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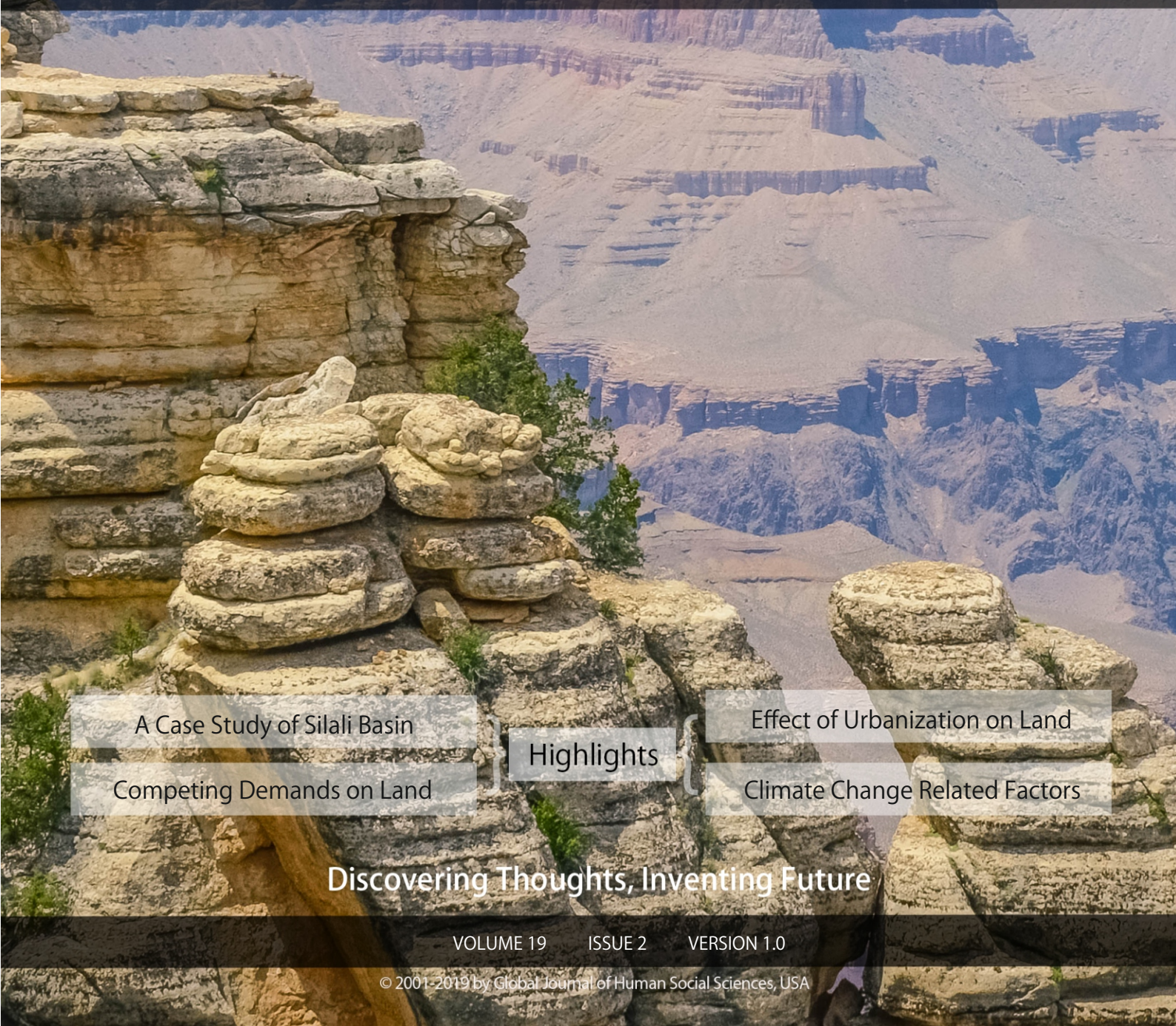

Highlights

A Case Study of Silali Basin

Competing Demands on Land

Effect of Urbanization on Land

Climate Change Related Factors

Discovering Thoughts, Inventing Future

VOLUME 19 ISSUE 2 VERSION 1.0

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Extra-Terrestrial Impact Craters (Etics) and Related Geomorphology- A Case Study of Silali Basin, Kenya

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Abstract- ETICs are special features on the earth's surface; first because they are unique geomorphological formations and two, because they are created by heavenly forces. The formation of ETICs does not only modify the earth's surface but also leads to the genesis of many other landforms. This paper seeks to describe the various geomorphological features that compile an ETIC and the landforms that are linked to the formation of ETICs. According to Thompson and Turk (1992), Extra-Terrestrial Impacts are responsible for many geologic processes through the initiation of mantle plumes. A mantle plume is a vertical column of plastic rock, that rises through the mantle, like hot smoke through a stack. Among its many effects, are lithospheric plate motions, which are credited with the formation of spectacular geomorphological features around ETICs. Mantle plumes are found beneath ETICs.

Keywords: ETICs, crater, silali basin, geomorphology.

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Extra-Terrestrial Impact Craters (Etics) and Related Geomorphology- A Case Study of Silali Basin, Kenya

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Abstract- ETICs are special features on the earth's surface; first because they are unique geomorphological formations and two, because they are created by heavenly forces. The formation of ETICs does not only modify the earth's surface but also leads to the genesis of many other landforms. This paper seeks to describe the various geomorphological features that compile an ETIC and the landforms that are linked to the formation of ETICs. According to Thompson and Turk (1992), Extra-Terrestrial Impacts are responsible for many geologic processes through the initiation of mantle plumes. A mantle plume is a vertical column of plastic rock, that rises through the mantle, like hot smoke through a stack. Among its many effects, are lithospheric plate motions, which are credited with the formation of spectacular geomorphological features around ETICs. Mantle plumes are found beneath ETICs. Near the earth's surface, they create divergent boundaries and facilitate the formation of beautiful sceneries on the earth. Beneath the lithosphere, mantle plumes drive unending volcanicity, in the quest for enhancing isostatic adjustment of the earth, leading to the development of varied landforms in the proximity of ETICs. Mantle plumes are also the reason why some ETICs have magma reservoirs beneath them and some have experienced volcaniciy. Though an ETIC's volcanicity enhances its complexity, it also misleads scholars into classifying an ETIC as a volcano, as it is the case with Silali basin.

Keywords: ETICs, crater, silali basin, geomorphology.

I. Introduction

For a long time, Silali crater/basin has been described as a volcanic crater that formed through volcanicity. This would ordinarily entail the release of magma from inside the earth, through a volcanic pipe or vent, onto the earth's surface. A violent volcanic eruption can blast the earth to form a crater. The eruption can also pile up magma all around the blasted area, forming walls of lava (cooled magma).A recent study that was carried out in Silali basin: *Identification of an Extra-Terrestrial Impact Crater (ETIC): A Case Study of Silali Crater, Kenya*, by Kipkiror (2016), however, has unearthed facts that give an indication that Silali basin may be an Extra-terrestrial Impact Crater (ETIC); formed through an extra-terrestrial impact event. This involves the impact of an asteroid, comet or a meteor on the earth's surface, leading to the formation of a crater or a meteorite. When a heavenly body impacts on the earth's surface and excavates it, a crater is formed. If the heavenly body fails to completely burn up while transiting the earth's atmosphere, it will land on the earth's surface and if it does not get pulverized, it will form a shallow crater and rest on the crater as a meteorite.

The objective of this paper is to describe Silali basin as an ETIC and to enumerate the geomorphological features that form around ETICs and are directly related to the formation of the ETICs; Silali basin being the case study. Information for the paper was derived from the mother study: *Identification of an Extra-terrestrial Impact Crater (ETIC): A case Study of Silali Crater, Kenya* (Kipkiror, 2016). Data has been presented in the form of analysed satellite images, a chart (morphological section), pictures, a LIDAR image, a DEM and discussions.

II. Background Information

Extra-terrestrial impact cratering is a continuous process that may be going on even this very minute, somewhere in the universe. Consequently, the earth, just like other members of the solar system, is targeted by extra-terrestrial falling objects; that can fall on any place on the earth's surface and can cause crustal deformation, mayhem and even desolation. This research paper provides geological and morphological evidence implicating Silali basin to be a possible ETIC and describes morphological features found around Silali basin, that enhance its ETIC nature.

The principal criteria for determining if a geological feature is an impact structure; formed by the hypervelocity impact of a meteorite or a comet, are outlined below. These are classified as either mega scopic (overview – bird's eye/satellite scale) or macroscopic (visible to the naked eye) or microscopic (those that require observation under a microscope).

i) Presence of shatter cones that are on site (macroscopic evidence).
ii) Presence of multiple planner deformation features (PDFs) in minerals within the site lithologies (microscopic evidence).
iii) Presence of high-pressure mineral polymorphs within in situ lithologies (microscopic evidence and requiring proof via X-ray diffraction).

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iv) The morphometry of the crater: -On other heavenly bodies such as the Moon and Mars, the shape of an impact crater is relied upon to determine its presence and type (simple or complex). This is a megascopic characteristic that can be seen, unaided, by the human eye, though requiring remote sensing and aerial photography for detailed mapping. On the earth, recognizing impact structures, solely by their morphology, is hampered by denudation and tectonic forces which deform the craters. The situation is worsened by certain terrestrial features having a circular shape and appearing like impact craters, for instance volcanic craters, such as Maars, salt diapirs, some glacial features, like cirques and kettle lakes and solution aided craters. This disqualifies the circular form, alone, as enough claim for a structure to be accorded the status of an impact crater. Buried craters that are revealed by geophysical techniques, also require a drill core to reveal macro and microscopic evidence to prove an impact origin.

v) Presence of an impact melt sheet and breccias: - These are generated by hypervelocity impact and are macroscopic. Impact melt has a crustal composition derived from the fusion of target rocks and meteoritic/ impactor's components. The rock may also have some suevite, especially around the centre of the crater. Impact melt can be determined by sampling, followed by microscopic observation and geochemical analysis.

vi) Pseudotachylites and breccias: - Pseudotachylite is a rock type generated by faulting at either microscopic or macroscopic scales. Unfortunately, pseudotachylites are also associated with tectonic faulting and are not therefore, exclusively impact generated. However, association of pseudotachylites with the above factors can make them one of the evidences of ETICs.

vii) Presence of unshocked or preserved fragments of the impactor around or within a crater.

As for the reasons why heavenly bodies fall onto the earth, three hypotheses have been advanced by scientists(www.csienceclarified.com/Ge-He/Gravity-and-Gravitation.html), as follows:

i) The sun has a faint undiscovered companion star that revolves on a highly eccentric orbit with a period of 26 million years. When this star passes close to the sun, it draws a stream of materials from the sun and sets them in motion around the sun. Some of these materials cool down to form new planets and some are attracted by the forces of gravity of other heavenly bodies, causing impacts, as these materials slam into these heavenly bodies.

ii) There is a massive undiscovered planet that orbits beyond Pluto and periodically disturbs an unseen disk of comets in the neighbourhood. These comets, once disturbed, are scattered and some fall onto heavenly bodies, including the earth.

iii) The up and down oscillations of the sun through the massive central plane of the Milky Way, may cause gravity differences between heavenly bodies of the galaxy. Consequently, some of the heavenly bodies may become unstable and vulnerable to the earth's gravitational pull, which attracts them, leading to extra-terrestrial impacts on the earth (Allen, 2014).

Extra-terrestrial impact Craters are divided into three categories according to their morphology, namely:

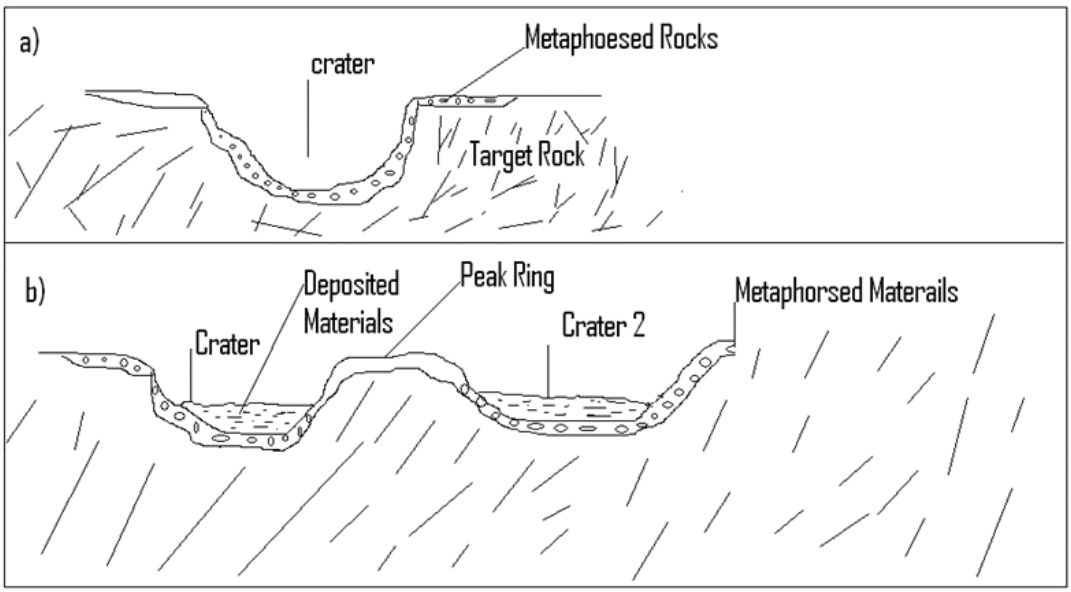
i) Simple Craters
ii) Complex Craters
iii) Basins

Simple craters are relatively small with a smooth bowl shape. In larger craters, though, gravity causes initially steep crater walls to collapse downward and inward, forming a complex structure with a central peak or peak ring and a shallower depth (Figure 1). The diameter at which craters become complex depends on the surface gravity and the planet. The greater the gravity, the smaller the diameter that will produce a complex crater. On the earth, the transition diameter of a complex crater is 2 to 4 km, depending on the target rock properties (www.solarviews.com). On the moon, where gravity is low, the transition diameter is 15-50 kilometres (www.solarviews.com).

The peak ring or the central peak of a complex crater is formed as the initial (transient) deep crater floor rebounds from the compressional shock of impact. Slumping of the rim further modifies and enlarges the final crater. Complex structures on crystalline target rocks will also contain sheets of impact melt rock, atop the shocked and fragmented rocks of the crater floor. On the earth's surface, weathering and erosion of the target rocks, as mentioned earlier, quickly alter the surface appearance of the structure, though in some cases, the resistant rocks will stand out as concentric rings/peak rings within the crater. On the surface of the moon, complex craters are said to be intact till they are destroyed by subsequent impact events (www.solarviews.com).

A basin, on the other hand, is an ETIC whose diameter is large and with the increasing diameter, a ring of peaks appears within it, transiting the complex crater into a basin. A single interior ring can qualify an ETIC into a basin (Therriault *et al.*, 2002).

It must be noted that ETICs can also form in marine environments and the morphology of a marine ETIC is quite distinct. Marine impact structures are characterized by a broad shallow brim, extensive sedimentary infilling and prominent fault blocks on the floor (Tsikalas *et al*., 1999).



Source: Kipkiror, 2016.

Figure 1: Diagram showing a simple crater (a) and a complex crater (b) with associated features.

III. Formation of Silali Basin

Silali basin, also known as Silale,is found in East Pokot/Turkana East, within the mid Graben of the Great Rift Valley, 50 km north of L. Baringo and near Kapedo Town. It is located on Latitude $1^0$10' N and Longitude $36^0$12' E. The basin or crater is named *Kotong*, by the Pokot community living around it, which means a depression. The Turkana people call it Silali while the Pokot call it Silale. The basin covers an area of about 850km^{2}and has a NNE diameter of about 5 km and an ESE diameter of 8 km. Spectacularly, Silali basin has a distinctive ring fracture structure all around it; which the study attributes to the impact origin of the basin. It can be estimated that the impactor's size, could be 0.25-0.4 km in diameter or 42.5km^{2}in area, based on the rule that an impactor's size is 1/20 the crater's size (Beatty *et al.*, 1999). Consequently, the Silali impact event may have been a great event.

According to Dunkley *et al.* (1993), Silali volcano was formed around 225ka and the caldera (crater or basin) collapsed around 66-62ka.

Silali basin is a basin within a larger basin (the outer basin) with smaller basins within it. In addition, there seems to have been impacts at different times in the area, the oldest being the one that formed the huge 'outer basin' and probably triggered the formation of a section of the Great Rift Valley, example the mid graben and the many spectacular geological features within and around it. The 'outer basin' covers the area around the crater walls and it is as near circular as the Silali basin itself, going all around Silali. It is covered by alluvial material and volcanic flows in many places and thus, on Plate 1, it appears as the dark and bright circular area around the Silali basin. This is the basin in which the Suguta gorge, Suguta River and the Kapedo hot water falls are situated, alongside the Chemolingot shatter cones, cross bedding slumps, sink holes and several breccias. Different volcanic rocks, prehistoric caves, smaller craters, swamps, hot springs, fumaroles and alluvial deposits are also found in this basin.

Previous studies, by some scholars who carried out research in Silali basin, indicated that a volcanic shield existed where the Silali basin is. The shield seems to have been stretching in a north-south direction. According to Smith *et al.,* (1995), Silali's volcano started forming 400-220ka. This included the formation of a low relief lava shield. Volcanic eruptions in Silali occurred during different times and some of the later ones, according to the authors, resulted in an inward collapse of the shield summit, owing to the lateral drainage of magma from beneath the volcanic shield. According to the scholars, these are the eruptions that led to the formation of the caldera around 66-62ka (Smith *et al*., 1995 and Dunkley *et al*., 1993). The existence of a volcanic shield in Silali before the ETIC formed is favoured by the following incidences:

- The fact that Silali basin's wall is made up of volcanic materials placed in layers;
- The non-contemporaneous nature of the wall materials in terms of age and physical characteristics; and
- The 'break off' or stepped walls of Silali basin, which may be layers of different volcanic materials, bearing different strengths against denudation.

Other scholars, however, came up with a proposition that there existed an earlier caldera before the present 'volcanic caldera'. According to Dunkley *et al.,* (1993) the 'break off walls' (stepped walls) of Silali basin, mark the traces of an earlier caldera. Not all scholars agree with this and according to Williams *et*

al.,(1984), were these features indicative of a bonding within an early caldera, then some mechanism of topographic inversion is required (Williams *et al,.*1984). This mechanism of topographic inversion can be provided for by an extra-terrestrial impact.

As a volcanic shield, caldera formation by subsidence involving a volcanic pipe is not plausible for Silali basin. This is because subsidence would not be a quiet event and an explosion would most likely occur, pouring out magma onto Silali walls. One would then expect Silali to exhibit magma outpourings from its ring structure onto its flanks. This is not the case. Again, the collapse would not produce a perfectly circular structure unless there was an outline of a ring structure in existence, before the collapse, which again is not the case, as indicated by earlier studies.

Caldera subsidence occurs in various ways, such as through plate/piston subsidence, trap door subsidence, chaotic subsidence and down-sag subsidence, among others. Plate or piston subsidence involves the subsidence of a coherent block of rock into a magma chamber that evacuates magma along a ring fault. The caldera floor may be variably faulted, but the faults are less active than the ring faults (Traver, 2007). Trap door subsidence on the other hand, is subsidence that involves multiple collapse centres. It is a piecemeal subsidence. As for chaotic subsidence, wholesale disruption and brecciation of caldera floor rocks is involved. This generates low density materials which cause a caldera to register a low gravity signature. Finally, down-sag subsidence occurs when ring faults either do not form or do not penetrate the ground surface so that summit material subsides by bending downwards.

Silali's subsidence may be said to be a plate or piston type of subsidence because the rock layers forming the basin's walls show continuous uniformity in material type and height. This is supported by observations made by Dunkley and team, that; the caldera has a regular outline and vertical walls suggesting that it was formed by a piston like collapse (Dunkley *et al*., 1993). Unlike in the case of volcanic calderas, Silali's ring fracture was less active compared to the floor fractures, in magma emission. It is thus the crater floor fractures that evacuated most of the magma that may have been beneath the volcanic shield on which Silali basin was built. The lava flow to the northeast of Silali basin can be evidence of such an event. This is because it appears that the magma jetted off the base of the basin's wall. Notably the floor fractures of the basin extend outwards from the basin and not otherwise. The subsidence can also be termed chaotic because of the presence of brecciated rock on Silali's floor and walls. The lower layers of the north-eastern wall of the caldera, for instance, consist of massive trachyte lithic breccias while the northern wall has up to 10m of polymict lava lithic rich breccias (Dunkley et al., 1993). Lithic and Polymict breccias are breccias whose particles are cemented in a way that they form a matrix. In fact, lithic breccia is an impact breccia that contains shocked and unshocked clastic material in a clastic matrix.

A more apt subsidence theory for Silali basin is any theory that involves withdrawal of magmatic support hence collapse. Silali's formation, as a volcanic shield or an ETIC, lacks a volcanic cone and a volcanic vent/conduit. According to McCall and Hornung (1972), Silali volcano was built by clustered vents (not a central single vent or a volcanic pipe). For the study on which this paper is based, Silali volcanic shield was built by a single fissure with limited branches, which build the shield's parasitic cones. Again, an extra-terrestrial impact, provides a viable explanation on how Silali developed a crater, via impact and consequent subsidence. The extra-terrestrial impact appears to have blasted a crater at the centre or near centre of the Silalivolcanic shield, creating the first crater which later subsided to form the present crater.

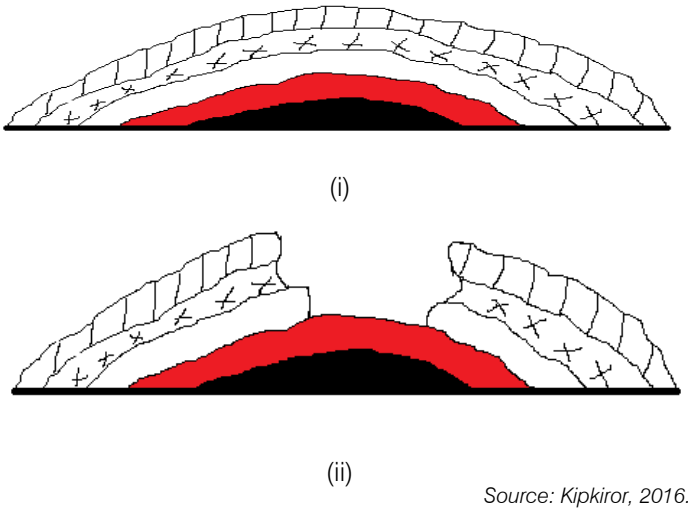
Silali's subsidence can be said to be the factor behind the basin's stepped or 'break off' walls, because as subsidence occurred, the more resistant rocks of the basin's wall remained 'standing' while the softer parts collapsed more and later got washed away by denudation. Denudation removed the softer rocks that made up the initial walls of the volcanic shield, forming scalloped areas, while resistant rocks, such as the young volcanic rocks making up the top most layer of Silali basin's wall, remained intact, forming the wall's protruding parts. There is a lot of evidence along the basin's wall, supporting subsidence and especially block/piston/plate subsidence. These include;

- The layers that make up Silali basin's wall are almost uniform and continuous around the basin and at the same height from the basin's floor (about 300m for the top most layer).
- The walls appear to have collapsed inwards, towards the basin. There is an appearance of 'turning inwards' on Silali basin's inner walls, which is different from the 'turning outwards' appearance of the basin's outer walls. Slumping has modified the appearance of the basin's inner walls, giving the walls a concave appearance.

