream and agricultural drains. The lake has rich aquatic life, the lake has always been exploited by local population (Figure 1).

A total of one hundred and forty four fishes (ranging between 90-100 g in weight and 16-81 cm in length and three months in age) were collected with the help of a fisher man using the gill net. The water samples were collected in sterilized bottles from three sites, with one meter in depth to analyze the various physico-chemical parameters such as water temperature, pH, free carbon dioxide,

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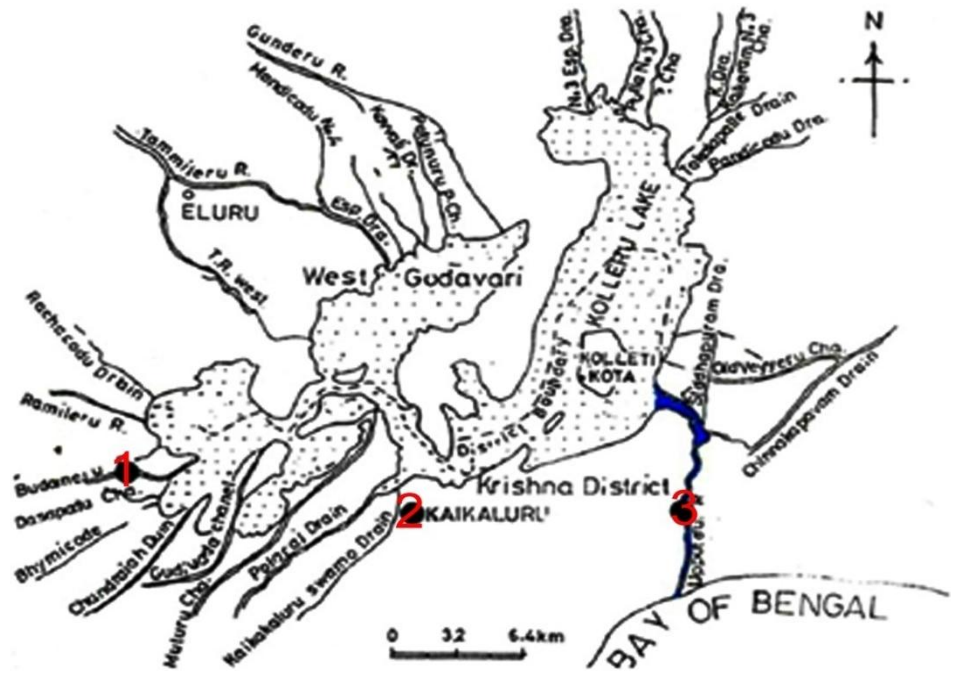

Figure 1. Geographical distribution of sampling sites in Kolleru Lake, Andhra Pradesh.

total hardness and dissolved oxygen. Dissolved oxygen (DO) was fixed at sampling site itself and estimated in the laboratory. Both fish and water samples were collected for one year from July 2009 to June 2010.

100 ml of water sample was collected in sterilized bottles from each site and was acidified with 10% HNO_3 and brought to the laboratory. The samples were filtered through what's man filter paper (No. 42) and kept in refrigerator until further analysis. The samples were subjected to analysis directly.

In each month of all the three seasons, 6 fishes of *Labeo rohita* and *Channa striatus* were caught from the lake. They were brought to the laboratory and dissected, and the organs viz. liver kidney, gills and muscles were removed with clean sterilized instruments. Tissues such as liver, kidney, gills and muscles were washed with double distilled water and put in sterilized Petri dishes to dry at 120°C in oven until they reached a constant weight. One gram of each dried tissue of liver, kidney, gills and muscles were then digested with diacid ($HN0_3$ and $HClO_4$ in 2:1 ratio) on a hot plate set at 130°C until all materials were dissolved. Digested samples were diluted with double distilled water appropriately in the range of the standards, which were prepared from the stock standard solutions of the metals (Merck). The metal concentration in the samples was measured using a Perkin-Elmer Analyst 300 Absorption Atomic Spectrophotometer (AAS). The results were expressed as µg g^{-1}dry weight and mg $L^{-l}$for fish and water, respectively.