Subsidence was possible for Silali basin because, after a probable extra-terrestrial impact, fractures formed around the basin, encouraged by pre-existing rock weaknesses, some of which built the Silali volcanic shield (400-200ka). The impact must have also widened the existing rock cracks, triggering the exit of magma from within the shield's magma chamber onto the areas around the basin. This should have formed some amount of emptiness beneath the impact basin, bringing about a collapse that left high stepped walls. There is evidence (in the form of brecciated and

metamorphosed rocks on the crater walls) that hot gases and liquids hissed out of the crater chamber through the many fractures surrounding the crater. From pictures and satellite images of the basin, one can clearly see volcanic cones around the basin. These were built by magma that outpoured from the impact area, forming part of the evidence of subsidence in Silali. The volcanic cones sitting on the basin's walls would be as old as the Silali volcanic shield, being the products of the shield's parasitic fissures.

The following simplified schematic diagrams can explain the formation of Silali basin, especially the volcanic shield and impact stages.



Source: Kipkiror, 2016.

Figure 2: Schematic diagrams showing the formation of the Silali basin. (i) Represents the pre-impact volcanic shield. The shield is made up of different layers of volcanic rock. (ii) Represents the post impact volcanic shield.

Source: Google maps.

Plate 1: A natural colour SPOT satellite image showing the Silali crater, Marigat- Kapedo road (yellow), Suguta River (characterized by whitish sediments) and the outer basin around Silali. (A) is the Silali crater, (B) are the almost circular walls that surround the crater and (C) is the outer basin surrounding the crater. The hot springs feeding the Suguta River are the white patches extending from the base of the basin's wall towards the river, westwards of the basin.

IV. Morphological etic Characteristics of Silali Crater

a) The Circular Shape of Silali Basin

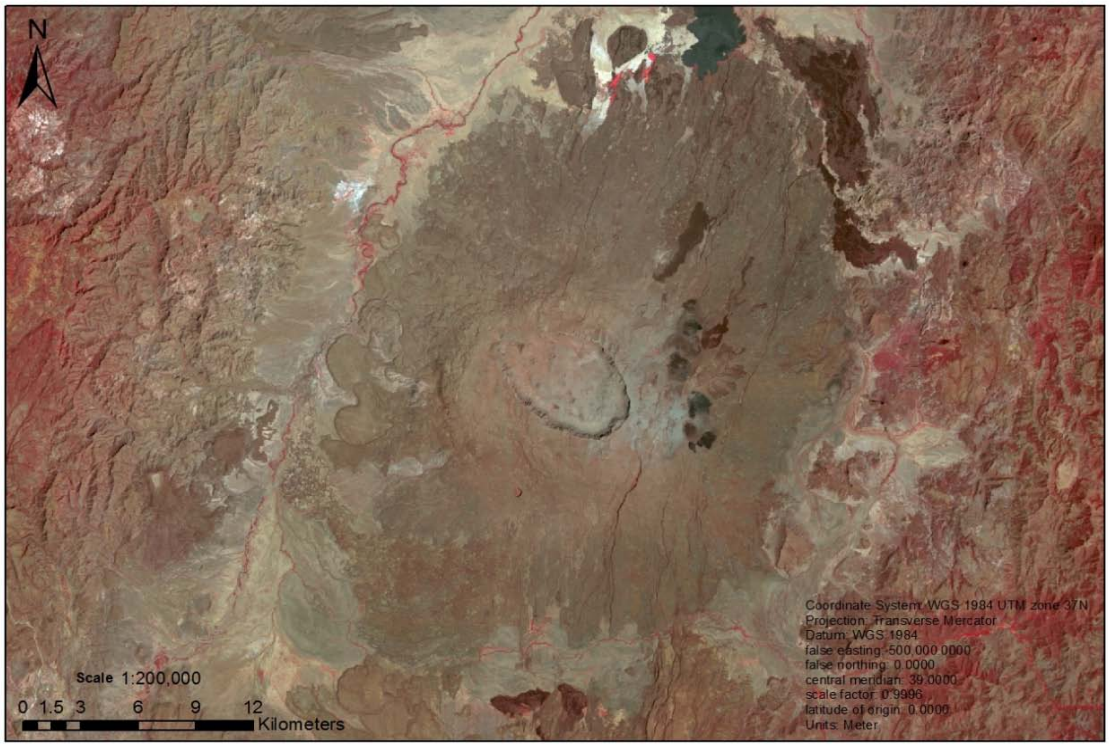
As stated earlier, Silali's near circular shape is a product of remodelling of the original crater shape by various geological processes; which include subsidence, plate tectonic movements, erosion and sedimentation. Further, the Silali crater can be classified as a complex crater, because of its hummocky floor, or a basin, because its diameter is above 4km (it is 5-8km). Silali's floor is hummocky/ lumpy, as shown by the satellite images of the area. The basin does not also display a clear peak ring but there is an outline of a peak ring as shown by Plate 1. The original peak ring may have been distorted by the basin's collapse, faulting, erosion and volcanicity. Faulting and volcanicity are not uncommon to impact cratering. These processes though, have not only re-shaped the basin but have made its origin quite complex.

Plate 2 also shows the circular shape of the Silali basin. However, in the image, the basin's walls appear to be very steep and five mini craters are clearly visible within the crater. Also evident are cones that look like volcanoes, on the basin's floor. Ground truthing placed the number of the mini craters at 5 and 2 cones with summit craters on them. There is a possibility that the cratering that led to the formation of the Silali basin may have triggered a spate of volcanicity within the crater and around it. There is also another possibility that the area may have been hit more than once by extra-terrestrial bodies, as it happened to Arounga crater in Chad. Multiple impact cratering, in Silali, is favoured by the presence of minor craters within the basin and around it, together with the fact that the Silali basin appears to be a basin formation within another basin (Plate 1).

Source: Google maps.

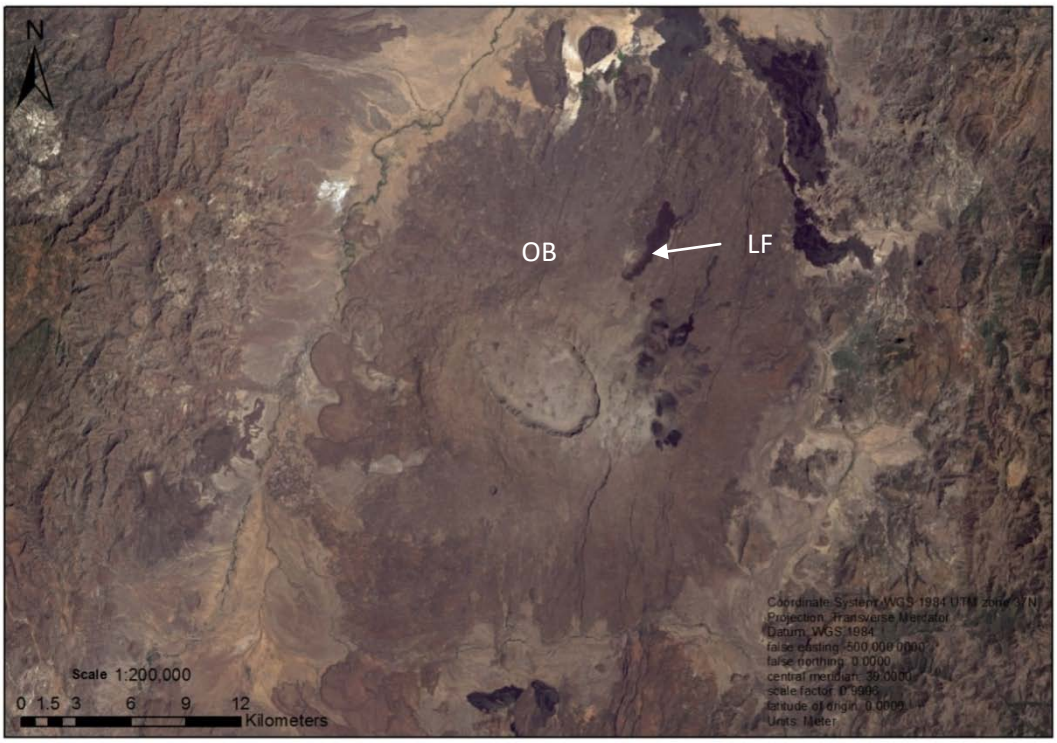
Plate 2: A natural color SPOT satellite image showing the Silali crater.

Plates 3 and 4, are Landsat satellite images that further show the circular shape of the Silali basin and some of the associated topography and physical features. The same circular shape is seen on the LIDAR image of the area, the area's topographical section and the Digital Elevation Model (DEM) of the basin.



Source: Remote Sensing of Resources for Regional Development (RCMRD).

Plate 3: A false colour image of Landsat 8, bands 5 (Red), 4 (Green) and 2 (Blue), showing the Silali basin.

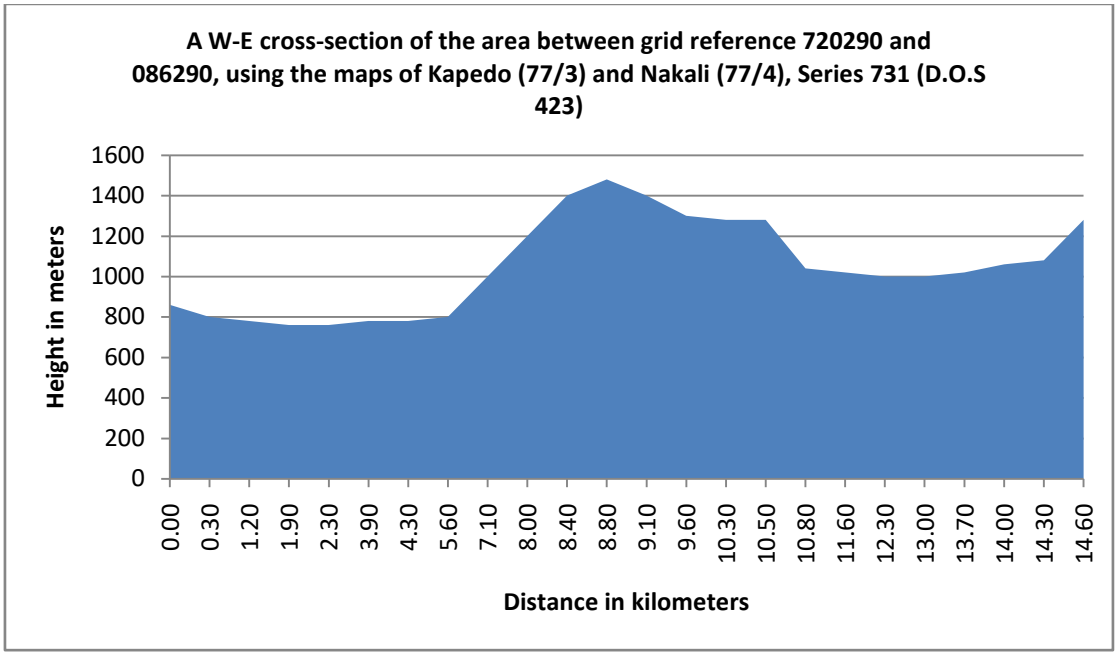


Source: RCMRD.

Plate 4: A natural colour image of Landsat 8, bands 4 (Red), 3 (Green) and 2 (Blue), showing the Silali basin.

The dark volcanic rock surface of sections of the outer basin (OB), can be seen on Plate 4, as labelled. The young lava flows (LF) to the east of the basin can also be seen from the plate and they appear to start right at the base of the Silali basin's wall. Thelava flows within and around Silali basin are rooted in the formation of the basin.

Figure 3 shows a morphological section of Silali basin and the outer basin. The section was drawn using the topographical maps of Kapedo and Nakali, which were acquired from the Survey of Kenya office.



Source: Kipkiror, 2016.

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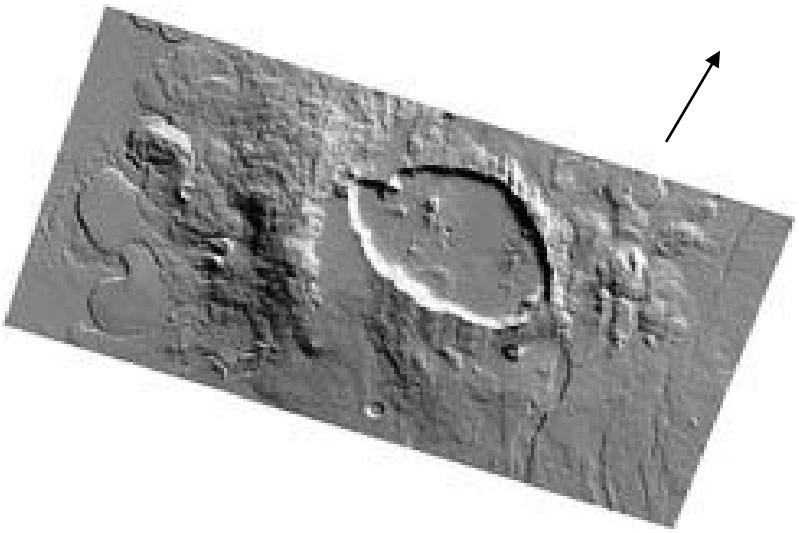
Vertical scale = 1 cm represents 200 m
Horizontal scale = 1 cm represents 2.5 km

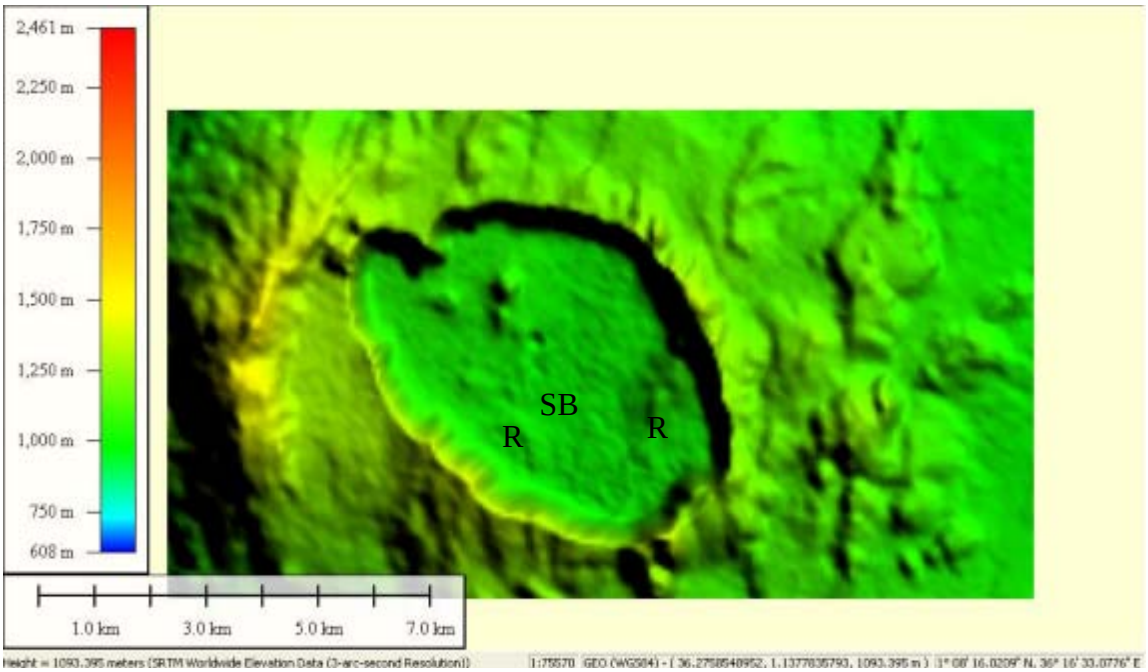
Figure 3: A morphological section of theSilali basinand the outer basin.

From the morphological section, it appears that the outer basin's floor to the east of Silali is higher than the floor to the west of the basin. This is possible because of the recent lava flows covering the area. Much of the magma that exited Silali basin, before subsidence, appears to have poured out more to the east of the basin than to the west. The lava flows are very evident from the satellite images presented in this paper.



Source: Geothermal Development Corporation- GDC-Kenya library.

Plate 5: A LIDAR image showing the crater and the fault lines within and around it.



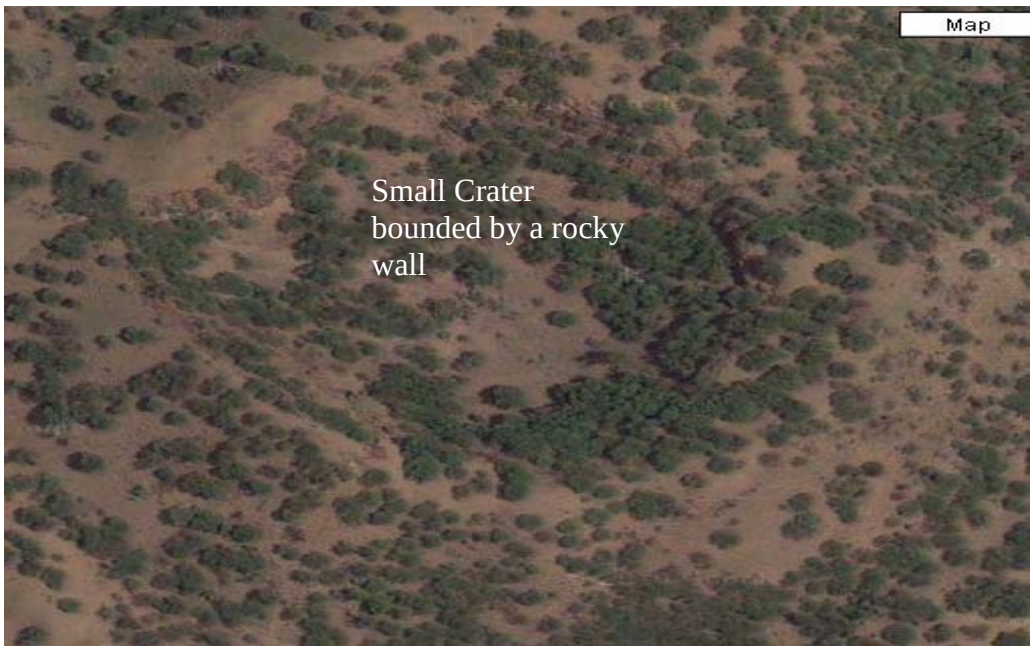
Source: Kipkiror, 2016.

Plate 6: A DEM (with elevations) showing Silali basin's (SB) hummocky terrain and morphology. The DEM also shows the outline of Silali's probable peak ring (R).

b) The basin's flat and hummocky floor

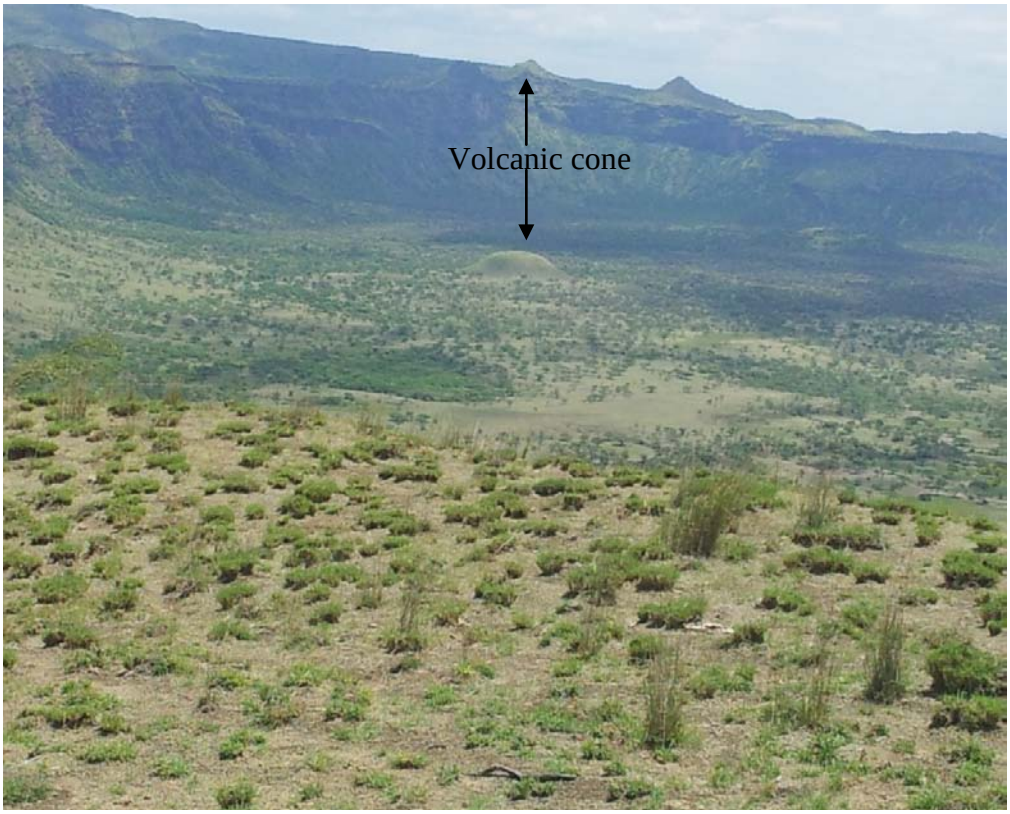
Silali basin's floor, like the floor of other Extra-Terrestrial Impact Craters (ETICs), is uniformly flat and hummocky. It is characterised by smaller circular craters, volcanic cones, pseudotachylites, ridges that are remnants of a possible peak ring and heaps of slumped soil and rock material.

Plate 7 showsone of the small craters within the Silali basin and like the Silali basin itself, the small crater has very steep walls and its floor is flat and hummocky. Plate 8 shows one of the most prominent volcanic cones within the basin.



Source: Google Earth maps.

Plate 7: A SPOT satellite image showing one of the smaller craters (mini craters) found within the Silali basin.

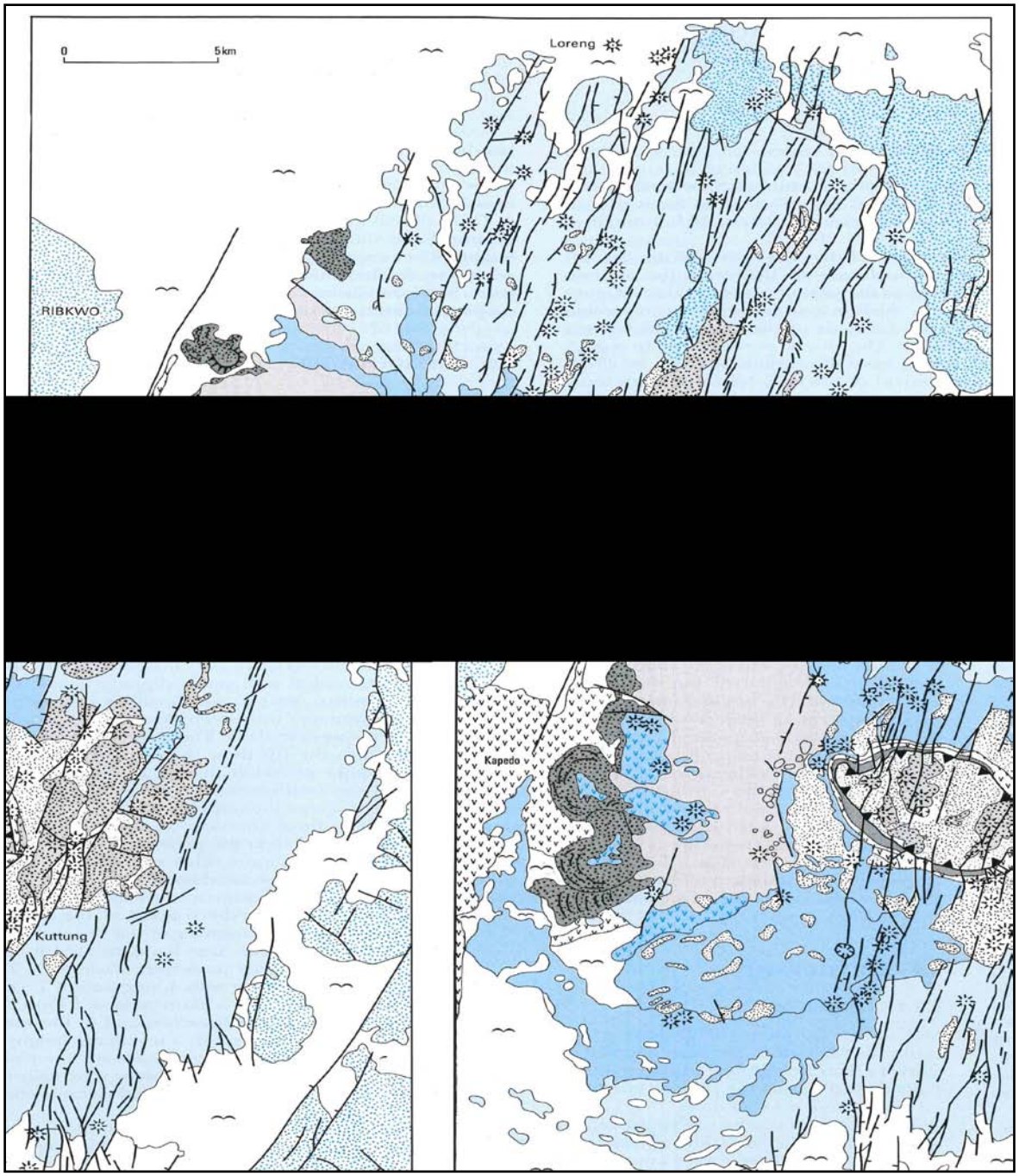


Source: Kipkiror, 2016.

Plate 8: A picture showing one of the cones found on the Silali basin's floor.

c) Silali's ring fracture structure

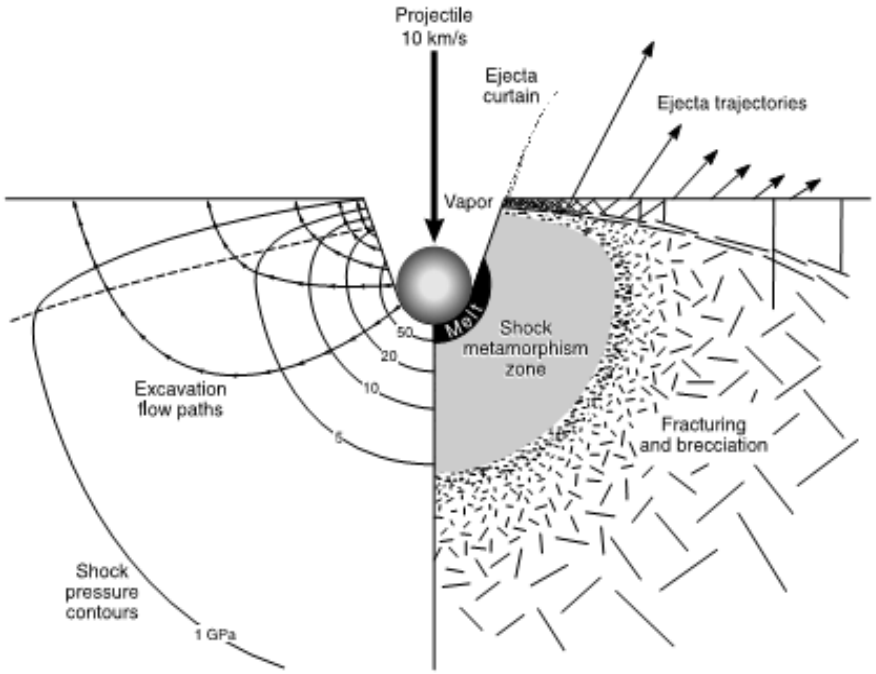
Subsidence does not completely explain the circular shape of Silali basin, especially if it is a product of a fissure eruption and not a vent type eruption. Fissures mainly build up volcanic shields and elongated domes, which in most cases do not have craters, let alone the 5-8kmwide crater formation of the Silali basin. The question that arises here is how the fissures that are responsible for the building of the Silali basin occurred in a concentric formation culminating into the formation of a near circular depression. Additionally, how these developed lithologically into a ring-like structure. The map below (Figure 4) of Silali area, provides evidence of fractures all around the basin that appear concentric in formation.



Source: Dunkley et al., 1993.

Figure 4: Simplified geological map of Silali basin, showing the basin's ring like structure and the fault lines cutting across the basin.

Although in some cases, caldera subsidence can cause ring structures like those found in Silali basin, due to doming effects, the caldera must be associated with a volcanic pipe/vent. Silali's ring fracture structure could be the product of an extra-terrestrial impact because; when a heavenly body falls on an area, it causes the area rock to fracture in a concentric manner. The fractures are the result of hypervelocity shock waves, which usually radiate outwards from the impact point at speeds of 10km/s or more (Therriault*et al.*, 2002). Further outward pressure can produce distinctive shock deformation effects (shattering and fracturing) in large volumes of unmelted target rock (Melosh, 1989).Figure 5illustrates how an extra-terrestrial impact results in concentric fracturing of rocks.

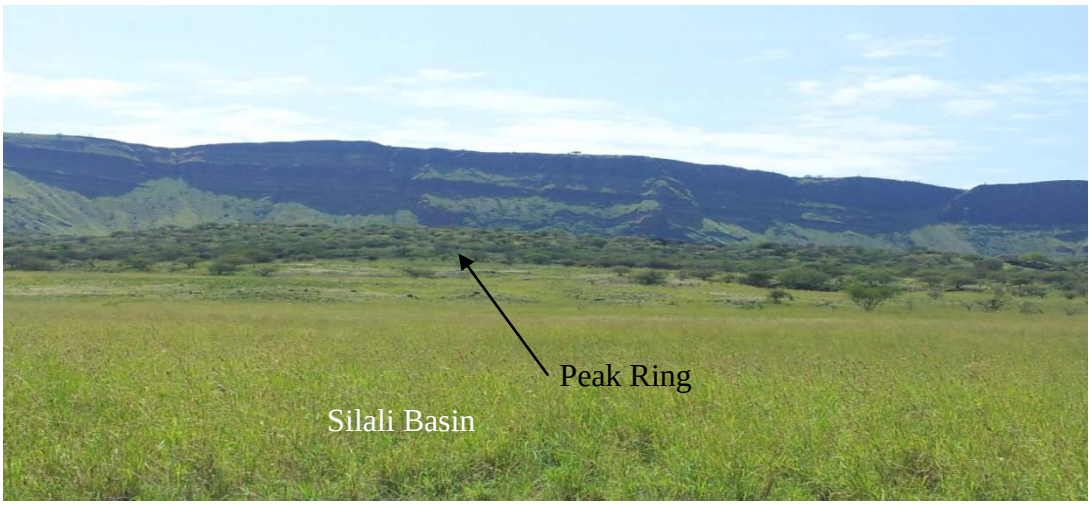


Source: www.lpi.usra.edu/publications.

Figure 5: A cross section of an ETIC showing the effects of shockwaves on target rocks (shattering and fracturing). GPa is Gigapascal that is measured in newtons/square millimetre (N/mm^2).

d) Silali Basin's upraised rim and Peak Ring

ETICs have upraised rims that mostly consist of proximal impact ejecta. The rim of an ETIC defines the circular shape of the ETIC and encloses the ETIC's wall. Notably, the walls of ETICs vary in height from their floors.A peak ring, on the other hand, is a concentric raised ridge that goes all around a complex crater. Notably, some complex craters/basins may have more than one peak ring and in other instances, a complex crater may develop a central pit (s)/depression(s) instead of a peak ring (s) (https://en.m.wikipedia.org and French, 1998). A peak ring forms when the initial (transient) deep crater floor rebounds from the compressional shock of impact, dragging impact eject a backwards into the basin. In some instances, though, a peak ring is formed when slumping material converges around an ETIC floor, as in the case of Silali basin and Tenoumer crater, Mauritania (French et al., 1970).Plate 9shows Silalibasin's raised walls and a ridge that may be a remnant of the crater's peak ring. Subsidence and slumping, in Silali basin, has raised the crater's rim, creating a steep wall that is about 300 m below the crater rim. Plate 10shows Silali basin's peak ring. It consists of a ridge ring that is broken in places.



Source: Kipkror, 2016.

Plate 9: A picture showing Silali basin's peak ring.

Source: Google maps.

Plate 10: A SPOT image showing Silali basin's crude peak ring (PR).

e) The basin's steep, slumped and stepped walls

ETICs are generally circular and their outer walls are rough with an overflow of proximal and distal ejecta. The immediate inner walls are steep, especially on the upper parts, due to slumping of materials and later denudation. The lower inner walls are gently sloping upwards (conically) due to melt material lining up the inner walls and the slumped or eroded materials that cover the melt.

Large ETIC walls collapse/slump more spectacularly giving rise to wall terraces (Melosh et al.,1999). According to Heiken and a team of other researchers, true complex craters contain terraces on their interior walls, a flat floor and a single peak or group of peaks in the centre of the crater floor (Heiken et al., 1991). For them, the interior wall terraces are products of landslides as evident in one of the craters on the moon called Copernicus (Heiken et al., 1991). Silali basin's walls could thus be products of subsidence, slumping and erosion. Plate 11 shows the basin's slumped walls while Plate 12 shows a slumped section of the basin's wall.

Source: Kipkiror, 2016.

Plate 11: A section of Silali basin's wall that is both stepped and slumped.

Plate 11shows the height of the basin's wall against an average human height. The slumping of the basin's walls may be an indication that the basin is still be in the process of subsiding, especially following the release of hot gases and steam from the basin's magma chamber.

From ground truthing, Silali basin's wall is stepped all around, though irregularly and this is ingrained in the basin's formation, as explained earlier. The basin's wall is also slumped all around, as can be seen in the ground pictures and satellite images presented in this paper.

Though slumped walls are associated with faulting, even in the rift valley where Silali basin is located, the slumping in Silali basin defines a circular basin and enhances the basin's circular morphology.

It is advisable that anyone desiring to climb down into and out of the Silali basin should do so with the help of a helicopter, especially if one has a heart or a breathing problem. This is because temperatures within the basin are high and the basin's walls are not only extremely steep but very rugged, making it possible for human exhaustion to easily turn fatal. Some of the rocks on the basin's wall are also loose and movable.

Source: Kipkiror, 2016.

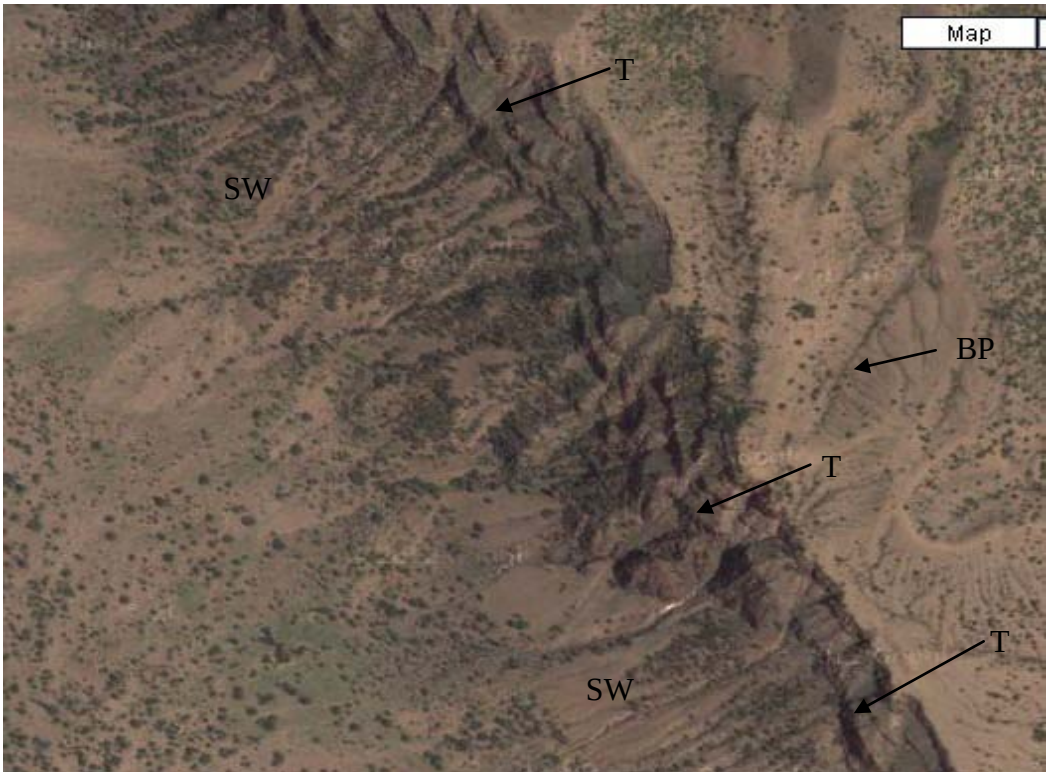
Plate 12: A picture showing more of Silalibasin's slumped inner walls (SW).

f) The basin's butterfly pattern of ejecta

Lichoro (2013) observed that there is absence of massive lava deposition on the flanks of Silali basin. There are no visible lava deposits on the basin's floor either and according to the book on the geology of the Maralal area 'the caldera walls have inner vertical drops of about 300m; they remain unbreached and the caldera is not infilled by a lava pool' (GOK, 1987).

As it is, the basin is surrounded by an 'apron of alluvium' which can be proximal ejecta or allochthonous materials, according to the study that bore this paper. Indeed, an explosive volcanic eruption is capable of depositing lots of dust around a crater and Silali basin's ejecta are like volcanic ash because they consist ofrock minerals and volcanic glass.This would suggest that the dust on the flanks of Silali basin is pyroclastic material erupted from the Silali shield. However, this is not the case because the dust does not have recent lava deposits on it.It is just loose dust, of non-specified shape, broken by huge rock blocks (hummocky ejecta and allochthonous material) in places. Volcanic ash also has vesicles and the ash particles display some distinctive shape in their looseness, such as being blocky, convoluted, vesicular and spherical or plate like (http://en.wikipedia.org/wiki/volcanic_ash).

Interestingly, the ejeta on Silali basin displays the butterfly pattern of spread that is common in some ETICs (https://en.m.wikipedia.org/wiki/ejecta). Plate 13, below, shows this butterfly pattern of ejecta spread.



Source: Google maps.

Plate 13: A SPOT satellite image showing terrace like features (T) on a part of the Silalibasin's eastern wall, a portion of the basin (SB), butterfly pattern (BP) of ejecta spread and slumped walls (SW).

V. Etic Associated Geomorphological Features

Extra-terrestrial impacts and impact cratering are responsible for many geologic processes, that in turn are the forces behind the formation of different geomorphological features, as stated by Thompson and Turk (1992), in their book on earth science.

In the case of Silali basin, an extra- terrestrial impact would be the seed for volcanicity in and around the basin, besides faulting and other modes of land transformation.

Volacnicity, in Silali, has led to the formation of volcanic cones, such as those found on the floor and walls of the crater, as seen in the pictures and satellite images presented. Mt.Paka, a huge edified cone on the same plane as Silali basin and to the south of Silali, may also be a product of Silali's impact. The magma that exited Silale basin, after impact, may have constructed Mt. Paka and other neighbouring volcanic cones, such as the black hills to the east of Silale, which are believed to be made of pure black glass (McCall and Hornung, 1972). This black glass may be impact glass.

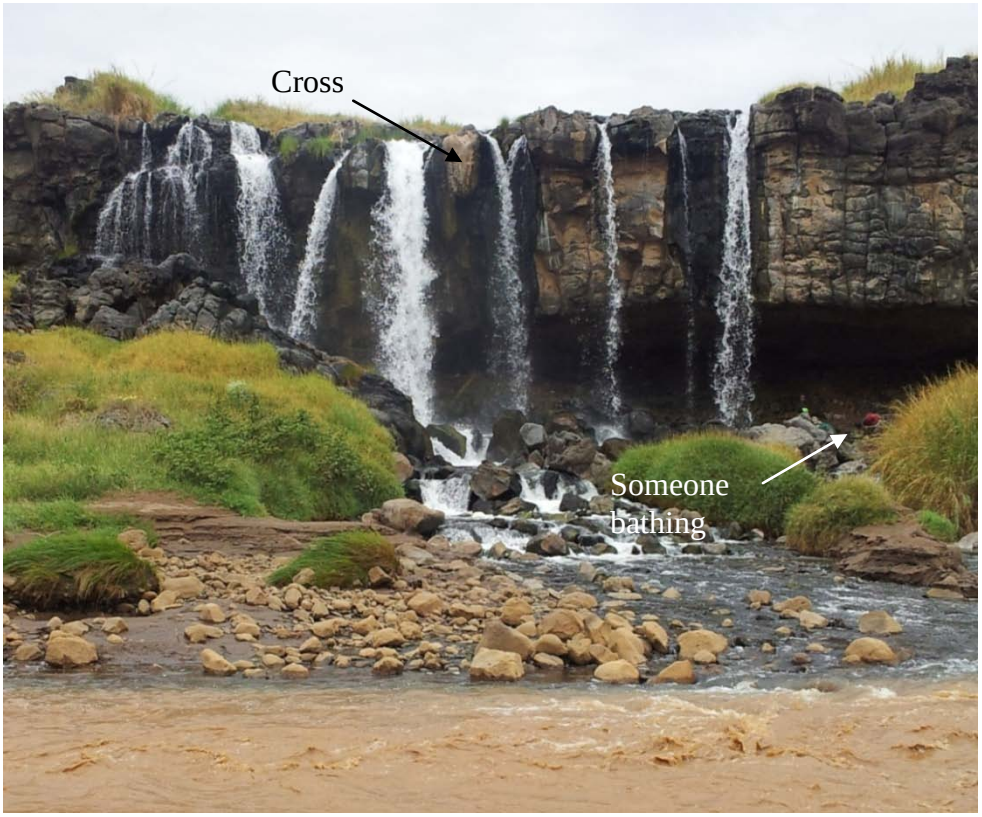
Faulting is prevalent within and around Silale crater and one of its main products is the Suguta gorge, in which River Suguta flows. A huge extra-terrestrial impact has all the potential that is adequate to move crustal rocks apart, leading to the creation of faults, some of which may criss-cross. While some of the major faults of Silali became conduits for the construction of huge volcanoes, the minor ones (fissures) provided avenues through which hot water and steam gushes onto the earth's surface, as occurs around the Silali basin. Suguta gorge, the caves, the lava flow and the sinkhole around Silali basin are fault associated features. Silali area is heavily faulted and it is a volcanic hot spot with unending volcanic capabilities.

On the outer basin, there are impact related rocks that have formed unique sceneries. Examples are the shatter cones near Chemolingot (Plate 19) and the slumped wall areas of the outer basin (Plate 20). Chemolingot is to the south of Silali basin, near Chemolingot town on the outer basin. Since shatter cones only form inside an impact crater, their presence in Chemolingot is a likely suggestion that the Chemolingot area is an extra-terrestrial impact area. Consequently, the outer basin could bea product of an extra-terrestrial impact cratering. However, more research on the outer basin is advised.

Plates 13 shows a part of the steep Suguta River gorge. Plate 14 shows the hot water falls on the eastern wall of the Suguta gorge and Plate 15 shows the area that is the source of the hot springs that feed the hot water falls.

Source: Kipkiror, 2016.

Plate 13: A picture showing a part of the steep walls of the Suguta River valley, which may pass for a gorge.



Source: Kipkiror, 2016.

Plate 14: A picture showing the hot water falls of the Suguta River, near Kapedo.

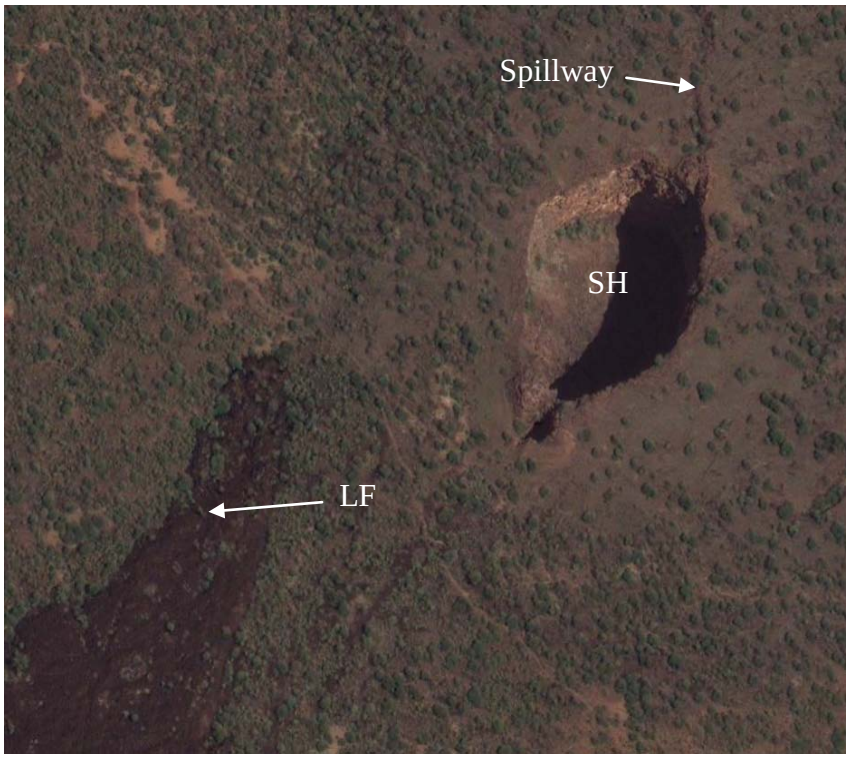
Near the heavier water fall, on the wall, there is an engraving of the cross as known to Christians. This may have been done by missionaries who had built a church at Kapedo. They are no longer in the area.

The picture also shows someone bathing at the water falls.

Source: Kipkiror, 2016.

Plate 15: A picture showing the plain land above the hot water falls, where hot springs are found, on the outer basin.

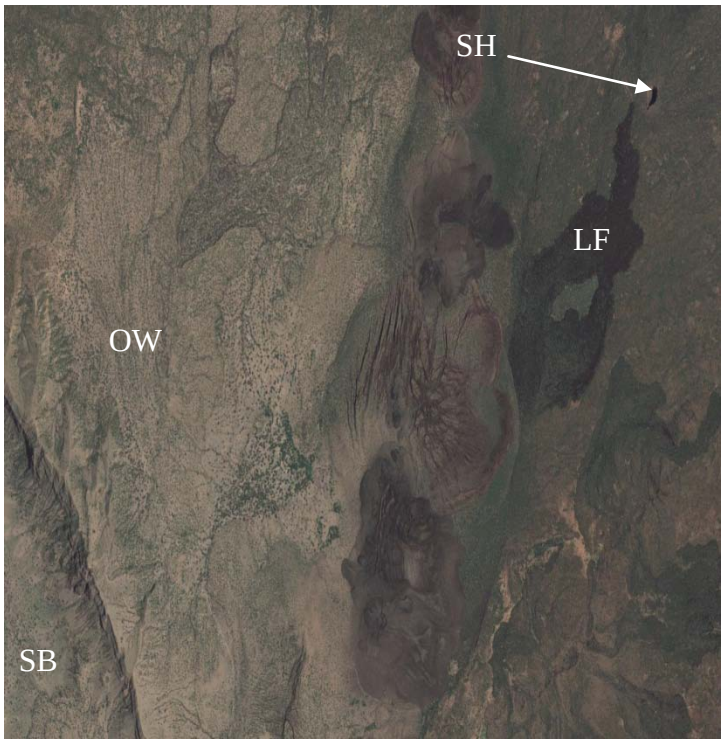
To the northeast of Silali basin, there are other spectacular geological features, most of which are visible from the satellite images presented in this paper. Examples of these features include a sinkhole and a mass of dark volcanic rock that seems to dip towards the NE of Silali. Evidence of this is the direction of water flow from the volcanic rock. When it rains, overland flow, from the bare volcanic rock, runs north-eastwards towards the sinkhole. When the sinkhole fills up, its spilled water runs further north-eastwards along a valley that appears dry. Notably, the sinkhole does not retain any water for it appears dry on the SPOT satellite image (Plate 16) and has vegetation. There could be more sinkholes around Silali basin.