Physico-chemical parameters of the water were analyzed as per the procedures described in APHA (2012). The obtained data were subjected to statistical analysis using a computer program (SPSS, 2001) for mean and standard deviation.

RESULTS AND DISCUSSION

The physico-chemical parameters are paramount, important and influenced by natural and manmade activities. They are also depends upon the depth of water body and ecological conditions of ecosystem. In the present study, water temperature ranged between 22 and 34.8°C from summer to winter. The pH of the water was alkaline throughout the study ranging from 7.2 to 9.0. Similar findings were recorded by Mohan et al. (2007) and Malik et al. (2010). Free carbon dioxide showed an irregular pattern and ranged from 0 to 3.8 mg L^{-l}. Dissolved oxygen (DO) is an important water parameter indicating the quality of water and organic production in lake (Wetzel and Likens, 2006). Survival of aquatic flora and fauna especially fish fauna, depends on the dissolved oxygen in water. In the present study, DO levels ranged between 6.0 and 8.6 mg L^{-l}. Low DO levels were recorded during summer season, indicating that DO level decreases with the increase in temperature. The hardness of water varied from 58-192 mg L^{-l} (Table 1) which was within the permitted levels for drinking water proposed by of Bureau of Indian standards.

In the water of Kolleru Lake, average concentration of heavy metals namely, Pb, Cd, Zn, Cu, Cr and Hg, were 0.034, 0.012, 0.304, 0.013, 0.436 and 0.001 mg L^{-l}, respectively (Table 2).

Zinc content was highest and Hg was the lowest in water. The concentration of heavy metals was in the range of Zn, Cr, Pb, Cu, Cd and Hg. Gupta et al. (2009) have reported that the concentration of Zn in the water of river Ganges at Allahabad was highest and followed by Pb, Cu, Cr and Cd, The high content of Zn and the lowest content of Hg were also reported by Jain and Sharma (2001), Sarkar et al. (2007) and Malik et al. (2010). The concentrations of heavy metals were highest in summer

Table 1. The range of water quality parameters of Kolleru Lake, A. P. in different seasons during the study period.

Physico-chemical parameter	Spring	Summer	Rainy	Winter	Permissible limits for drinking water (BIS, 1991)
Temperature (ºC)	26 - 32.1	28 - 34.8	26 - 29	22 - 25.6	-
P^H	7.6 - 7.8	7.6 - 8.0	8.2 - 8.6	8.2 - 9.6	6.5 - 8.5
Free CO_2 (mg L^{-l})	0.20 - 2.8	0.20 - 3	0 - 2	0 - 3.8	-
Total hardness (mg L^{-l})	120 - 189	120 - 192	68 - 172	56 - 86	300
D.O (mg L^{-l})	6.0 - 6.5	6.0 - 6.8	6.8 - 7.9	6.8 - 8.6	6

Table 2. Heavy metal concentration (mg L^{-1}) in water of Kolleru Lake, Andhra Pradesh, in different seasons during the study period.

Heavy metal (mg L^{-1})	Spring	Summer	Rainy	Winter	BIS, 1991 limit
Pb	0.019 ± 0.014	0.034 ± 0.002	0.027 ± 0.001	0.038 ± 0.001	0.1
Cd	0.011 ± 0.001	0.012 ± 0.001	0.001 ± 0.000	0.010 ± 0.000	0.01
Zn	0.301 ± 0.001	0.304 ± 0.002	0.279 ± 0.017	0.299 ± 0.006	15
Cu	0.012 ± 0.001	0.013 ± 0.001	0.113 ± 0.001	0.012 ± 0.001	1.5
Cr	0.014 ± 0.001	0.043 ± 0.002	0.042 ± 0.005	0.039 ± 0.001	0.05
Hg	0.001 ± 0.000	0.001 ± 0.000	0.001 ± 0.001	0.001 ± 0.001	0.001

Values expressed in mean ±SD of three replicates.