Source: Modified from www.Google.com.

Plate 16: A SPOT image showing the lava flow (LF), the sinkhole (SH) and the sinkhole's spillway more clearly.

The sinkhole is found to the northeast of Silali basin and the Lava flow starts right at the base of the north-eastern wall, flowing outwards. This flow can be seen from the rim of the eastern wall.



Source: Modified from www.Google.com.

Plate 17: A SPOT image showing the sinkhole (SH) and lava flow (LF), Silali basin (SB) and Silali basin's outer wall (OW).

The features shown on Plate 17 are found to the east and northeast side of the Silali basin. It is the side of the basin where massive lava outpourings appear to have occurred, near the base of the basin's wall. Though the area was inaccessible for a close study, due to insecurity as a result of cattle rustling in the area, the image clearly shows the sinkhole and the lava flow, which are shown by Plate 16. Plate 17 also shows the Silali basin itself, its stepped inner walls and the basin's outer wall on the eastern side. It is important to note the rippling away appearance (butterfly pattern) of the rough dust covering the basin's outer wall (ejecta). This is a characteristic of the dust that could not be seen clearly while standing directly on it.

In ETICs, 'ejecta are layered thickly at the crater's rim and thin to discontinuous at the blanket's outer edge' (www.google.com). This may probably be because of the decompression wave that follows an impact event, which causes impact ejecta to shrink backwards into the crater.

Source: Kipkiror, 2016.

Plate 18: The entrance (E) of one of the large caves found near Natan market, on the plains south of the Silali basin.

The caves could have formed due to the widening up of existing faults around Silali basin, following Silali basin's possible impact.

Source: Kipkiror, 2016.

Plate 19: The cave on Plate 18 from the inside.

Source: Kipkiror, 2016.

Plate 20: A picture showing shatter cones (SC) around Chemolingot area of East Pokot. These compare well with the shatter cones at Beaverhead impact structure, Montana, shown by Plate 21.

Source: www.impact-structure.com/impact-rocks-impactites/the-shatter-cone.

Plate 21: Assemblage of massive shatter cones with sizes of up to one meter, at Beaverhead impact structure, Montana.

Source: Kipkiror, 2016.

Plate 22: A picture showing asection of the slumped walls of the outer basin; to the southwest of Silali basin.

VI. Conclusion

Silali basin can be said to be a probable ETIC that is rich in volcanic features. Old and recent volcanicity has created many volcanic features in the basin to an extent that the basin can easily pass for a volcano. However, Silali crater may not be considered a volcano because it is not found at the top of a volcanic edifice the way summit craters are found at the top of volcanic cones. The lack of a cone shape in the raised area surrounding the basin is clearly visible, even from the side of the basin captured by Plate 23.

Source: Kipkiror, 2016.

Plate 23: A picture showing the outside western walls of the Silali basin, in the background, at a distance.

Besides the basin's ETIC morphological characteristics, Silali basin has many other ETIC characteristics that include; the basin's ETIC related geology and rock chemistry, the basin's geophysics and the many geomorphological features that are associated with the basin. In Conclusion, Silali basin seems to have formed, as an ETIC, not only on an area of volcanic rock but on a volcanic shield; through an extra-terrestrial impact and later, subsidence. The basin also bears the morphological classic hallmarks of an impact crater, which include slumped walls inside the rim, rough irregular crater floor, stepped walls, shatter cones, polimict breccia, circular morphology and hummocky deposits (ejecta) outside the basin- among other features.

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Competing Demands on Land: Implications for Carbon Sink Enhancement and Potential of Forest Sector in Karnataka to Contribute to the INDC Forest Goal of India

By Indu K Murthy, Vinisha Varghese & K V Devi Prasad
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Introduction- The land is a critical resource that provides food for a burgeoning population of about 7 billion, supports livelihoods and is important for sustainable development. Growing demands for food, feed, fuel, fiber, and raw materials create local as well as remote pressures for land-use change (Lambin and Meyfroidt, 2011). The cascade of outcomes resulting from these demands is complicated by urbanization and globalization (Barles 2010; Kissinger and Rees 2010). Climate change is an additional stress that will exacerbate the pressure on land as there is a conflict between goals related to production and those related to conservation and climate change mitigation. In light of this, the Sustainable Development Goals of the United Nations (UNDP, 2015) have recognized the need for integration of human development and the environment as mutually reinforcing development goals.

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Indu K Murthy,[ρ] Vinisha Varghese [α,*] & K V Devi Prasad [ρ]

I. Introduction

The land is a critical resource that provides food for a burgeoning population of about 7 billion, supports livelihoods and is important for sustainable development. Growing demands for food, feed, fuel, fiber, and raw materials create local as well as remote pressures for land-use change (Lambin and Meyfroidt, 2011). The cascade of outcomes resulting from these demands is complicated by urbanization and globalization (Barles 2010; Kissinger and Rees 2010). Climate change is an additional stress that will exacerbate the pressure on land as there is a conflict between goals related to production and those related to conservation and climate change mitigation. In light of this, the Sustainable Development Goals of the United Nations (UNDP, 2015) have recognized the need for integration of human development and the environment as mutually reinforcing development goals.

The main goal of the forestry sector in India is to meet the current and projected biomass demands sustainably and conserve the existing natural forest for biodiversity and watershed protection (Ravindranath et al., 2001). India has a long-term goal of enhancing its forest cover to 33% of the geographic area (MoEF, 1999). It has the Forest Conservation Act, 1980, which regulates the conversion of forest land to non-forest uses, and further, there is a ban on logging in reserve forests (Ravindranath and Hall, 1994). Thus, the only option for meeting India's biomass demands is through afforestation and reforestation, coupled with sustainable plantation forestry management practices. Added to this demand and need is creation of carbon sinks to mitigate climate change, as indicated in the Intended Nationally Determined Contribution (INDC), submitted to the UNFCCC by the Government of India. Karnataka is one of the forested states in India and its potential to contribute to the INDC goals and targets is assessed by estimating the mitigation potential of land-based sectors. This study makes a model-based assessment of mitigation potential.

The state of Karnataka, with a total land area of 1,91,791 sq. km accounts for 5.83% of the total area of India and as per the 2011 Census, the state's population was approximately 61 million with a population density of 319 persons/sq. km. Karnataka is prone to disasters due to cyclones and rainfall and is highly susceptible to floods, droughts, and coastal erosion. Land-use strategies will have implications for food security, self-sufficiency, the economy, and the contribution to climate change will be profound. In this study, an assessment is conducted to elucidate the following:

1. What are the trends in area under different land uses in Karnataka?
2. What land categories, and to what extent is land potentially available for climate change mitigation through forestry?
3. What is the mitigation potential of forest sector in Karnataka and its percentage contribution to INDC?

II. Trends in Land use in Karnataka

Land use in Karnataka, like elsewhere in the country, is driven by human and livestock pressure, availability of irrigation facilities, expanding urbanization, industrial growth, diversion of forest land to other uses, the law of inheritance, and natural calamities such as flood and drought. In the following sections, the current land use pattern and trends in land use in Karnataka are discussed. Trends in area under different land use categories help gain an understanding of the dynamics of land use over the decades, which gives a broad understanding of the direction of change in the future as well.

a) *Trends in the Area under Agriculture Land Categories in Karnataka*

Table 1 presents the area under different agriculture land categories for the period 1960-61 to 2012-13. The percentage area under crops was highest in 1990-91, after which, it shows a declining trend.

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i) Land under cultivation: The gross cropped area recorded in 2012-13 was about 12 Mha (Table 1) as reported by the Agricultural Department and the Directorate of Economics and Statistics (2012-13). The area increased marginally from 10.39 Mha in 1960-61 to 11.75 Mha in 2012-13, only a 1.35% increase over more than 50 years. The net sown area has decreased over the long-term period of 1960-61 to 2012-13 and even during the last decade, by about 3%. Over this period, the area sown more than once has increased by almost 83% while the cropping intensity has increased from 103.31% to 120%, an increase of 16% (Figure 1). Further, it is to be noted that although the population of Karnataka has been increasing steadily, the net sown area has remained almost stable (Figure 1).

An analysis of the area under cereals, pulses and oil seeds shows that the overall area under cereals has reduced by about 26%, and area under pulses and oil seeds have also decreased by 37% and 40%, respectively (Figure 2).

ii) Land not available for cultivation: The trend of land put to non-agricultural use is an important indicator of the extent of urbanization if it does not involve afforestation and reforestation activities. As seen from Figure 3, the land put to non-agricultural use increased significantly during the period 1960-61 to up till the year 2000-01. In the past decade (2002-03 to 2012-13), the increase is only 8%. The land area under the other category - barren and uncultivable has stabilized over the past decade.

iii) Uncultivated land excluding fallow land: The area under permanent pastures saw a sharp decline before early 2000s (Figure 3). The decline in area under permanent pastures could be because of agricultural and industrial expansion and lesser importance given to grazing land when compared to land for food crops (FAO, 2012). The area under permanent pastures and other grazing land in 2013 is 48% lesser than the area reported during 1960-61 (Figure 3). However, in the recent past – over the past decade, this area has stabilized.

iv) Fallow land: The area under current fallow land category although fluctuating, shows an overall increasing trend (Figure 4).

From 0.6 Mha in 1960-61, current fallow land increased to an all-time high of 1.83 Mha in 2002-03 (2.05% increase in area). Post this period, the area under current fallow land showed a decreasing trend till 2010-11. During the 3-year period of 2010-11 and 2012-13, there has been an increase of about 52% in the area under current fallow. The other fallow land category shows a marginal increase of about 4% during the decade of 2003-03 to 2012-13.

It is evident from the trends in the area under agriculture land use category that the land under cultivation i.e., the net sown area has decreased over the decades. Further, the area under cereals, pulses, and oil seeds have all decreased. Over this period, an increase in cropping intensity is recorded, which is in concurrence with an increase in area irrigated in the state. This period also witnessed an increase in the area under the fallow land category, an indication of more and more land being left uncultivated.

- Trends in the area under rainfed agriculture and crop yields in Karnataka: The area under rainfed agriculture in Karnataka is 68%. The presence of rainfed/dryland regions is compounded by frequent climatic aberrations and not so frequent but devastating floods. Failure of technology to meet these challenges has resulted in low average productivity and consequently, low income. Rainfed areas confront harsh environment and economic hardship. The basic problem of rainfed areas is one of a vicious cycle that starts with low water availability, degradation of natural resource base because of poor management, which ultimately results in low productivity leading to over-exploitation of the existing natural resources causing further degradation.

It can be seen from Figure 5 that the area under majority of the cereals such as Jowar, Ragi, Maize, Bajra and, Minor Millets is predominantly rainfed. In the case of pulses, the area is almost completely rainfed, except for a small percentage of area under Bengal Gram. Similarly, oil seeds are also grown principally as a rainfed crop.

Figure 6 presents the yield of rainfed crops – cereals and pulses. In the case of cereals, the yield per hectare is consistently low in the rainfed regions, as compared to irrigated regions. There is no comparison in the case of pulses as they are predominantly rainfed.

A close look at the area under cereals, which are predominantly rainfed shows that not only the area but the yield of cereals such as Ragi, Jowar and, Bajra have declined over the decades (Figure 7). In the case of pulses, the area under Green Gram, Horse Gram and, Black Gram have reduced substantially and, their yields are variable and, in the recent decades, a decline is recorded (Figure 7).

- Comparative analysis of yield of major rainfed crops with states recording highest yield in India: An analysis of the trends in yield of minor millets and some pulses shows that the yield per hectare is very low at 0.5 to 1 t/ha. Further, there has been no significant increase in yields over the last two to three decades, and in the case of Ragi, the yields have even declined. Further, the yields of these rainfed crops are highly variable across the decades. Comparison of the yield of some of the

major crops of Karnataka with average yield of states reporting highest yield in India shows that Karnataka has a large gap in yield, particularly rainfed crops such as Jowar, Bajra, Tur and Soybean (Table 2).

While production of food grains across India is steadily increasing, in Karnataka, the production of food grains is not only highly fluctuating but also has declined substantially over the decades (Figure 8). It is evident from the analysis that there are issues concerning food production in Karnataka, as evident from the decreasing area and declining yield of cereals and pulses. There also exists a huge yield gap when compared with the highest yield reported for the different crops, particularly in the case of cereals. There has also been stagnation in crop yields both in the case of rainfed and irrigated crops. All these point to the fact that there is no great demand for land for agriculture purposes and that it is possible to sustain food production even without expanding land under agriculture, as indicated by the increase in cropping intensity over the decades.

b) Trends in Area under Forests in Karnataka

Karnataka has 41.97 Mha of forest and tree cover, which is 21.88% of the state's geographical area (FSI, 2015). During the period 1983 to 2015, the area under forest increased from 30.30 Mha in 1983 to 41.97 Mha as reported by the State Forest Department in 2015, which is a 43.09% increase in area under forests. During the 1986-2003 period, reforestation has been significant and more than deforestation, resulting in an overall increase in forest cover. However, industrial plantations do not have high biodiversity as did the natural forests, but they are often planted on degraded lands and therefore represent an improvement in vegetation cover over what has existed for the past few decades (Virk and King, 2006).

The State of Forest Reports published by the Forest Survey of India (1987–2015) categorizes forests based on crown density as (i) Very dense forest – All lands with tree canopy density of 70 percent and above; (ii) Moderately dense forest – All lands with tree canopy density of 40 percent and more but less than 70 percent, and (iii) Open forest – All lands with tree canopy density of 10 percent and more but less than 40 percent. Figure 9 presents the trends in area under forests across the crown density classes. Dense forests saw an increase from 1987 to 2001. The Open Forests initially saw a nearly 50% decline from 1987 till 2001 where it increased again. Post-2001, the area under open forests, has been continuously increasing.

Area under forests in Karnataka has stabilized. But, there is degradation of forests, as indicated by the decrease in area under dense forest cover between 2001 and 2015 and the consequent increase in area under open forest.

c) Trends in Area under Wastelands in Karnataka

Wasteland in India is described as ''degraded land which can be brought under vegetative cover with reasonable effort (and cost), and which is currently under-utilized or land which is deteriorating for lack of appropriate water and soil management or because of natural causes''(NRSC, 2011). Wastelands are divided into two categories namely; (i) cultivable wastelands comprising various land categories such as shifting cultivation areas, degraded forestland, degraded pastures and mining wastelands which can be brought under tree cover, and (ii) uncultivable wastelands. The extent of wastelands in Karnataka is 1.44 Mha, accounting for 7.53% of the geographical area (NRSC, 2011).

The area under wastelands in Karnataka has marginally decreased during the period 1986 to 2009. The reduction in area under wastelands could be due to various wasteland reclamation and watershed development projects being implemented in the state. However, there remains 1.44 Mha of wastelands, with many of the wasteland categories potentially available for forestry mitigation options.

d) Summary of Analysis of Trends in Land Use

The key findings of this analysis include:

- The area under agriculture is decreasing but cropping intensity is increasing.
- The area as well as yield of rainfed crops has decreased substantially and there exists a large yield gap in cereals and pulses, compared to states reporting highest yields in India.
- Fallow land area is increasing – indicating lesser area being cultivated over the years and failure of agriculture, particularly rainfed agriculture in Karnataka.
- Area under forests has stabilized but there is pressure on forests, as indicated by the increase in area under open forest.
- Area under wastelands show a net marginal reduction in area, and the state is undertaking afforestation on these lands over the decades.

This analysis gives us an indication on the demand for land for multiple purposes and the extent of land that could potentially become available for climate change mitigation purposes, to implement forestry mitigation options on these land categories.

III. Need for Tree and Forest Plantations on Marginal Croplands

It is evident from the discussion in the previous section that significant area under croplands in Karnataka is rainfed with very low productivity. The return on investment and labor on such lands to farmers is meager and therefore, putting such lands under

multifunctional tree plantations or agroforestry systems or fruit orchards is an option.

Agroforestry systems are designed and managed for maximizing positive interactions between tree and non-tree components. The fundamental idea behind agroforestry is that trees are an essential part of natural ecosystems, and their presence in agricultural systems will provide a range of benefits. Agroforestry is also increasingly gaining recognition as a tool for mitigating climate change and building resilience in farming communities to cope with climate change impacts.

Cnversion of marginal croplands with low productivity to tree plantations will help rehabilitate nutrient-depleted cropland soils, promote carbon sequestration, and improve livelihoods (Murthy et al., 2016). Tree farming on marginal croplands can increase the productive potential of land, increase the efficiency of irrigation water use, contribute to climate change mitigation, and rural incomes (Djanibekov *et al*., 2012; Khamzina *et al*., 2012; Castro *et al*., 2012). Further, such tree plantations have been reported to serve as adaptation measures during crop failure, particularly in rainfed dryland agriculture areas (Kattumuri *et al*., 2015).

Agroforestry is thus one of the key strategies that will help design multifunctional landscapes that can deliver multiple ecosystem services. Given its potential to contribute positively to climate change mitigation as well as adaptation synergistically, it is gaining importance as a land-based mitigation option and as a reliable coping strategy or adaptation measure, particularly in regions with rainfed agriculture dependent farming communities, because of the potential of agroforestry to generate income during drought or rainfall deficit years.

India is one of the pioneering nations to have formulated an agroforestry policy. India's National Action Plan on Climate Change has also included agroforestry as one of the mitigation and adaptation measures. In this context, considering agroforestry for the greening of marginal croplands in Karnataka has multiple co-benefits in addition to being a climate change mitigation-adaptation measure.

IV. Demand for Land in Karnataka: Implications for Forestry Mitigation

The population in Karnataka during 1901 was about 13 million, and it has grown exponentially to about 61 million during 2011. The net addition in population over the decades has steadily increased during this period. However, from 1981-1991, the decadal growth rates have shown a declining trend, which implies that although the population is steadily growing, the rate of growth is on the decline. The increase in population has implications for food security as well as infrastructure and settlement expansion and development. Similarly, when the forest land category is considered, the issues are forest degradation, encroachment, and conversion of forest for non-forestry purposes. Wasteland reclamation has been underway for decades. Despite such aggressive measure, there is still area under wastelands, requiring reclamation. In the following section, the pressures and demands on agriculture land, forestland, and wasteland are discussed, and finally, their implications for land availability for forestry mitigation are highlighted.

- *Agriculture land:* Discussions in Section 2 highlighted decreasing area under agriculture in India and the yield gap, particularly concerning cereals and pulses grown in Karnataka. Section 3 highlighted the need for promoting tree crops on the marginal croplands, given the returns for investment and labor to the farmer under the current conditions is meager. Further, increase in area under agriculture, population, and per capita income are not significantly corelated (R^2 = 0.25 and 0.35, respectively). also, there is potential to increase food production in currently cultivated areas to bridge the yield gap that exists. This could help meet the food demands of a growing population, rather than expanding the area under agriculture.
- *Forestland:* The overall area under forests in Karnataka is increasing, but the transition across tree crown cover classes is a cause of concern as dense forests are dwindling, and the area under open forests are increasing. This requires measures to halt degradation and promote conservation of the existing forests.
- *Wastelands:* There is a significant area under wastelands, requiring reclamation. There are also potential alternate uses such as land required for infrastructure development, for wind and solar projects, and road development.

Competing demands for the land include land needed for infrastructure development with urbanization and other developmental needs. The total urban population of Karnataka is projected to be 35.14 Mha by 2025, which will constitute about 42.29% of the total population. This would require an additional 2.96% of the total geographical area to support the growing population (GoK, 2009). The land requirement for urban use in Karnataka is estimated to be 0.57 Mha by the year 2025, the estimated additional land requirement to be 0.14 Mha. However, what is of consequence here is the fact that area under urban and infrastructure in Karnataka is only about 7.5% of the geographic area and has not undergone much change over the decades.

The area under settlements is only about 12%, and the growth in this land category has been only about 0.8% per annum during the period 1995 to 2010.

Thus, the demand for land for urbanization and infrastructure is unlikely to limit land available for forestry mitigation. Infact, urbanization could be accompanied by greening programs such as the establishment of parks, gardens, multi-rows of avenue trees to have >10% tree cover, qualifying them as 'Forest'. Even the Greening India Mission, recognizing the importance of greening urban areas, has a sub-mission for peri-urban areas.

As a progressive state, Karnataka envisionsed job-oriented, inclusive economic growth through sustainable industrialization and accelerated urbanization. These transitions are likely to increase the demand for resources and energy significantly. Promotion of renewable energy to meet the energy demands of the state is given prominence by Karnataka as evident from formulation and rolling out of renewable energy policy at the state level. These again place demands on land. In this section, two such renewable energy sources – solar and wind power, and the demand for land for these are discussed.

Solar power: Karnataka is among the states with the highest consumption of electrical energy with an annual consumption of 36,975 million kWh (2010-11). Per capita, annual consumption is around 604 kWh and despite a total installed plant capacity of 13,490 MW, Karnataka is an electrical energy deficit state. Karnataka currently has a 6 MWp grid interactive system and 29.41 kWp capacity stand alone solar power plants. The state receives an annual average solar insolation of 5.55 kWh/m^2/day (Ramachandra, 2003 & 2011). It is one of the states with good solar potential and favorable government policies towards solar energy utilization. Ganesh and Ramachandra (2012) assess the potential for generating solar energy from wastelands and estimate the wasteland requirement for the generation of 42,233 MU to be 2% of the total area under wastelands, which is 26,061 ha.

Wind power: A study by CSTEP (2014) analyzing the key green growth opportunities for the state outlays increasing the energy efficiency in industry, reducing T & D losses, intensifying public transport, and generating more electricity from wind power as the options. The study analyses the land requirement of the power sector and concludes that wind power could increase land requirement primarily because of 3 GW of additional installed capacity of wind (from 8 GW in BAU to 11 GW). The estimated land requirement for the generation of wind power as a source of renewable energy is 0.04 to 0.19 Mha and 0.05 to 0.25 Mha for windmills of 80 m and 120 m hub, respectively. This is an important strategy in the light of the INDC, wherein increasing the installed capacity of wind energy to achieve a target of 60 GW by 2022 from the current capacity of 23.76 GW is one of the targets.

It is clear from the discussion above, there will be population increase and therefore demand for development. However, trends in the past show that this demand is not likely to place immense pressure on land. Given this understanding, land availability for an emerging demand on land – climate change mitigation is analyzed.

V. Assessment of Forestry Mitigation Potential in Karnataka

The overall methodological approach and framework for the assessment of mitigation potential are presented in Figure 10.

a) Scale, Land Categories and Area Considered for Assessment of Forestry Mitigation Potential

The scale of assessment pertains to both spatial and temporal. In this study, the spatial scale of assessment is the state of Karnataka. The temporal scale of assessment is one that coincides with the INDC commitment period of 2016-2030.Three key land categories are considered, to be potentially available for implementing forestry mitigation options; they include forestland, wasteland, and agriculture land sub-categories. Table 3 presents land category-wise area considered for assessment.

i) *Forestland:* The forests in Karnataka are under pressure as indicated by the decrease in area under dense forest cover between 2001 and 2013 and the consequent increase in area under open forest. In all, 3.44 Mha of forestland, spanning 2.018 Mha of moderately dense forest and 1.418 Mha of open forest are considered for this assessment for the purposes of conserving carbon sinks as well as enhancing the carbon sink capacity of forestland category.

ii) *Wasteland:* Wastelands are 'degraded lands which can be brought under vegetative cover with reasonable effort (and cost), and which is currently under-utilized' (NRSC, 2011). The wastelands are categorized into 23 categories, of which only 15 categories are distributed in Karnataka (NRSC, 2011). For this assessment, wasteland categories including, land with dense and open scrub, under-utilized/degraded forest – both scrub dominated and agriculture, mining wastelands, and gullied and ravinous land and riverine and coastal sands are included. This spans a total area of 1.31 Mha.

iii) *Agriculture:* There are several sub-categories of land under agriculture. Among these sub-categories, the assessment considers permanent pasture and grazing land, long fallow lands and marginal croplands, which are currently under low productive agriculture with meager returns on investment and labor, and which could benefit from growing trees or promoting multi-functional forestry. The total area

considered for forestry mitigation in agriculture land category is 3.20 Mha.

b) Mitigation Scenarios and Models for Assessment of Forestry Mitigation Potential

The mitigation scenarios considered for this assessment are "Technical Potential" scenario and "Economic Potential" scenario. Under the "Technical Potential" scenario, all lands potentially available under forestland, wasteland and, some of the agriculture land sub-categories are included for the assessment (Table 3). In all, 7.94 Mha of land encompassing wastelands, forestland, and agriculture land categories, is considered. Of the total 7.94 Mha, 43% is forestland category, 40% is agriculture, and the remaining is wasteland.

In the "Economic Potential" scenario, competing demands for urbanization and infrastructure development such as renewable energy projects of solar and wind are accounted for in the wasteland category.

- In the agriculture land category, the area under both long fallow and permanent pasture land is included, but all area under marginal cropland is excluded, considering the shift from annual crops to tree farming may require awareness building and institutional mechanisms.
- In the forestland category, only 50% of the total land available under the two forest cover classes – moderately dense and open forests are considered, factoring in the limited organizational capacity of forest personnel that may currently exist in the state.
- The total area considered for forestry mitigation under the "Economic Potential" scenario is 3.86 Mha (Table 6), including 0.91 Mha (24% of total area) of wastelands, 1.65 Mha (39% of total area) of forestland and 1.45 Mha (38% of total area) of agriculture land categories.

Model: PROCOMAP model is used in this study. PROCOMAP model scored the highest when a decision criteria framework was applied.

It is clear from Section 4 that there is a demand for land for multiple purposes, particularly agriculture, urban infrastructure, and generation of renewable power such as wind and solar. These competing demands are taken into consideration to obtain area potentially available for mitigation under the "Economic Potential" scenario. The rationale for the same is as follows:

- Demands for infrastructure and power generation place direct demands on the wasteland category. These demands require about 0.44 Mha and these could be met from the wasteland area of 1.3 Mha, leaving a total of about 0.864 Mha for forestry mitigation activities.
- When agriculture is considered, it is to be noted that the area under agriculture has not increased in proportion with population (R^2 = 0.25) nor has it done so with increasing per capita income (R^2 = 0.35) over the decades. Further, there is potential to increase food production in currently cultivated areas to bridge the yield gap that exists, which could help meet the food demands of a growing population. Based on an assumption that an increase in extent of area under agriculture is not a path that Karnataka is likely to follow, long fallow (currently uncultivated for long periods) and degrading pasture lands are considered. Additionally, a percentage of the marginal croplands which are under low-productive agriculture is also considered, without compromising on food production demands of an increasing population. Further, agro forestry as a forestry option will help promote synergistically the twin goals of mitigation and adaptation, in addition to improving soil fertility and improving livelihoods.
- Forestland category, despite conservation and aggressive afforestation by the Karnataka Forest Department, is experiencing degradation. This land category needs to be protected for maintaining, increasing, and improving carbon stocks.

Thus, under the "Technical Potential" scenario, all land available under the three land categories, without considering the competition for land, are potentially available. In the "Economic Potential" scenario, the competing demands on land are considered, and land apportioned for alternate uses before land availability for forestry mitigation activities is assessed. In this scenario, economic incentives are envisaged to promote forestry along with appropriate policies and forestry practices.

VI. Mitigation Potential Estimates for Forestry Mitigation Scenarios and Options

The mitigation potential of forestry options for the three land categories in Karnataka - forestland, wasteland, and agriculture is estimated. The model was run for each of the land categories and sub-categories, and for the identified mitigation option. There were two runs to estimate the mitigation potential under "Technical" and "Economic" Potential scenarios

a) Mitigation Potential Estimates

The forestry mitigation potential estimates per hectare, incremental as well as cumulative up till 2050 are presented in this section. In Figure 11, land category-wise carbon mitigation potential under baseline and mitigation scenarios – corresponding to the technical potential and economic potential land area (scenarios) are presented.

As can be seen from Figure 11, the aggregate carbon flow under the mitigation interventions during

2015-2050, for the three land categories considered for mitigation assessment is highest on forestland, followed by agriculture lands and finally wastelands. This is because, on the forest lands, there is substantial baseline carbon stocks which are conserved and (or) enhanced through protection in the case of moderately dense forests or enhanced through natural regeneration on open forests. Wastelands, on the other hand have very poor soil quality and low baseline biomass, therefore leading to slower rates of carbon accumulation over the years.

Table 4 provides the baseline, mitigation, and incremental mitigation potential estimates for the different forestry mitigation options for every 5-year interval spanning 2015 to 2050. The baseline assumed for all land categories and forestry mitigation options is static. It is evident from Table 4 that the highest mitigation potential is realized on forestlands (forest protection and natural regeneration options), followed by agriculture lands (agroforestry) and then finally wastelands (afforestation option).

By 2030, which is the NDC target year, the overall mitigation potential achieved, considering all the options is 2887 Mt CO_2-e, which increases to 3572 Mt CO_2-e by 2050. Maximum mitigation potential of 1452 Mt CO_2-e is realized through forest protection option, followed by agroforestry (646 Mt CO_2-e), natural regeneration (615 Mt CO_2-e) and afforestation (173 Mt CO_2-e) options. Table 5 provides mitigation potential estimates for the different forestry mitigation options under the "Economic Potential" scenario. By 2030, highest mitigation potential of 692 Mt $CO_{2\text{-}e}$ is achieved through forest protection option, followed by agroforestry (321 Mt $CO_{2\text{-}e}$), natural regeneration (308 Mt $CO_{2\text{-}e}$), and afforestation (122 Mt $CO_{2\text{-}e}$) options. By 2030, in the "Economic Potential" scenario, the mitigation potential of all options together is 1341 Mt $CO_{2\text{-}e}$ and this increases to 1650 Mt $CO_{2\text{-}e}$ by 2050.

Between the two scenarios, by 2030, the realized mitigation potential is about 50% lesser in the "Economic Potential" scenario, as compared to the "Technical Potential" scenario, area is about half of what is considered in the "Technical Potential" scenario.

b) Mitigation potential per hectare of different forestry mitigation options

The mitigation potential for the period 2015–2030 (on a per hectare basis) is lowest for the afforestation option (at 132 Mt $CO_{2\text{-}e}$/ha) and highest for forest protection option (at 729 Mt $CO_{2\text{-}e}$/ha). The mitigation potential per hectare for the natural regeneration option is 434 Mt $CO_{2\text{-}e}$/ha, and under the agroforestry option, it is 351 Mt $CO_{2\text{-}e}$/ha (Figure 12). Under natural regeneration and forest protection, no harvesting is considered for two reasons – (i) there is a ban on logging, and (ii) the goal is biodiversity conservation. Woody litter, however, is often collected for use as fuelwood by local communities for subsistence needs. The annual mitigation potential on a per hectare basis ranges from 9 Mt $CO_{2\text{-}e}$/ha/year for the afforestation option to 49 Mt $CO_{2\text{-}e}$/ha/year for the forest protection option (Figure 13).

c) Cumulative forestry mitigation potential of different mitigation options

The cumulative mitigation potential of options implemented on forestland namely, forest protection on moderately dense forests and natural regeneration on open forests is highest, and in the year 2030, it is cumulatively about 395 Mt CO_2-e. The next highest mitigation potential is of agroforestry on agricultural land, encompassing degrading pasture and grazing as well as long fallow and marginal croplands (253.7 Mt $CO_{2\text{-}e}$). Least mitigation potential is realized on wastelands wherein afforestation through short and long-rotation plantations are the mitigation options (Table 6).The cumulative mitigation potential achieved by 2030 through all the options under the "Technical Potential" scenario is 710.3 Mt CO_2-e. It is 405 Mt CO_2-e under the "Economic Potential" scenario - 57% of the potential realized under the "Technical Potential" scenario.

VII. Role of Karnataka Forest Sector in Meeting the NDC Targets

Karnataka has about 22% of its geographic area under forest. The National Forest Policy target is to have 33% of the geographic area of the country under forest and tree cover. Karnataka needs to bring an additional 11% of its area under forest cover, if the same target is to be achieved in the states. The current area under forests is 3.6 Mha. The average annual afforestation rate in Karnataka is about 47,000 ha. The additional area that will be brought under tree cover considering only the "Economic Potential" scenario is 1.1 Mha. The forest cover may increase from 3.6 Mha to 4.7 Mha, therein increasing the forest cover of Karnataka to 24.5% of the geographic area, against the national goal.

As part of its INDC, India has envisaged a massive afforestation drive to sequester an additional 2.5-3.0GtCO_2 by 2030. Globally, the COP 21 agreement relies heavily on forests to achieve zero carbon emissions in the next half of this century – which is a pre-requisite for limiting warming below 2°C. In this context, the potential of Karnataka to contribute to the NDC target becomes relevant. The cumulative mitigation potential achieved by 2030 through forestry mitigation in Karnataka is about 710 Mt CO_2 and 405 Mt CO_2, respectively under the "Technical Potential" and "Economic Potential" scenarios. This can help India meet 24% to 28% and 14% to 16% of the NDC forestry

sink creation commitment, considering the "Technical Potential" and "Economic Potential" scenarios.

To conclude, it is evident from this assessment that land availability for climate change mitigation through forestry is not a constraint in Karnataka. It is possible to achieve this without compromising on the competing demands of food production, infrastructure, and urban settlement requirements. Forestry mitigation potential is significant, provided forestland, agriculture lands and wastelands are all included, as promotion of tree plantations on these lands would create forests– that is in line with the definition adopted by India and submitted to the UNFCCC, and create or enhance carbon sinks, as envisaged in the INDC. These mitigation activities further promote mitigation-adaptation synergy in addition to the delivery of several co-benefits. However, for the realization of forestry mitigation potential in Karnataka, barriers need to be overcome.

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Table 1: Trends in area (Mha) under different land use categories in Karnataka

Category	1960-61	1970-71	1980-81	1990-91	2001-02	2011-12	2012-13
Land under Cultivation							
Net Sown Area	10.065	10.248	9.899	10.381	10.031	9.941	9.773
Gross Cropped Area	10.398	10.887	10.660	11.759	11.670	12.059	11.748
Area Sown More Than Once	0.333	0.639	0.761	1.378	1.638	2.118	1.955
Cropping Intensity (%)	103.310	106.240	107.690	113.270	116.340	121.310	120.000
Land not Available for Cultivation							
Land put to non-agricultural use	0.853	0.937	1.066	1.189	1.325	1.433	1.436
Barren and uncultivable land	0.844	0.839	0.844	0.799	0.788	0.787	0.787
Uncultivated Land Excluding Fallow Land							
Permanent Pastures and Other Grazing Land	1.744	1.619	1.346	1.098	0.956	0.908	0.908
Miscellaneous Tree Crops and Groves not included in Net Sown Area	0.374	0.311	0.342	0.316	0.302	0.285	0.283
Cultivable Waste	0.621	0.615	0.502	0.446	0.423	0.413	0.413
Fallow Land							
Current Fallow	0.669	0.811	1.459	1.29	1.728	1.672	1.822
Other Fallow	0.665	0.672	0.558	0.457	0.426	0.539	0.535

Source: PPM & SD, 2014-15

Table 2: Comparative yield estimates of major rainfed crops of Karnataka with National average and states reporting highest yield (kg/ha)

Crop	Highest - State	Yield of crops in Karnataka
Jowar	1433 – Madhya Pradesh	1183
Bajra	1938 – Madhya Pradesh	1082
Maize	5351 – Andhra Pradesh	3442
Tur	1333 - Bihar	596
Bengal gram	1241 – Andhra Pradesh	656
Groundnut	2308 - Tamilnadu	871
Sunflower	2500 – Uttar Pradesh	610
Soyabean	1692 – Andhra Pradesh	882

Source: Agriculture Statistics at a Glance 2012, GoI, MoA, New Delhi

Table 3: Land category-wise area considered for mitigation assessment under "Technical and "Economic Potential" scenarios

Land category	Area (Mha)	
	Technical potential	Economic potential
Wasteland	*1.30*	*0.86*
Wasteland – multiple categories	1.304	0.860
Mining wastelands	0.003	0.003
Forestland	*3.44*	*1.65*
Moderately dense forest	2.018	0.939
Open forest	1.418	0.709
Agriculture land	*3.20*	*1.45*
Long fallow lands	0.539	0.539
Permanent pastures and grazing land	0.908	0.908
Marginal croplands	1.754	-
Total (Wasteland+Forestland+Agriculture)	7.94	3.86

Table 4: Carbon stocks ($MtCO_{2-e}$) under baseline, cumulative and incremental mitigation under "Technical Potential" scenario for different mitigation options

Option		2015	2020	2025	2030	2035	2040	2045	2050
Afforestation *(Wastelands)*	Baseline	112	112	112	112	112	112	112	112
	Cumulative mitigation	113	131	157	173	192	202	211	230
	Incremental mitigation	1	19	44	61	80	89	99	118
Forest protection *(Forestland)*	Baseline	1241	1241	1241	1241	1241	1241	1241	1241
	Cumulative mitigation	1242	1276	1356	1452	1547	1619	1658	1686
	Incremental mitigation	1.0	34.5	114.9	210.7	305.8	377.8	416.7	444.8
Natural regeneration *(Forestland)*	Baseline	431	431	431	431	431	431	431	431
	Cumulative mitigation	432	461	531	615	699	764	804	835
	Incremental mitigation	0.8	30.2	100.8	184.7	268.2	333.6	373.0	403.9
Agroforestry *(Agriculture land)*	Baseline	392	392	392	392	392	392	392	392
	Cumulative mitigation	431	448	555	646	732	773	790	821
	Incremental mitigation	39	56	162	254	339	381	398	429
Total	Baseline	2176	2176	2176	2176	2176	2176	2176	2176
	Cumulative mitigation	2218	2316	2599	2887	3169	3358	3463	3572
	Incremental mitigation	41.1	139.5	422.3	710.3	992.9	1181.8	1286.9	1395.2

Table 5: Carbon accumulation (Mt CO_{2-e}) under baseline, mitigation and the increment under "Economic Potential" scenario for different mitigation options for the period 2015 to 2050

Option		2015	2020	2025	2030	2035	2040	2045	2050
Afforestation *(Wastelands)*	Baseline	79	79	79	79	79	79	79	79
	Cumulative mitigation	79	92	110	122	135	142	148	161
	Incremental mitigation	0.4	13.2	31.0	42.8	55.8	62.6	69.3	82.2
Forest protection *(Forestland)*	Baseline	590	590	590	590	590	590	590	590
	Cumulative mitigation	591	607	646	692	738	773	792	805
	Incremental mitigation	0.5	16.7	55.6	102.0	148.0	182.8	201.5	214.9
Natural regeneration *(Forestland)*	Baseline	215	215	215	215	215	215	215	215
	Cumulative mitigation	216	230	266	308	349	382	402	417
	Incremental mitigation	0.4	15.1	50.4	92.4	134.1	166.8	186.5	201.9
Agroforestry *(Agriculture land)*	Baseline	203	203	203	203	203	203	203	203
	Cumulative mitigation	204	239	312	371	426	459	474	491
	Incremental mitigation	1.0	36.1	108.3	167.8	222.9	255.3	270.4	287.8
Total	Baseline	1088	1088	1088	1088	1088	1088	1088	1088
	Cumulative mitigation	1090	1169	1333	1493	1649	1755	1816	1875
	Incremental mitigation	2.3	81.1	245.4	405.0	560.7	667.5	727.7	786.9

Table 6: Cumulative mitigation potential (Mt CO_{2-e}) of forestry mitigation options during 2015 to 2030

Land category	Mitigation option	Mitigation potential (Mt CO_2-e)							
		2015		2020		2025		2030	
		Tech[1]	Eco[2]	Tech	Eco	Tech	Eco	Tech	Eco
Forestland	Forest protection	1.0	0.5	34	16.7	114.9	55.6	210.7	102.0
	Natural regeneration	0.8	0.4	30	15.1	100.8	50.4	184.7	92.4
Wasteland	Afforestation	0.5	0.4	19	13.2	44.3	31.0	61.2	42.8
Agriculture land	Agroforestry	1.6	1.0	56	36.1	162.3	108.3	253.7	167.8
Total		3.9	2.3	139.5	81.1	422.3	245.4	710.3	405.0

[1]*Afforestation includes short rotation and long rotation plantations, agroforestry option includes block and bund plantations*
[2]*"Technical Potential" scenario, considering a total land area of 7.94 Mha*
[3]*"Economic Potential" scenario considering a land area of 4 Mha.*

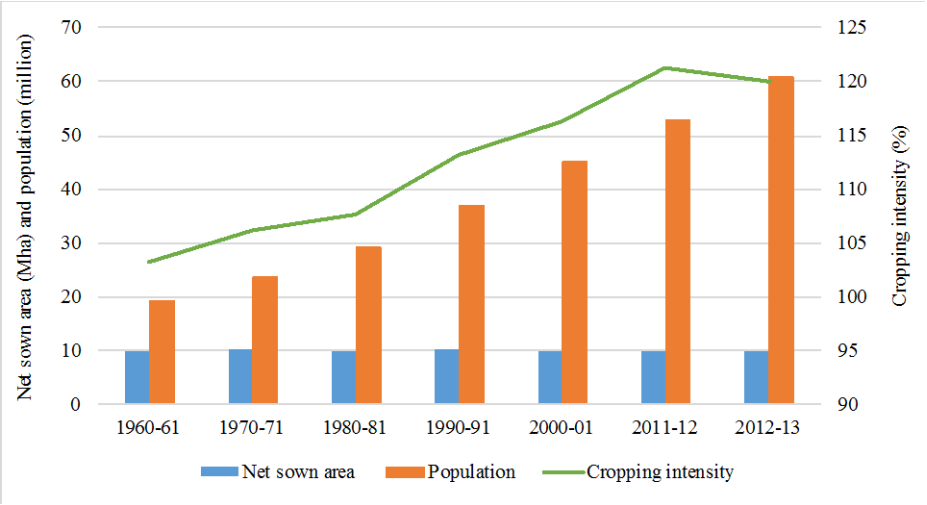

Figure 1: Trends in land under cultivation (Mha), population and cropping intensity (%)

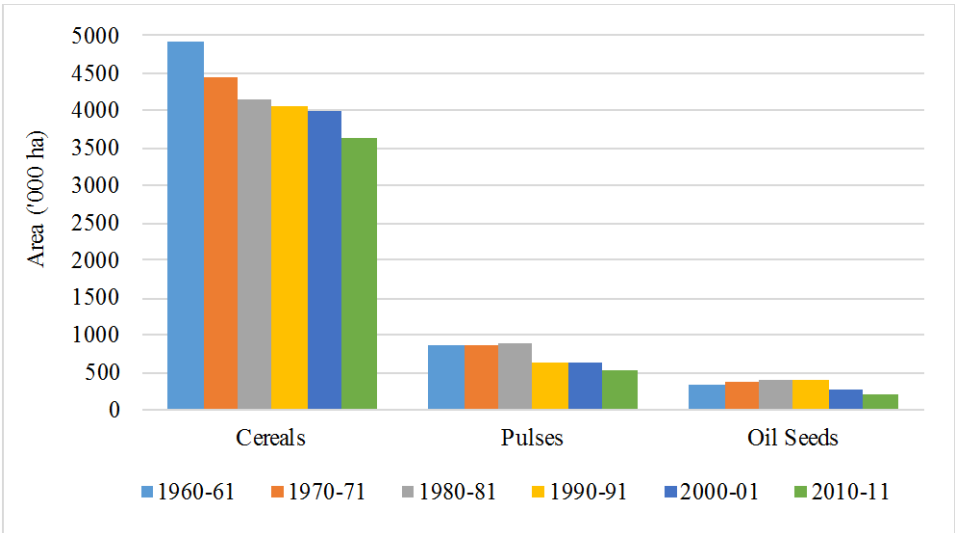

Figure 2: Trends in total area under cereals, pulses and oilseeds

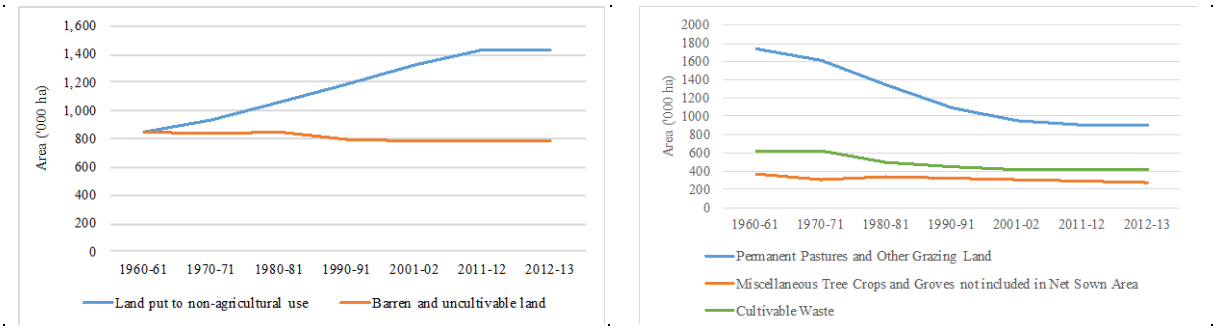

Figure 3: Trends in land not available for cultivation (left panel) and area under permanent pastures and other grazing land, miscellaneous tree crops and groves and cultivable waste