Table 3. Heavy metal concentration (µg/ g/d.w) in various tissues of *L. rohita*.

Heavy metal (µg g^{-1})	Liver	Kidney	Gill	Muscle	FAO*/WHO** guideline
Pb	1.483 ± 0.206	0.553 ± 0.032	0. 300 ± 0.010	0.223 ± 0.152	4
Cd	0.616 ± 0.249	0.250 ± 0.046	0.383 ± 0.153	0.316 ± 0.006	-
Zn	1.036 ± 0.004	0.943 ± 0.031	0.19 ± 0.0173	O.380 ± 0.020	50
Cu	1.056 ± 0.124	0.233 ± 0.042	0.090 ± 0.000	0.090 ± 0.000	10
Cr	0.696 ± 0.349	0.716 ± O.035	0.196 ± 0.015	0.023 ± 0.012	2
Hg	0.270 ± 0.552	0.070 ± 0.001	0.047 ± 0.001	0.036 ± 0.015	-

Values expressed in mean ± S.D of three replicates, unit- µg /g/d.w,*FAO (1983), **WHO (1985).

and the lowest in rainy months due to the dilution effect of water. Similar results have also been reported by Jain and Sharma (2001) and Malik et al. (2010). In the present study, it has been observed that, all the metals were below the permitted levels of BIS.

The heavy metals were accumulated at varying levels in different tissues of *L. rohita* and *C. striatus*. The concentration of heavy metals in different organs of fishes followed the decreasing order Pb > Cd > Zn > Cu > Cr > Hg. The concentration of Pb varied between 1.483 ± 0.206 and 0.223 ± 0.152 µg g^{-1}. While that of Cd, 0.616 ± 0.249 and 0.250 ± 0. 045, Zn, 1.036 ± 0.004 and 0.19 ± 0.017, Cu, 1.056 ± 0.124 and 0.0.090 ± 0.001, Cr, 0.716 ± 0.357 and 0.023 ± 0.012, Hg, 0.270 ± 0.552 and 0.036 ± 0.015 µg g^{-1} in *L. rohita* whereas the respective values for *C. striatus* were recorded as Pb 1.353 ± 0.070 and 1.30 ± 0.010, Cd 0.480 ± 0.314 and 0.160 ± 0.040, Zn 1.140 ± 0.295 and 1.013± 0.050, Cu 1.033± 0.646 and 0.028 ± 0.002, Cr 0.853 ± 0.535 and 0.326 ± 0.050, Hg 0.256 ± 0.060 and 0.123 ± 0.086 µg/g/d.w. The concentrations of metals were higher in the livers than gills and muscles (Tables 3 and 4).

Heavy metals in aquatic environment and aquatic biota pose a risk to fish consumers and other wild life. Heavy metals may enter aquatic ecosystem from different natural and anthropogenic sources including industrial or domestic sewage, storm runoff, leaching from landfills-/dump sites and atmospheric deposit (Forstner and Wittmann, 1983; Bhupander et al., 2011; Laxmi et al., 2011).

Table 4. Heavy metal concentration (µg/g/d.w.) in various tissues of *C. striatus*.

Heavy metal	Liver	Kidney	Gill	Muscle	FAO*/**WHO guideline
Pb (µg g^{-1})	1.353 ± 0.070	1.333 ± 0.704	1.30 ± 0.529	1.30 ± 0.010	4
Cd (µg g^{-1})	0.480 ± 0.314	0.160 ± 0.040	0.316 ± 0.125	0.456 ± 0.109	-
Zn (µg g^{-1})	1.013 ± 0.050	1.213 ± 0.208	1.140 ± 0. 295	0456 ± 0.109	50
Cu (µg g$^{-1)}$	0.993 ± 0.600	1.033 ± 0.646	0.028 ± 0.002	0.530 ± 0.305	10
Cr (µg g^{-1})	0.326 ± 0.050	0.470 ± 0.160	0.596 ± 0.205	0.853 ± 0.535	2
Hg (µg g$^{-1)}$	0.203 ± 0.125	0.256 ± 0.060	0.123 ± 0.086	0.140 ± 0.135	-

Values were expressed as mean ± S.D of three replicates, unit- µg g^{-1}/d.w. *FAO (1983), **WHO (1985).