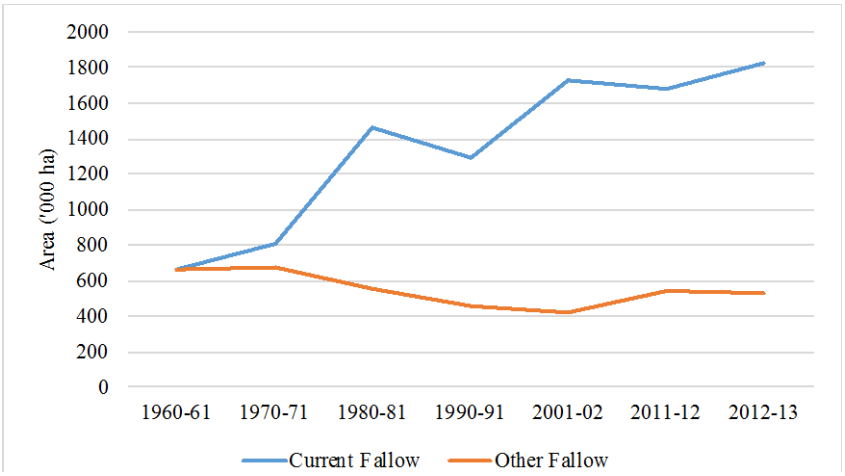

Figure 4: Trends in area under fallow land category

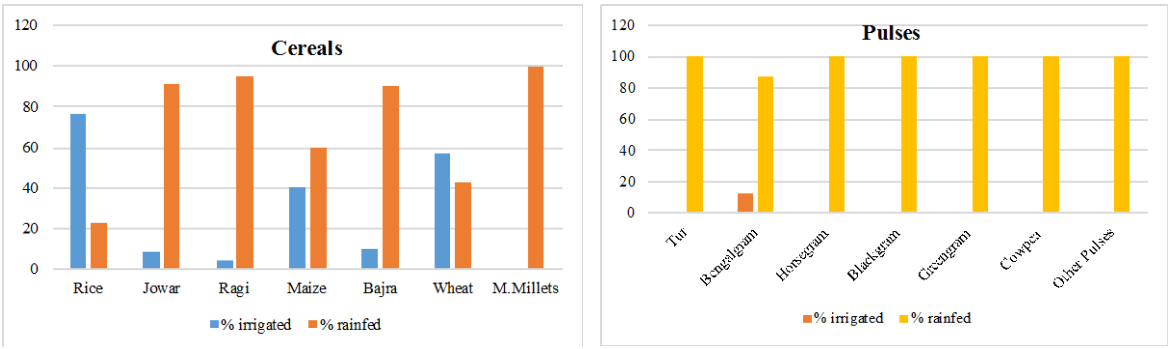

Figure 5: Area under major irrigated and rainfed crops in Karnataka during 2011-12

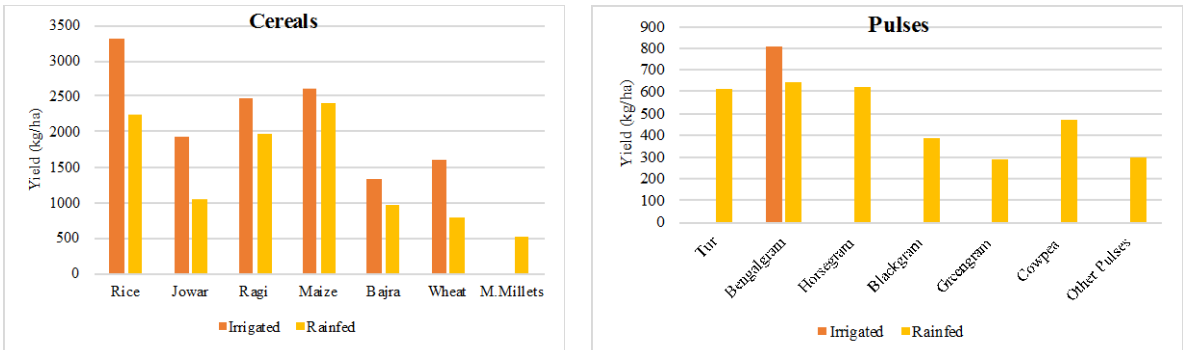

Figure 6: Yield of major irrigated and rainfed crops in Karnataka during 2011-12

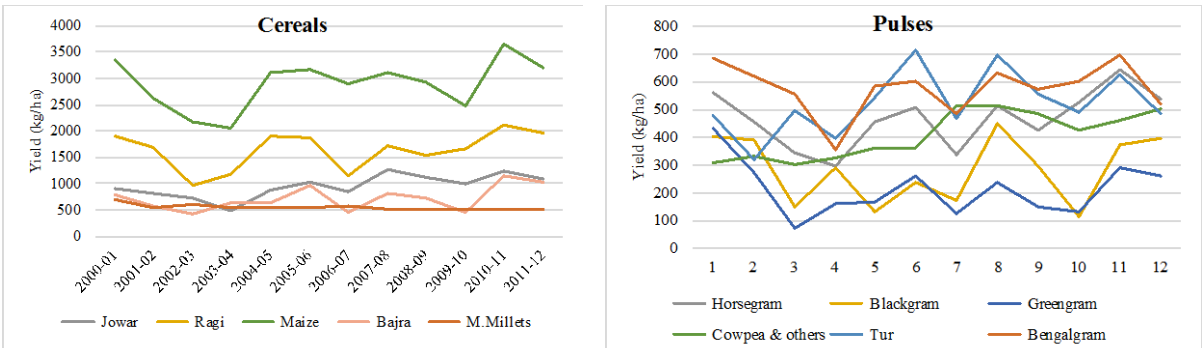

Figure 7: Trends in yield of major cereals and pulses in Karnataka

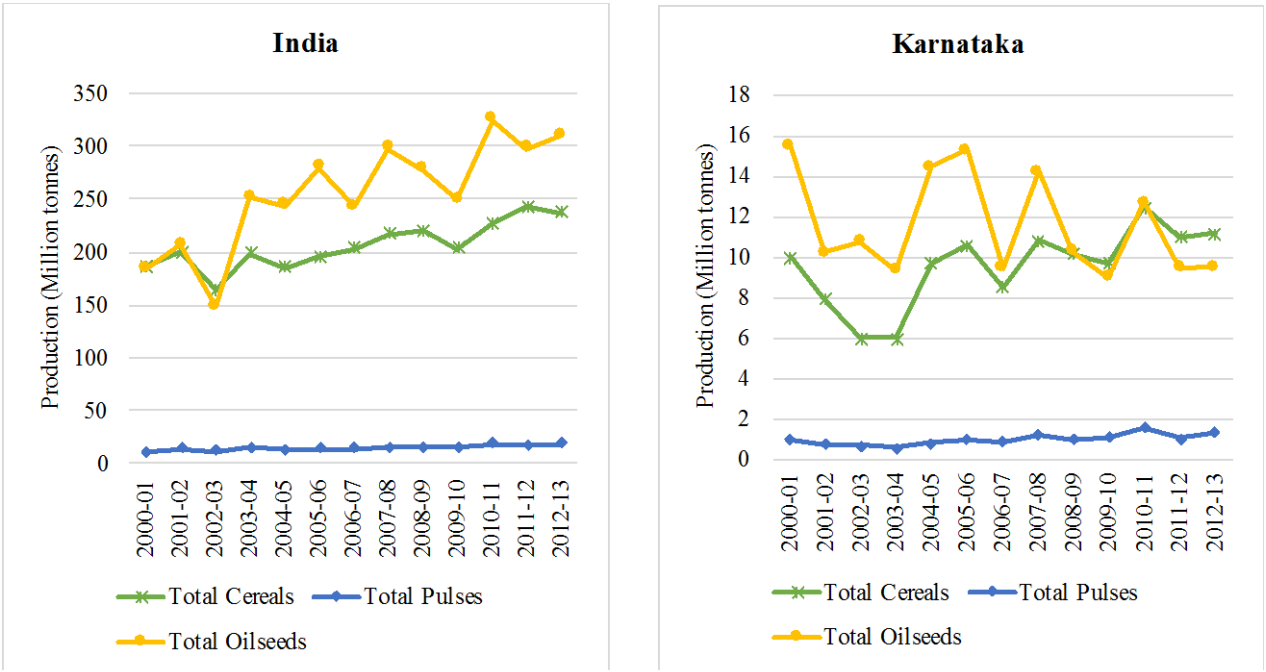

Figure 8: Trends in food grain production in Karnataka and India

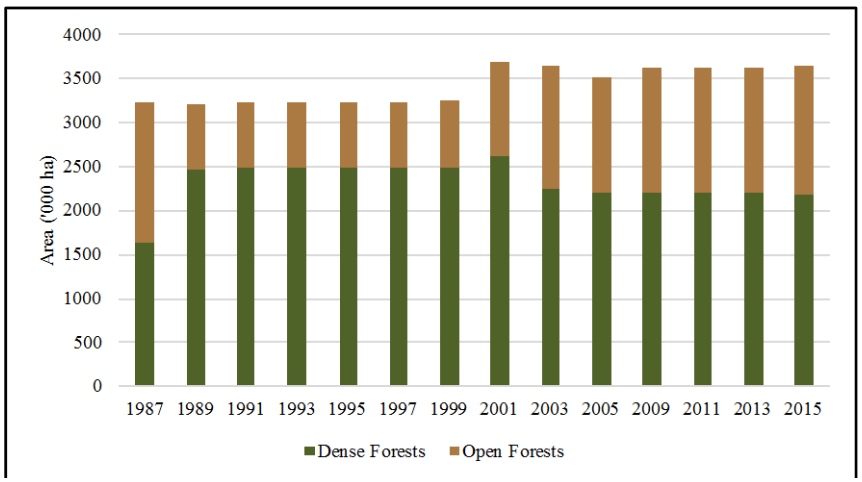

Figure 9: Trends in area under forests in Karnataka ('000 ha) during 1987 to 2015

Step 1	Selection of scale of assessment
Step 2	Selection of land categories and estimation of area available for mitigation purposes
Step 3	Selection of mitigation scenarios
Step 4	Selection of model for assessment of mitigation potential assessment
Step 5	Selection of mitigation options and matching of options to identified land categories
Step 6	Selection of carbon pools

Step 7	Generation of data for inputting into the model
Step 8	Model runs for estimating the mitigation potential

Figure 10: Approach to assessment of mitigation potential of forest sector

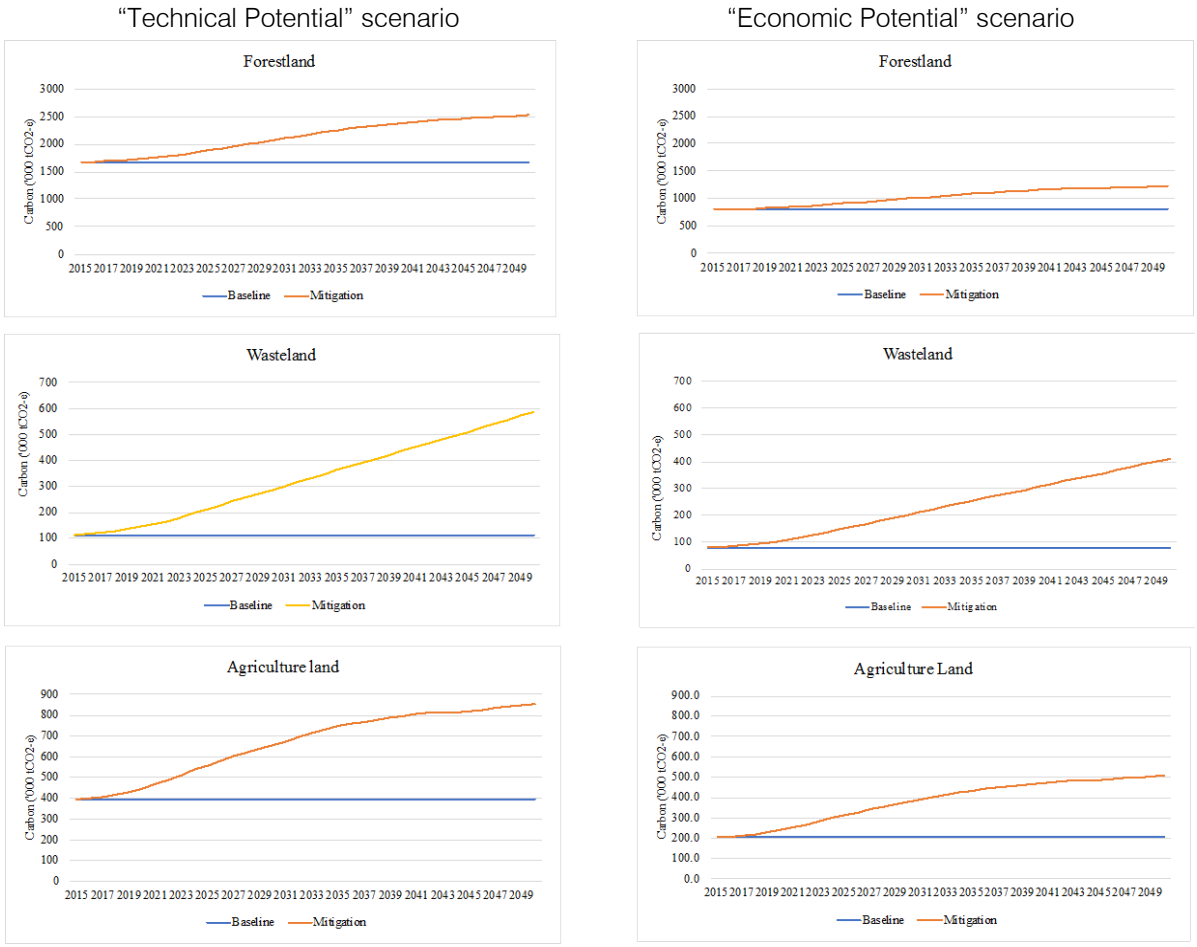

Figure 11: Cumulative carbon stock accumulation across land categories during 2015-2030 under "Technical Potential" (left panel) and "Economic Potential" (right panel) scenarios

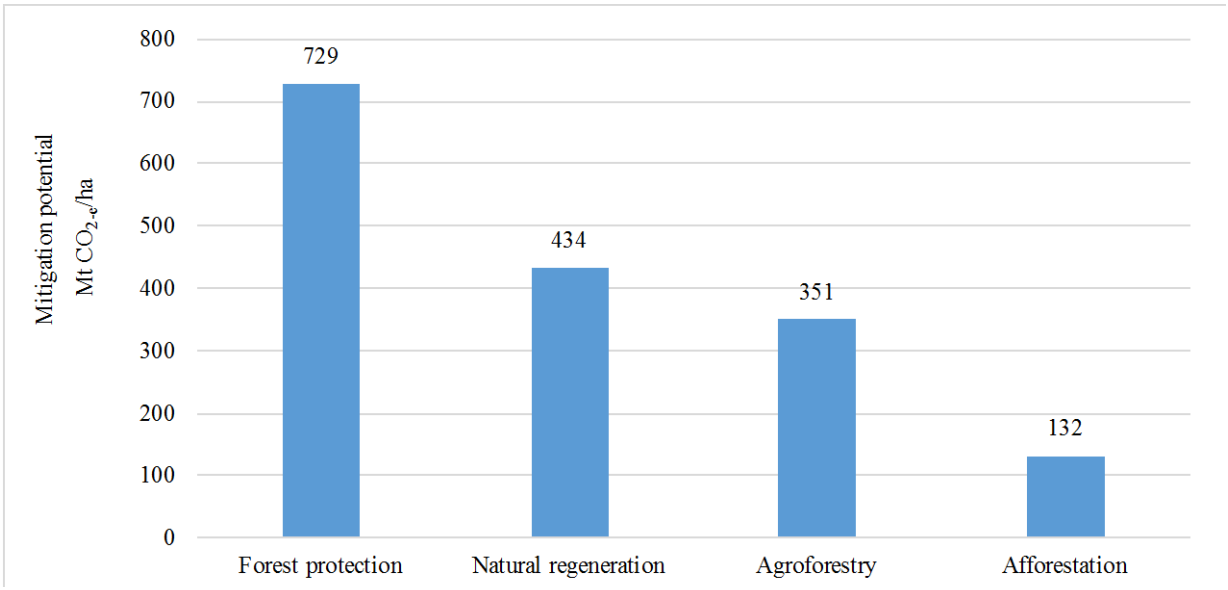

Figure 12: Mitigation potential per hectare of different forestry mitigation options for the period 2015-2030

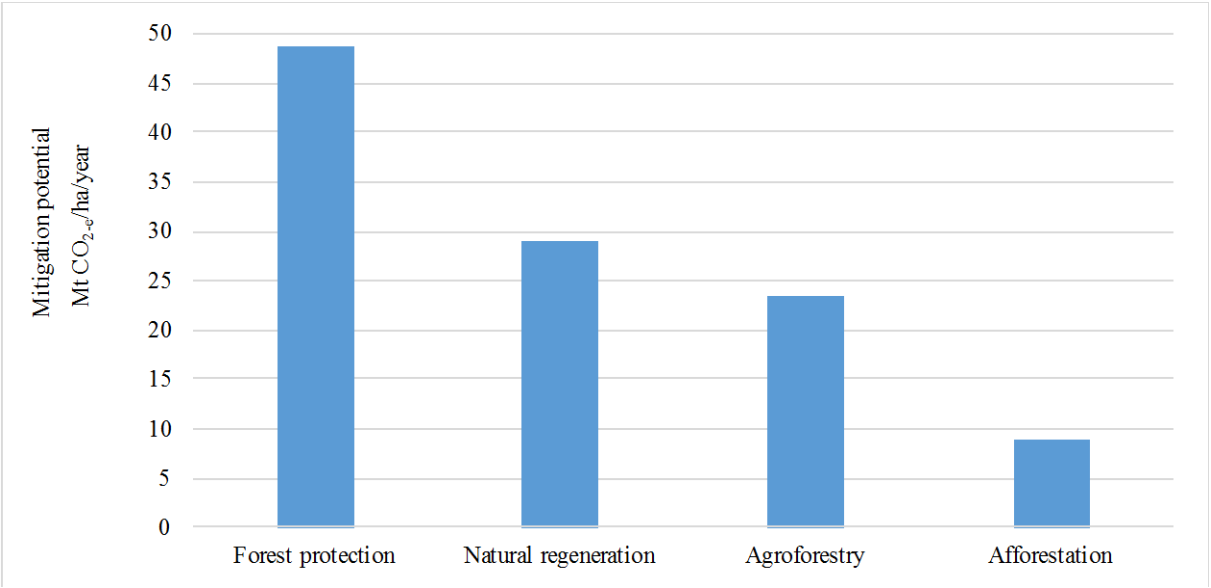

Figure 13: Annual mitigation potential per hectare across mitigation options for the period 2015-2030

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Impact of Urbanization on Vegetation Cover in Gombe Metropolis and Environs

By L.A. Mbaya, G. O. Abu, Y.C. Makadi & D.M. Umar
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Abstract- Demographic characteristics and economic development are the major determinants of urban shape and pattern of urbanization in Gombe which gave rise to rapid population growth. These determinants resulted to unplanned urban growth, unprecedented urbanization and land use change as a result contributing in the rapid reduction of vegetation cover and loss of arable land in the surrounding urban environment. The aim of this paper is on the impact of urbanization on vegetation cover. Both primary and secondary data was employed in this work. Socio-economic data and information on the status of tree species were gathered through questionnaire survey that involved 195 respondents using purposive sampling techniques in the study area. While the land use land cover analysis was carried out using ArcGis 10.5 and Edras Imagine 9.0. The finding was made to capture as accurate as possible six land use land cover classes as they changed through time.

Keywords: environment, urbanization, vegetation, population, expansion.

GJHSS-B Classification: FOR Code: 969999

Strictly as per the compliance and regulations of:

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L.A. Mbaya [α], G. O. Abu [σ], Y.C. Makadi [ρ] & D.M. Umar [ω]

Abstract- Demographic characteristics and economic development are the major determinants of urban shape and pattern of urbanization in Gombe which gave rise to rapid population growth. These determinants resulted to unplanned urban growth, unprecedented urbanization and land use change as a result contributing in the rapid reduction of vegetation cover and loss of arable land in the surrounding urban environment. The aim of this paper is on the impact of urbanization on vegetation cover. Both primary and secondary data was employed in this work. Socio-economic data and information on the status of tree species were gathered through questionnaire survey that involved 195 respondents using purposive sampling techniques in the study area. While the land use land cover analysis was carried out using ArcGis 10.5 and Edras Imagine 9.0. The finding was made to capture as accurate as possible six land use land cover classes as they changed through time. The result of the work shows a rapid decrease on the vegetation and a gradual increase in settlements between 1976 and 2016 due to the fact that Gombe metropolis became the capital of Gombe state in 1996. Also only few tree species were found within the study area, as most trees are cut down for various developmental purposes. The study recommends that urgent attention on conservation of vegetal resources within the metropolis should be encouraged.

Keywords: environment, urbanization, vegetation, population, expansion.

I. Introduction

Changes in the ecology of urban environment occasioned by increasing population, overcrowded habitations and uncontrolled exploitation of natural resources may have accounted for this wide ecological footprint of urban areas which is not peculiar to developing countries (Stoel, 1999 and Hales, 2000). Hales,(2000), observed that the pace and scale of growth have outstripped the capacity to maintain acceptable standards of public health, environmental safety and sustainable economic growth in urban areas in less developed nations in Africa, Asia and Latin America. Undoubtedly, urbanization is a process that continuously initiates changes in land use.

For any meaningful development to take place in an area there is the need for adequate information on the past and present land use patterns. Sufficient records on land and its uses are generally scanty in Nigeria (Abbas and Arigbede, 2011). This may be due to the tedious nature and cost of conducting ground surveys, and the bulky nature of data generated. The use of remote sensing and GIS techniques to capture data and process for safe keeping, management and regular updating, therefore, serves as a reliable alternative to the analogue methodology.

Thus, the monitoring of land cover/land use (LCLU) using satellite imagery has been adequate for general extensive synoptic coverage of large areas (Lilles and, *et al.,* 2004). As a result, this has reduced the need for expensive and time consuming ground surveys conducted for validation of data.

One of the major problems arising from urbanization is thus vegetation degradation. It is a decline in the quantity and quality of the grasses, herbs and woody species found in an ecosystem (Douglas, 1994). Vegetation degradation as defined by Conacher and Sala, (1998), "is the temporary or permanent reduction in the density, structure, species composition or productivity of vegetation cover". Vegetation condition is the key aspect of degradation in grasslands, wood/forest lands and croplands. Thus, over exploitation and management practices may result in vegetation degradation and tend to enhance land degradation risk. Pressure on the natural vegetation has arisen from changing agricultural practice, fire and livestock grazing, and the feed-back with the loss of bio-diversity.

Natural land degradation develops because the sparse native vegetation and its inherently low productivity are not able to contribute the necessary organic matter that gives life to soil and binds soil particles. With this degeneration in soil quality, productivity falls, leading to reduction of vegetation. However, natural degradation of vegetation is typically gradual and often reversible (Michael, 2013). In contrast, man-induced destruction is mostly rapid with diminished time or chance to compensate for the loss.

II. Materials and Methods

a) Study Area

The study area is Gombe town and, it is located on latitude 10^0 13'and $10^0$20'N and longitude $11^0$02'and $11^0$16'E. The study area is limited to the urban area and environs. Some 9km radius around the town has been

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arbitrarily demarcated for the study with Union Bank round about, along Biu Road being the centre point (Fig.1).Gombe is located within the sub-Sahara climatic zone. It is characterized by two distinctive seasons, that is, dry season (November-April) and wet season (May-October). The rainfall here averages 907 mm. The vegetation of Gombe is within Sudan/Guinea savannah. This is characterized by shrubs and scattered trees with a different species of grasses. The predominant tree species include Locust bean tree, Baobab tree, Tamarin, Moringa, Date-palm, Neem trees and *Azadirachtaindica*. The soils are highly ferruginous, formed as a result of intensive weathering of the basement rocks.

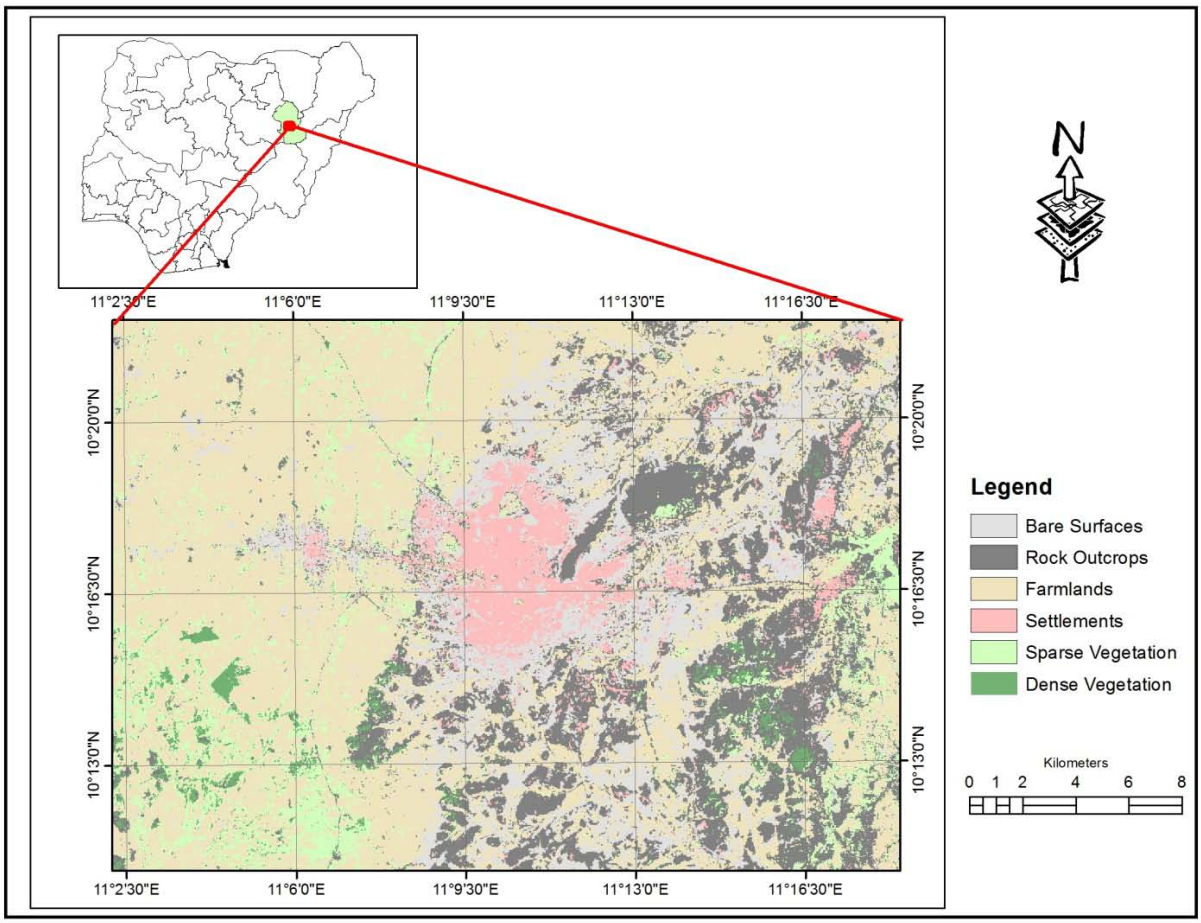

Figure 1: The Study Area

b) Procedure for Data Collection

Both primary and secondary data was employed in this work. Socio-economic data and information on the status of tree species were gathered through questionnaire survey that involved 195 respondents using purposive sampling techniques in the study area.

The remote sensing and the geographic information system (GIS) technology and applications were applied in the determination of the land cover changes. The interpretation and classification of satellite images involved subsetting and other pre-processing steps including geo referencing, colour composite and unsupervised classification; ground truthing, screen digitization of some features, supervised classification and change detection. Subsetting consisted mainly in selecting and extracting the study area from the full scene images. Colour composite and unsupervised classification enabled us to establish major land cover classes before ground truthing to match the reality in the field with the classified image. After ground truthing, the supervised classification enabled to proceed on land cover map composition for each image.

c) Data Analysis

The obtained result was analyzed using tables, charts and maps. The size and area of the land cover changes were calculated and represented in hectares. The rationale for these was based on the total size of the study area.

III. Results and Discussion

a) Socio-Economic Characteristics of Respondents

Table 1 shows the distribution of respondents by age, sex, educational level and level of income. As presented in Table 1, majority of the respondents that responded to the questionnaires constitute 67% males and 33% females. The data on Table 1 also indicates

that majority of the respondents are between the ages of 21-30 years which is 44%, those in ages between 31 -40 years, 37%, 41- 50 years constituted only 8% while those above 51 years accounted for 11% respectively.

The distribution of respondents by educational level reveals that, 12% have attained primary school education, 28% secondary school education, and 49% tertiary education while 11% have no formal education. The result reveals that most of the respondents are literate which cut across different educational backgrounds.

Table 1: Distribution by Sex, Age group, Educational level and Occupation of Respondents

Socio-economic attributes		
Sex	Frequency	%
Male	131	67.2
Female	64	32.8
Total	195	100
Age (years)		
21-30	86	44.1
31-40	73	37.4
41-50	15	7.7
>51	21	10.8
Total	195	100
Educational level		
No formal education	21	10.8
Primary education	24	12.3
Secondary education	54	27.7
Tertiary education	96	49.2
Total	195	100
Occupation of the respondents		
Civil servant	72	36.9
Trader/business person	64	32.8
Farmer	28	14.4
Others	31	15.9
Total	195	100

Source: Fieldwork, 2017

The occupation of the respondents indicates that 37% of them are civil servants and 33% constituted the traders/ business person. This two categories were the highest and simply be due to the fact that the study was carried out within the metropolis where majority of the people are either government works or businessmen. The farmers constituted only 14% which can only explain the fact that due to urbanization, fertile land for agriculture is hardly found.

b) Vegetation Cover Characteristics

i. *Distribution of Tree Species.*

The study sought to identify dominant species found in the study area, in all 12 tree species were identified belonging to 9 families as shown in the Table 2. The Fabeceae family has the largest number of species. The woody vegetation was hardly found in the study area as a result of urbanization and infrastructural development. The few species found were mostly planted by house owners as shades and wind breakers. Also, around the Gombe State University and Old GRA, trees such as date palm, neem tree, mahogany were dominant.

Table 2: Distribution of Tree Species

S/N	Scientific Names	Family Names	Local Names	Common Names
1	Adansoniadigitata	Bombacaceae	Kuka	Baobab
2	Azardirachtaindica	Fabeceae	Dogonyaro	Neem
3	Balanitesaegyptiaca	Balanitiaceae	Aduwa	Desert date
4	Ficusplatyphylla	Moraceae	Gamji	Fig tree
5	Grewiamollis	Tiliaceae (Malvaceae)	Dargaza	Apple ring acacia
6	Hyphaenethebaica	Arecaceae (Palmae)	Goriba	Doum palm
7	Khayasenegalensis	Meliaceae	Madaci	Mahogany
8	Pakiabiglobosa	Fabeceae	Doruwa	Locust beans
9	Prosopis Africana	Fabeceae	Kirya	Iron tree

10	Tamarindusindica	Fabeceae	Tsamiya	Tamarind
11	Vitellariaparadoxa	Sapotaceae	Kadanya	Shea butter tree
12	Vitexdonaina	Verbenaceae	Dinya	Black plum

Source: field survey

The trees in the area present significant importance almost in all human endeavors. A large percentage of the trees in the area have their advantage which made them of great use and advantage to the people of the area. Almost every tree or shrub has one or more uses that attract people's attention to put proper care on such plants.

Table 3 below shows the status of the woody species, reasons for the vegetal loss and the challenges experienced when urbanization takes place at the detriment of vegetation cover.

Table 3: Vegetation Cover Exploitation

Status of the woody species		
Abundant	10	5.1
Moderate	58	29.7
Sparse	110	56.4
None	17	8.7
Total	195	100
Reasons for vegetation cover loss		
Cutting of tree branches for grazing/fencing	30	15.4
Agricultural expansion	32	16.4
Fuelwood	36	18.5
Urban development	95	48.7
Others	2	1.0
Total	195	100
Challenges experienced due to urbanization		
Flooding	22	11.3
Erosion	62	31.8
Flooding and Erosion	104	53.3
None	4	2.1
Others	3	1.5
Total	195	100

Source: Fieldwork

The status of the woody species indicates that the area is majorly composed of sparse vegetation constituting about 56% while moderate and abundant vegetation constitutes only 30% and 5% respectively. The major reasons for these were attributed to urban development (64%) as seen in Figure 2 and closely followed by cutting the trees for fuelwood (19%) and agricultural expansion (16%). Despite the fact that the study area is in the centre of the town, people who purchase parcels of land for development and find trees within it cut them and either sell or use for their consumption. Likewise, as the economic situation is telling on the people, they tend to clear any available land or space within their environs for cultivation and livestock rearing. The challenges experienced due to urbanization were majorly flooding and erosion which constituted 53% and this is due to cutting down of trees which has made the environment prone to this hazards.

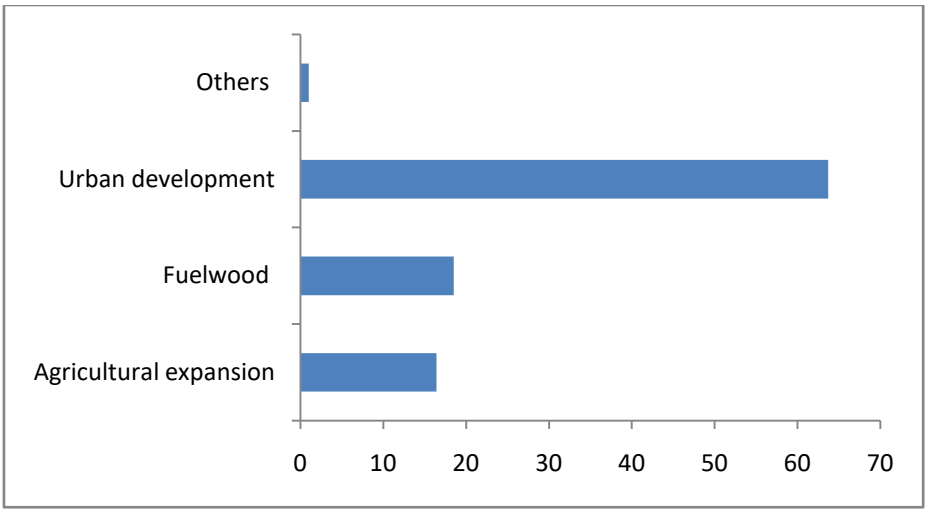

Figure 2: Reasons for Tree Loss in the Area

IV. Land use Land Cover Variation

As shown in Figure 3, the land-use/land-cover distribution clearly indicate, that there is considerable variation in the land use/land cover of the studied area over the examined period. There is however no consistent variation in the area coverage of the different land uses over time. The only exception is the built-up area that showed a consistent increase over time.

The bare surfaces covered about 11% in 1976then increased to about 13% in 1996 and increased again to 17% in 2016. This may be attributed to the fact that open spaces can easily be used for urban development. In a similar fashion, the area covered by vegetation decreased from 62% in 1976 to 27% in 1996 then decreased again to 11% in 2016. The farmland increased from 25% in 1976 to 43% in 1996 and decreased to17% in 2016.This was as a result of the conversion of farmlands to infrastructures. By contrast, the settlements increased from 2% in 1976 to 15% in 1996 and subsequently to 51% in 2016. So also, the rock outcrop increased from 0.36% in 1976 to 10% in 2016.

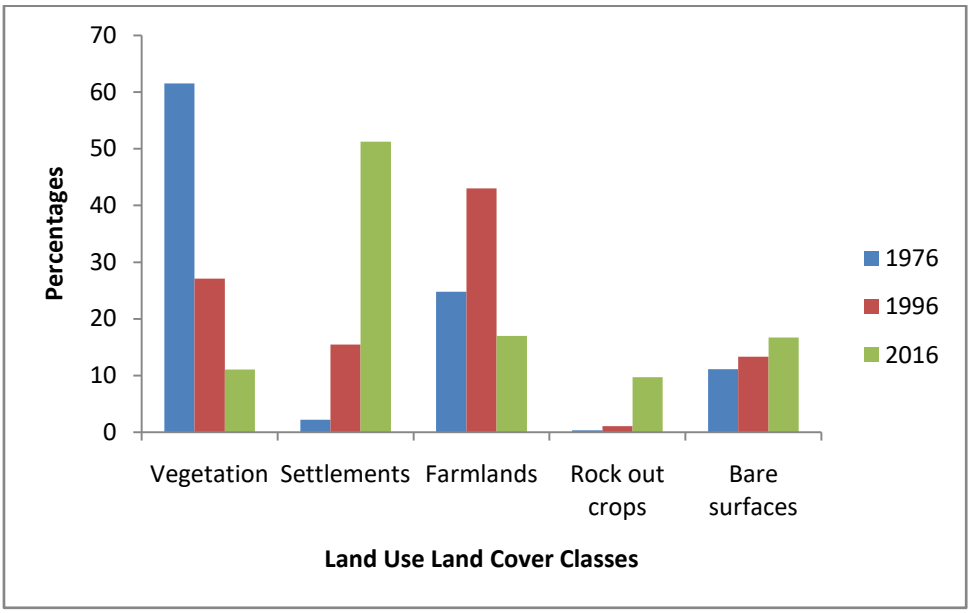

Figure 3: Land use land cover classes variation

The studies of Chigbu, *et al.,* (2011) and Oluseyi (2006) conforms with the results of this work as they noted a significant disparity and trend in vegetation landcover due to rapid urbanization and socio economic activities. Likewise, Bisong (2007) and Ujoh et al (2011) opined that deforestation was higher due to rapid urban expansion.

V. Conclusion

Attempt was made to capture as accurate as possible six land use land cover classes as they changed through time. The six classes were distinctly produced for each study year but with more emphasis on vegetation as it is affected by a combination of natural and anthropogenic activities and indeed, it is one that affects the other classes. The result of the work shows a rapid decrease on the vegetation and a gradual increase in settlements between 1976 and2016 due to the fact that Gombe metropolis became the capital of Gombe state in 1996. As a result there was an influx of people from other part of the state and the country mounting pressure on the land for development purposes. Since then the area had been growing spatially to the detriment of other land cover types especially vegetation and agricultural land. Thus, the study aimed at assessing the impact of urbanization on vegetation cover in the Gombe town and its environs.

Using maximum likelihood classifier, it was found out that the settlement increased steadily over the years at the detriment of vegetation and agricultural land that decrease rapidly from 1976 to 2016.

The status of the woody species indicates that the area is majorly composed of sparse vegetation constituting about 56% while moderate and abundant vegetation constitutes only 30% and 5% respectively.The study also sought to identify dominant species found in the study area, in all 12 tree species were identified belonging to 9 families. The Fabeceae family had the largest number of species.

The study has shown that the vegetation of Gombe state is undergoing degradation at an unsustainable rate which may likely disrupt the ecological functioning of the ecosystem in the state. Therefore, the study recommends that urgent attention on conservation of remaining vegetal resources in order to preserve the valuable assets of flora and fauna which are indigenous to the area. This can be done by insuring strict compliance with rules and regulations guiding conservation in the region and Nigeria as a whole also efforts should also be geared towards enlighten of the communities on the benefits of vegetation and the need for conservation in the ecosystem.

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Climate Change Related Factors and Management of Primary Schools in Benue State, Nigeria

By Mahmud Pinga & Sr. Justina Nguveren Jor
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Abstract- The study investigated climate change related factors and management of primary schools in Benue State. Two research questions and two hypotheses guided the study. Descriptive survey research design was adopted for the study. The population comprised 15,987 teachers from 2,407 primary schools in Benue State. A total of 1000 teachers from 122 primary schools were selected using multi-stage sampling strategy (Proportionate stratified random sampling and incidental simple random sampling techniques). Climate Change Related Factors Questionnaire (CCRFQ) was used for data collection. The data collected was analyzed using mean and standard deviation to answer the research questions and chi-square to test the hypotheses at 0.05 level of significance. The findings revealed that changing rainfall patterns and flood significantly impact on the management of primary schools in Benue State.

Keywords: climate change, changing rainfall patterns, flood & management of primary schools.

GJHSS-B Classification: FOR Code: 040104

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Climate Change Related Factors and Management of Primary Schools in Benue State, Nigeria

Mahmud Pinga[α] & Sr. Justina Nguveren Jor[σ]

Abstract- The study investigated climate change related factors and management of primary schools in Benue State. Two research questions and two hypotheses guided the study. Descriptive survey research design was adopted for the study. The population comprised 15,987 teachers from 2,407 primary schools in Benue State. A total of 1000 teachers from 122 primary schools were selected using multi-stage sampling strategy (Proportionate stratified random sampling and incidental simple random sampling techniques). Climate Change Related Factors Questionnaire (CCRFQ) was used for data collection. The data collected was analyzed using mean and standard deviation to answer the research questions and chi-square to test the hypotheses at 0.05 level of significance. The findings revealed that changing rainfall patterns and flood significantly impact on the management of primary schools in Benue State. Based on the findings of the study, it was recommended among other things that school management should take precautionary measures in maintaining school facilities that are exposed to continuous rainfall. Ceilings should also be installed in the classrooms to avoid unbearable noise that may be caused by the sound of rainfall.

Keywords: climate change, changing rainfall patterns, flood & management of primary schools.

I. Introduction

Climate change is one of the most important environmental issues facing the world today. This is evidenced by the spate of conferences, campaigns, reports and researches on the subject matter in the last 20 years; Agenda 21 of Rio Declaration (1992), Inter-governmental Panel on Climate Change (IPCC, 2001) and Copenhagen (2009) to mention but a few. Presently, there is widespread consensus in the scientific community and even among politicians that climate change is occurring and that the signs and impacts are glaring. These signs are noticeable in the areas of temperature variations, the drying up of soils and water bodies, increased pests and diseases, shifts in suitable areas for growing crops and livestock, increased desertification in the Sahara region, change in rainfall patterns which leads to erosions and flooding of farmlands, homes and schools (Pinga, 2018).

These signs are not just present in African and Nigeria, but seem to be surfacing in Benue state of Nigeria in the areas of changing rainfall patterns (time of arrival, intensity and duration among others) that have led to the flooding of areas that have never experienced flood before, increased incidence of soil erosion, increased incidence of storms, desert encroachment and excess heat are all signs that climate change is already evident and represents one of the greatest environmental, social and economic threats facing Africa. This change has been confirmed by the 4th Inter-governmental Panel for Climate Change (IPCC, 2007) assessment report that Africa would be worst hit by the effects of climate change which Nigeria is part of it.

The term climate change is generally referred to as the regular variation of weather in a particular place over an extended period of time (Tamuno, 2007). This helps to explain the unprecedented change that occurs in the weather condition of a given place over a long period of time. According to Obasi (2010), climate change symbolises the significant deviation from the normal range of the atmospheric condition required to sustain human life and the biodiversity. Ayoade (2003), Tamuno (2004) and Tamuno (2007) define climate change as variations in the atmospheric condition over a long period of time that helps to discern a shift in the climate characteristics of a place for years without reversing to former characteristics. This is also seen as the change in the average weather that a given region experiences for an extended period of time. This average weather includes the entire features associated with daily weather characteristics such as temperature, wind pattern, humidity and precipitation. The United Nations Framework Convention on Climate Change (2002) is of the opinion that climate change is the increased frequency and intensity of extreme climate hazards as change in annual rainfall, flood, rise in sea level, drought and disease.

Climate change is attributed to the increase in the Greenhouse Gases (GHGs) caused by both anthropogenic (man activities) and natural activities. Some of the anthropogenic sources include industrialization, deforestation, fossil burning (greenhouse gases), bush burning and desertification (Mbah, 2014). These activities result in the production of carbon dioxide, methane, nitrogen dioxide, chlorofluorocarbons and ozone. All these gases are

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greenhouse gases which lead to the depletion of the ozone layer in the atmosphere mainly located in the stratosphere, thereby leading to global warming. Climate change can result from natural factors that are external to the climate system such as actions of volcanic activity, solar output, ocean variation and the earth's orbital movement around the sun (Ekpo, 2009).

To provide the basis for the development of a realistic and effective internationally accepted strategy for addressing climate change, several organizations have been established, one of which is the IPCC (1988); the World Meteorological Organisation (WMO, 1950), in collaboration with the United Nations Environment Programme (UNEP, 1972) established the Intergovernmental Panel on Climate Change (IPCC) in 1988. The issues of great concern for the IPCC include science, impacts and policy. Consequently, the panel established three working groups for these aspects which are charged with the responsibilities of assessing available scientific information on climate change in particular that arises from the human activities and available scientific, technical, environmental, social and economic information regarding response options to adaptation to and/or mitigation (Ojo, Ojo & Oni, 2006). Despite these measures and numerous achievements of the IPCC, the effects of climate change still persist.

According to Chiedozie, Ezengbor and Okoye (2015), climate change has been observed to have serious deleterious consequences for the earth in form of significant variations in regional climate, recurrent droughts, excessive heat waves, windstorms, and killer floods. In relation to the above assertions, this study attempts to assess the extent to which climate change related factors in the areas of changing rainfall patterns and flood influence the management of primary schools in Benue state, Nigeria.

Evidence is emerging that climate change is increasing rainfall variability in Nigeria and other parts of Africa (IPCC, 2007). According to Abdullahi (2015), rainfall is liquid water in the form of droplets that have condensed from atmospheric water vapour and then precipitates. This rain is a major component of water cycle responsible for depositing most of the fresh water on earth. Mike (2016) notes that rainfall is a type of precipitation that occurs when water vapour in the atmosphere condenses into droplets that can no longer be suspended in the air. The occurrence of rainfall is dependent upon several factors such as prevailing wind directions, ground elevation, location within a continental mass and location with respect to mountain ranges all have a major impact on the possibility of precipitation. The author further stresses that rain is a major component of water cycle and is responsible for depositing most of the fresh water on the earth. This rainfall when adequate, can increase food production in certain areas and also bring home a certain comforting atmospheric temperature that is conducive for teaching and learning in the classroom. Orogwu (2006) notes that rainfall stabilises the temperature and calm down the human body system that gives them the room to think more properly.

According to Jor (2019) changing rainfall patterns therefore, refers to the degree or variability in the amounts of rainfall recorded within the area of study which may cause flood, erosion, drought and other climate disasters that may influence school management effectiveness in the areas of school attendance, lateness, absenteeism, neatness, noise making and concentration in the class as well as instructional supervision and maintenance of physical facilities.

The intensity and frequency of rainfall variability is expected to be more evident. In recent times, there have been periods of delay in rains and associated water shortage mostly in the Northern part of the country, while the Southern part of the country experiences frequent and longer periods of rainfall, an indicator of rainfall variability. Recha, Makokha, Traore, Shisanya, Lodoun and Sako (2012) report that persistence of below normal rainfall is a great risk to people's livelihood in Tharaka district in Kenya, where majority of people have been left vulnerable to hunger and famine. Schools were not left out as families could barely afford one square meal talk more of paying their children's school fee and other school necessities. The authors further note that, the situation led to heat and dust that severely affected students' health in the area. Similar observations have been reported by various scholars studies, for example intra-seasonal factors, such as the timing of the onset of first rains affecting crop-planting regimes (Tennant & Hewitson, 2002), the distribution and length of period of rain during the growing season (Mortimore & Adams, 2001), and the effectiveness of the rains in each precipitation event (Usman & Reason, 2004), are the real criteria that affect the people as well as the management of schools. IPCC (2007) reported that changes in rainfall amount and patterns also affect soil erosion rates and soil moisture, both of which affects body temperature as well as condition of roads that leads to schools in the area.

Change in the rainfall patterns influences so many aspects of human life. In the school setting, discipline which is the major ingredient of effective school management is hardly observed due to constant and persistent temperature variations such as that of rainfall. The influence of rainfall on the management of primary schools can be felt in the disruption of teaching/learning activities, irregular class attendance by students and teachers as well as management finding it difficult to maintain infrastructural facilities and instructional materials (Pinga, 2018; Amanchukwu, et al., 2015).