In the present study, Pb concentration in all the tissues of *L. rohita* was higher than that of *C. striatus*. In *L. rohita*, highest concentration of Pb was recorded followed by Cu, Zn, Cr, Cd and Hg.

In nature, Cd is always associated with zinc ores (ZnS) due to its similarity with Zn. The Cd concentration in lake water and fishes has been reported by various workers (Malik et al., 2010; Bhupander et al., 2011). In the present study, Cd concentration in *L. rohita* was in the order of liver, kidney, gills and muscles. The highest level of Cd concentration was observed in liver, whilst the lower concentration was observed in muscles. In the case of *C. striatus,* highest level of Cd concentration was observed in liver and lowest concentration was observed in kidney. Similar results were also reported by Chandra Sekhar et al. (2004), Gupta et al. (2009) and Abdel-Baki et al. (2011).

Zinc is an essential trace element which plays an important role in the physiological and metabolic process of many organisms. However, in higher concentrations it can prove to be toxic. Zn showed protective effect against the Cd and Pb toxicity. The amount of Zn was highest in *L. rohita* than *C. striatus*. In *L. rohita* Zn content was higher in liver and kidney and lowest in gills. While in the case of *C. striatus*, Zn content was higher in gills followed kidney, liver and muscles. The results were in agreement with that of Gupta et al. (2009), Malik et al. (2010) and Ayejuyo et al. (2009) for *Clarias lazera*, but, were in disagreement with the work of Yang et al. (2007) for *G. nanensis* and *Ptychobarbus diposon*. Chandra Sekhar et al. (2004) reported that large fraction of Zn, Cd and Cu were associated with mobile fraction of sediment and showed grater bioaccumulation in fishes of Kolleru Lake. The concentration of heavy metals in liver and gills of *L. rohita* and *C. straitus* was found to be higher than the other organs, because liver acted as an important organ for storage and detoxification and gills acted as depot tissue. There was significant accumulation of metals in these organs, as was also reported by Yilmaz (2005), Malik et al. (2010) and Taweel et al. (2011).

Cu is an essential part of various enzymes necessary for the synthesis of hemoglobin (Sivaperumal et al., 2007); but at higher concentration it causes various health problems. In the present study, it has been observed that the concentration of Cu was higher in liver and followed by kidney, gills and muscles. While in the case of *C. striatus*, the concentration of Cu was highest in kidney followed by liver, muscles and gills. The same was also reported by Chandra Sekhar et al. (2004), Gupta et al. (2009), Abdel-Baki et al. (2011) and Laxmi Priya et al. (2011).

Cr plays an important role in carbohydrate (glucose) metabolism. The total amount of Cr was higher in *C. striatus* than in *L. rohita* .The concentration Cr was highest in liver and followed by gills and muscles. In the case of *C. striatus*, the highest accumulation of Cr was observed in muscle followed by gills, kidney and liver. Hg was the least accumulated metal in both fishes. The accumulation amount was slightly higher in *L. rohita* than in *C. striatus.* The same was also reported by Mackeviciene (2002), Malik et al. (2010) and Laxmi Priya et al. (2011). In the present study, values of all the heavy metals in the water and fish were within the permissible levels as per the codes of FAO (1983). The lake is very much suitable for fish culture.

Conclusion

The present study shows that the water quality parameter (temperature, pH, free CO_2, DO and hardness) were within the BIS standards for drinking water and fish culture. The concentration of heavy metals in the water of Kolleru Lake is under prescribed limits of BIS for drinking water. Liver was the highly metal accumulated organ, while muscle is lowest accumulated tissue of *L. rohita* and *C. striatus*. This is mainly important because muscle contributes major mass of flesh that is consumed as food. Heavy metal concentration in different tissues of fishes is below the limits of FAO. The fish of Kolleru Lake is suitable for human consumption.

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