Amakiri (2007) maintains that noise within the school environment caused by rainfall, thunder and

lightning could disrupt effective teaching and learning in schools as students and teachers may not listen to one another in addition to the fearful noise caused by the sounds of rain droplets and thunder. Amakiri (2010) also notes that during intense rainfall, the teacher will have to stress himself/ herself and strain his/ her voice to ensure that the pupils hear what he/she is saying and this has proven to be futile most of the times. This can lead to disruption of the lesson as pupils may be easily affected by the cold and even distracted by the noise caused as a result of the rain droplets. In addition, Steele (2010) in Amakiri (2010) posits that rainfall affects school children's health negatively, stating that many pupils develop cough and catarrh during rainy seasons and this makes them drowsy causing them to sleep excessively. In such scenarios, teachers find it difficult to manage a class of sick pupils effectively as discipline is lacking especially in an over populated classroom.

Osuji (2010) notes that continuous rainfall has worsened the situation of the roads which are neither tarred nor graded in most of our rural areas. This situation is more or less presents even in our urban areas. Cases abound where pupils go to school drenched and shivering. Such situations demoralise and make the pupils' uncomfortable, thereby disrupting effective teaching-learning in the classroom. Manjengwa et al (2014) also observes that almost one quarter of the school buildings were damaged during heavy rains and storms, while thirteen per cent (13) of the school pupils could not go to school when there was heavy rainfall. Manjengwa et al (2014) stress further that pupils who struggle to attend school in the rain may have their books and uniform socked with rain water and this may destroy their books and also cause them health challenges such as cough and catarrh that may become serious and keep them away from school for days or weeks.

According to Amanchukwu et al (2015), many children in River State of Nigeria fail to attend school during heavy rain, especially in the villages where there are no means of transportation. Such absenteeism may obviously influence pupils' academic performance, coordination, control and supervision as well as pupils' evaluation in the school. The situation is not different in Benue State of Nigeria as it is dominated by rural areas. Such pupils find it difficult making it to school during rainy season. It is possible for rain to fall uncontrollably for days, making it impossible for pupils to attend school and receive lessons as roads were covered with water thereby affecting the movement of human beings. This may invariably influence the school planned calendar as lessons that should have been held for the rainy days will be shifted forward. This may bring alteration or unnecessary rush to cover the school syllabus not minding the level of pupils' comprehension. The persistency of this rain could also lead to flooding.

Flood is amongst the most disturbing elements of climate change in Africa and Nigeria in particular. Flood is generally seen as the overflowing of water from rivers or other bodies of water due to excessive rainfall or other inputs of water which temporarily submerge homes, farmlands and other economic and social facilities such as the schools and hospitals (Yawe, Pinga & Ivase, 2018). Ajayi (2006) defines flood as the accumulation of excessive quantity of water in an area without flowing away easily. John (2006) describes flood as an overflow of water that submerges land which is usually dry or previously uncovered by water. This is usually caused by an overflow from water bodies such as the rivers, lakes and oceans or due to accumulation of rainwater on saturated ground. Flood as used in this study, refers to the overflowing of water from a river or other bodies of water due to excessive rainfall or other inputs of water which temporarily submerges homes and schools, thereby destroying infrastructural facilities, books and other documents that may lead to the allocation of more funds for the procurement of such facilities and the servicing of others as well as displacing teachers and pupils from the school; and consequently distorting the process of teaching and learning.

The incidence of floods is becoming a reoccurring decimal in most rural and urban areas leading to colossal loss of properties and lives in Nigeria. For example, cases of flood were recorded in the North Central states of Benue, Kogi, Kwara, Nasarawa and Niger in 2000 and 2011. Also in 2012 and 2014, an unprecedented tragedy unfolded in the Benue state as communities were swallowed by raging floods. This brought untold hardship, anguish and sorrow to many inhabitants in the state. As the surging floods spread into tributaries of the River Niger into many communities, many helpless poor people were killed amid wide spread damaged houses, school buildings and other properties worth billions of naira. The situation was such that many people urged the Federal Government to declare a state of emergency in the devastated areas.

Whenever floods occur, especially in Benue State of Nigeria, schools are submerged and many documents and properties damaged as well as bringing school attendance to a shutdown thereby influencing the entire school management process in the areas of coordination as well as supervision and worst of all, the provision of funds for the procurement of damaged facilities and maintenance of the serviceable ones.

Management of primary schools have been influenced drastically within this latter part of the 21st century as most school facilities such as buildings, playgrounds and documents have been submerged, thus keeping pupils and teachers out of the school as well as damaging school records and making it difficult for the authorities of such schools to retrieve the damaged documents in time of need (Ramalho, 2006).

According to the United Nations International Strategy Disaster Reduction (2006-2007), when flood disaster strikes, infrastructural facilities in the schools are greatly destroyed or damaged. This makes it hard for learners to continue with their learning activities for a long time. Especially that, the buildings, playgrounds, farmland and all records as well as instructional materials may be covered and destroyed by the flooding water. This by implication affects the coordination and control of such facilities by the school authorities.

According to Hassanain (2006), floods disrupt the daily life of teachers and pupils and life might not return to normal quickly. When it occurs, classrooms and playgrounds are flooded hence disrupting the daily routine of learning and coverage of the syllabus is affected which indirectly affects the school year calendar. Pupils are unable to play and have games which also affect the supervision and evaluation of their extra-curricular life. Furthermore, families affected by floods may take shelter in schools not affected hence disrupting learning and other planned academic activities in such schools. When education is interrupted or limited, pupils may drop out of school or the rate of absenteeism may rise (IFC, 2009). UNISDR (2006) adds that flood cause damage to roads thereby making schools inaccessible resulting to high absenteeism rates for both teachers and pupils. Principals estimate that half of pupils dropped out due to financial problems and other difficulties caused by floods. During heavy floods, pupils and teachers may be washed away leading to loss of lives, while others are displaced as families migrate to higher grounds. In addition, there is loss of furniture, textbooks, and damage to equipment. When floods occur during examinations time, the activity is disrupted and pupils may end up missing their examinations on the planned date. Thus, preparing for the possible occurrence of floods and it effects is important.

This clearly shows the damage flood disaster had caused and will still cause to education worldwide. The deleterious influence of climate disaster experienced in other parts of the world is not different from what is obtainable in Benue State and Nigeria at large as schools get inundated thereby destroying school facilities and also sending school children and teachers temporarily away from the school. Experience in this area has also shown that flood causes buildings to collapse as they are socked in the flooded water. Even when the flood is over, teachers and pupils find it difficult to commence schooling immediately especially if the flooded water stayed for a long period causing damage to the infrastructural facilities as well as instructional materials among others.

The issue of climate change and its seeming impact on primary schools today has reached the point where effective use of relevant strategies would be explored and employed to curb the menace. It is against this background that the study investigated the impact of climate change related factors in the areas of changing rainfall patterns and flood on the management of public primary schools in Benue State of Nigeria.

II. Statement of Problem

In spite of the efforts of government and the administrators of primary schools in the Benue state of Nigeria to ensure conducive teaching and learning environment and pupils' attendance at schools, the problems associated with climate change seem to hamper and overwhelm these efforts. For instance, pupils have on several occasions seemed to fail to attend school during heavy rainfall. Even when they get to school, the noise produced by the rain may also distract their attention. The water collected from the rain can also lead to flooding and collapse of school buildings. Flooding often seems to forces pupils in Benue state of Nigeria just like any part of the world to relocate with their families to places that are safe from flooding thereby making pupils to abandon their education. Even when this deluge is abated, most schools seems to be unable to resume immediately because the damage done by the flood may have influenced them so badly that the environment may not be conducive for teaching and learning processes to take place. Some schools may also be indirectly influenced as hundreds or thousands of people may be camped in their premises throughout the flooding period thereby, denying the pupils access to education as well as damaging school facilities. Despite the aforementioned speculations of climate change related factors on the management of primary schools in Benue state of Nigeria, the researchers observed that not much has been done on the impact of climate change on the management of primary schools in the area of study. The problem of the study therefore is: To what extent does climate change related factors impact on the management of primary schools in Benue State of Nigeria?

a) *Research Questions*

The following research questions guided the study:

1. To what extent do changing rainfall patterns impact on the management of public primary schools in Benue State of Nigeria?
2. To what extent does flood impact on the management of public primary schools?

b) *Hypotheses*

The following null hypotheses were formulated and tested at 0.05 level of significance:

1. Changing rainfall patterns have no significant impact on the management of public primary schools in Benue State of Nigeria.

2. Flood has no significant impact on the management of public primary schools in Benue State.

c) Research Method

The study adopted the descriptive survey research design. The study was conducted in Benue State of Nigeria. The population comprised 15,987 teachers from 2,407 primary schools in Benue State during the 2017/2018 academic session (Benue State Ministry of Education, Science & Technology, 2018). A sample of 1,000 (6%) respondents from 122 (5%) primary schools was selected using multi-stage sampling technique (proportionate stratified random sampling and simple random sampling techniques). However, only 921 or 92% were returned whereas 79 or 8% were not returned due to the non-cooperative attitude of some teachers. This sample size is considered adequate since it is in line with Achor and Ejigbo's (2006) assertion that for a larger population, a sample of 10% of the population is adequate. Achor and Ejigbo, further stressed that the percentage could be higher or less depending on the population of the study.

A well-structured questionnaire titled "Climate Change Related Factors Questionnaire (CCRFQ)" was used for data collection. The questionnaire was divided into Sections A and B. Section A contained information on the personal data of the respondents, while Section B contained information that bordered on the extent to which changing rainfall patterns and flood impact on the management of primary schools in Benue State of Nigeria. The responses of teachers were collated and analyzed for results. Mean and standard deviation were used to answer the research question. The decision was based on the real limit of numbers. Hence a mean response score of 3.50-4.00 was considered Very High Impact (VHI), 2.50-3.49 High Impact (HI), 1.50-2.49 Low Impact (LI), while 0.50-1.49 was considered as Very Low Impact (VLI). The chi-square test of goodness-of-fit was used to test the hypotheses at $p<0.05$ level of significance.

III. Data Analysis and Interpretation

The results were analysed and interpreted in line with the research questions and hypotheses as follow:

Research Question One: To what extent do changing rainfall patterns impact on the management of primary schools in Benue State of Nigeria?

Table 1: Mean Ratings and Standard Deviation of the Impact of Changing Rainfall Patterns on the Management of Primary Schools

S/No.	Item Description	N	VHI	HI	LI	VLI	*M*	*SD*	Decision
1	In my school, heavy rainfall stops pupils from attending school and this affects discipline.	921	400	359	85	77	3.23	0.73	High Impact
2	In my school, heavy rainfall causes erosion thereby preventing parents/guardians from taking their children/wards to school.	921	200	342	275	104	3.02	0.82	High Impact
3	In my school, heavy rainfall causes noise that interferes with effective teaching and learning in the classroom and this affects coordination.	921	622	145	104	50	3.15	1.17	High Impact
4	In my school, heavy rainfall leads to collapse of school buildings thereby forcing the school management to budget extra funds for the maintenance of such facilities.	921	182	409	124	206	2.82	1.04	High Impact
5	In my school, heavy rainfall disrupts extra-curricular activities in primary schools.	921	534	207	130	50	3.11	1.01	High Impact
	Cluster Mean and Standard Deviation	921					3.07	0.953	High Impact

Source: Fieldwork, 2018

Table 1 showed that the respondents have the mean rating scores of items 1-5 are 3.23, 3.02, 3.15, 2.82 and 3.11 with the corresponding standard deviations of 0.73, 0.82, 1.17, 1.04 and 1.01 respectively. From Table 1, the respondents agreed that in their schools, heavy rainfall stopped students from attending schools and this affected discipline. Heavy rainfall also caused erosion thereby preventing parents/guardians from taking their children/wards to school. The respondents further agreed that heavy rainfall caused noise that interfered with effective teaching and learning in the classroom and affected

coordination. The respondents similarly opined that heavy rainfall caused school buildings to collapse thereby forcing the school management to budget extra funds for the maintenance of such facilities. Moreover, the respondents also were of the opinion that heavy rainfall disrupted extra-curricular activities in secondary schools. The cluster mean of 3.07 with the standard deviation of 0.95 was above the cut-off point of 2.50. This means the respondents agreed that changing rainfall patterns influence the management of public secondary schools to a high extent.

Research Question Two: To what extent does flood impact the management of primary schools?

Table 2: Mean Ratings and Standard Deviation of the Impact of Flood on the Management of Primary Schools

S/No.	Item Description	N	VHI	HI	LI	VLI	*M*	*SD*	Decision
6	Flood covers roads that lead to my school thereby making pupils to stay away from attending school which affects proper coordination.	921	459	200	187	75	2.89	0.87	High Impact
7	Flood submerges classrooms in my area thereby disrupting effective teaching and learning as well as supervision.	921	300	242	275	104	3.16	0.96	High Impact
8	Flood water enters staff offices and destroys documents of schools in my area which influences effective record management.	921	422	345	100	54	2.63	0.80	High Impact
9	Flood submerges play grounds of schools in my school thereby disrupting students' extra-curricular activities.	921	282	309	125	205	3.33	0.87	High Impact
10	Families displaced by flood camp in my school thereby distorting school calendar.	921	534	107	230	50	2.62	1.01	High Impact
	Cluster Mean and Standard Deviation	921					2.93	0.90	High Impact

Source: Fieldwork, 2018

Table 2 showed that the mean ratings of items 6-10 are 2.89, 3.16, 2.63, 3.33 and 2.62 with the corresponding standard deviations of 0.87, 0.96, 0.80, 0.87 and 0.01 respectively. Item by item analysis showed that respondents were of the opinion that flood covered roads leading to schools thereby making pupils to stay away from attending school on time which affected proper coordination. Respondents also unanimously agreed that flood submerged classrooms thereby disrupting effective teaching and learning as well as supervision. The respondents further affirmed that flood water entered staff offices and destroyed documents of schools which affected effective record management. In addition to that, the respondents opined that flood submerged play grounds of schools thereby disrupting pupils' extra-curricular activities. Moreover, their responses showed that families displaced by flood were camped in respondents' schools thereby distorting schooling calendar. The cluster mean of 2.93 with the standard deviation of 0.90 was above the cut-off point of 2.50.This means that flood impact on the management of primary schools in Benue State of Nigeria to a high extent.

Hypothesis Ono: Changing rainfall patterns have no significant impact on the management of primary schools in Benue State.

Table 3: Chi-square Test of the Impact of Changing Rainfall Patterns on the Management of Primary Schools

Responses	Observed Frequency	Expected Frequency	df	Level of Sig.	χ^2-Cal.	χ^2-Crit.	*P-value*	Decision
NI	27	230.3						
LI	83	230.3	3	0.05	568.09	7.82	.000	Significant
HI	462	230.3						
VHI	349	230.3						
Total	921							

Source: Fieldwork, 2018

Table 3 shows that χ^2-cal. $= 568.090^{a} > 7.815$; $P<.05$ with 3 degree of freedom. Thus, the null hypothesis which states that changing rainfall patterns have no significant impact on the management of primary schools was rejected. This means that changing rainfall patterns have significant negative impact on the management of primary schools in Benue State.

Hypothesis Two: Flood has no significant impact on the management of primary schools.

Table 4: Chi-Square Test of the Impact of Flood on the Management of Primary Schools

Responses	Observed Frequency	Expected Frequency	df	Level of Sig.	χ^2-Cal.	χ^2-Crit.	*P-value*	Decision
NI	99	230.3						
LI	111	230.3	3	0.05	472.21	7.82	.000	Significant
HI	507	230.3						
VHI	204	230.3						
Total	921							

Source: Fieldwork, 2018

Table 4 shows that χ^2-cal.= 472.212$^{\alpha}$ > 7.815; *P<.05* with 3 degree of freedom. Thus, the null hypothesis which stated that flood has no significant impact on the management of primary schools was rejected. This result clearly shows that flood has significant impact on the management of primary schools.

IV. Discussion of Findings

The first finding revealed that changing rainfall patterns have significant impact on the management of primary schools in Benue State, Nigeria. This finding confirms Recha, Makokha, Traore, Shisanya, Lodoun and Sako (2012) who reported that persistence of below normal rainfall is a great risk to people's livelihood in Tharaka District in Kenya, where majority of people have been left vulnerable to hunger and famine. Schools were not left out as families could barely afford one square meal talk more of paying their children's school fee and other school necessities. Recha*et al,* further note that the situation led to heat and dust that severely affected pupils' health in the area. Similar observations have been reported by various scholars, for example intra-seasonal factors, such as the timing of the onset of first rains affecting crop-planting regimes (Tennant & Hewitson, 2002), the distribution and length of period of rain during the growing season (Mortimore & Adams, 2001), and the effectiveness of the rains in each precipitation event (Usman& Reason, 2004), are the real criteria that affect the people as well as the management of schools. IPCC (2007) reported that changes in rainfall amount and patterns also affect soil erosion rates and soil moisture, both of which affected body temperature as well as condition of roads that leads to schools in the area. However, Orogwu's (2009) study contravened the current findings as it discovered that rainfall has significant positive influence on human lives as it established that the temperature calm down the human body system that gives them the room to think more properly. Orogwu (2009) also found out that the calm temperature provided by rainfall influenced reading and better comprehension on the part of the students. This does not mean that the result of the current study is not relevant. The variation could be due to the nature of rainfall within the different areas as well as the kind of infrastructural facilities in place. The researchers' current observation during the fieldwork revealed that heave rainfall caused flood in the study area due to the poor drainage system as well as building of houses and schools on water channels. Pupils were unable to attend school or close from school as the roads that link schools with the homes were covered with water. The heavy rainfall also led to the falling down of some school buildings which would force the school management to make extra-budget to put them in place.

The second and the last finding revealed that flood has significant negative impact on the management of primary schools. This finding supports Kimei (2013) who found that five out of seven schools were affected by floods directly when facilities were flooded and indirectly when schools premises were used as shelter by the community when their homes were flooded. In times of flood, learning is severely disrupted by such flooding disasters as pupils and teachers are sent home during such disasters. This would thereby disrupt effective teaching and learning programmes in schools. Similarly, United Nations International Strategy Disaster Reduction (2006-2007) found that when flood disaster strikes, infrastructural facilities in the schools were greatly destroyed or damaged. This makes it hard for learners to continue with their learning activities for a long time. This is because the buildings, playgrounds, farmland and all records as well as instructional materials may be covered and destroyed by the flooding water. Hassanain (2006) concluded that floods disrupt the daily life of teachers and pupils and life might not return to normal quickly. The researchers discovered during their fieldwork that when flood occurred, important school facilities such as classrooms and playgrounds as well as documents were damaged thereby disrupting the daily routine of learning. It adversely affected the coverage of the syllabus and indirectly affected the school year calendar. Pupils were unable to play and have games which also affected school supervision and evaluation of their extra-curricular life.

V. Conclusion

Based on the results of the study, it has been established that climate change related factors in the areas of changing rainfall patterns and flood have significant impact on the management of primary

schools in Benue State of Nigeria. This therefore, forms the bases why it is necessary to have knowledge of the environment especially the climate, as any little change in it may influence all the aspects of life including the school and its management.

VI. Recommendations

Based on the findings of the study, the following recommendations were made:

1. School management should take precautionary measures in maintaining school facilities that are exposed to continuous rainfall. Ceilings should also be installed in the classrooms to avoid unbearable noise that may be caused by the sound of rainfall.
2. Educational planners should make sure that henceforth; schools should not be sited in flood prone areas and should train principals and teachers on disaster preparedness for those schools already sited in such areas.

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Effect of Urbanization on Land use Land Cover in Gombe Metropolis

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Abstract- This study examined the integration of Remote Sensing and Geographic Information System (RS/GIS) for analyzing land use and land cover dynamics in Gombe Metropolitan, the Gombe State capital for the period 1976 to 2016. Land sat (TM) images of 1976, 1996and 2016 were used. The study employed supervised digital image classification method using Erdas Imagine 9.2 and Arc GIS 10.5 software and classified the land use into undisturbed vegetation, sparse vegetation, Settlements, Farmlands, Rock outcrops, Bare surfaces. The images were analyzed viageo referencing, image enhancement, image resampling and classification. The results obtained show an increasing settlements (from 0.36% - 4.01%) and farmlands (from 24.8% - 51.2%), over a decreasing of other LULC classes (bare surfaces, undisturbed and sparse vegetation, and rocky outcrops) for the time period of 1976 to 2016.

Keywords: *urbanization, land use/cover, change detection, gombe, remote sensing, GIS.*

GJHSS-B Classification: *FOR Code: 070199*

Strictly as per the compliance and regulations of:

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L.A. Mbaya[α], G. O. Abu[σ], Y.C. Makadi[ρ] & D.M. Umar[ω]

Abstract- This study examined the integration of Remote Sensing and Geographic Information System (RS/GIS) for analyzing land use and land cover dynamics in Gombe Metropolitan, the Gombe State capital for the period 1976 to 2016. Land sat (TM) images of 1976, 1996and 2016 were used. The study employed supervised digital image classification method using Erdas Imagine 9.2 and Arc GIS 10.5 software and classified the land use into undisturbed vegetation, sparse vegetation, Settlements, Farmlands, Rock outcrops, Bare surfaces. The images were analyzed viageo referencing, image enhancement, image resampling and classification. The results obtained show an increasing settlements (from 0.36% - 4.01%) and farmlands (from 24.8% - 51.2%), over a decreasing of other LULC classes (bare surfaces, undisturbed and sparse vegetation, and rocky outcrops) for the time period of 1976 to 2016. These results could help city planners and policy makers to attain and sustain future urban development. It is therefore recommended that encouragement should be given to people to build towards the outskirts, like New mile 3 and Tumfure, etc through the provision of incentives and forces of attraction that is available at the city center in these areas to avoid the problem of overcrowdings.

Keywords: urbanization, land use/cover, change detection, gombe, remote sensing, GIS.

I. Introduction

Land is the most important natural resources on which all activities are based. Land use unlike geology, is seasonally dynamic and indeed is more changing. The increase in population and human activities are increasing the demand on the limited land and soil resources for agriculture, forest, pasture, urban and industrial land uses. Information on the rate and kind of changes in the use of land resources is essential for proper planning, management and to regularise the use of such resources.

Land use / land cover are very dynamic in nature and have to be monitored at regular intervals for sustainable environmental development (Zubair, 2006). Population is a very important factor or agent of change in land-use in an area. For instance, as population increases, construction of dwellings increases, thus engendering conversion of cropland and forest land to settlements. These urban land-uses are of various types which could be for industrial, commercial, government, as well as transportation purposes.

The most obvious effect of urbanization - an effect which is implicit in its definition is an intensification, as well as diversification, of environmental resource exploitation. There are usually changes in the land cover and landscape pattern brought about by the shift from less intensive to more intensive uses of land. Such diversification of environmental resources exploitation is accompanied by increases in environmental degradation. By environmental degradation, it is meant the long-term loss in ecosystem function and productivity. Its symptoms include soil erosion, nutrient depletion, salinity, water scarcity, pollution, disruption of biological cycles, and loss of biodiversity (UNCED, 1992).

Urbanization is the driving force for modernization, economic growth and development, there is yet an increasing concern about the effects of expanding cities, principally on human health, livelihoods and the environment (UN-Habitat, 2003). Rapid urbanization, particularly the growth of large cities especially in Nigeria, is often associated with problems such as unemployment, poverty, inadequate health facilities, poor sanitation, urban slums and general environmental degradation (UNDP, 2008). All these pose a formidable challenge in many developing countries. The question that arises is whether the current trend in urban growth is sustainable, considering the accompanying urban challenges, especially in the developing countries (UNDP, 2008).

Studies have shown that there remains only few landscapes on the earth that still exist in their natural state. Due to anthropogenic activities, the earth's surface is being significantly altered and man's presence on the earth and his use of land has had a profound effect upon the natural environment, thus resulting into an observable pattern in the land use/land cover over time (Lambin, Geist and Lepers, 2003; Zubair, 2006; Long, *et. al.,*2008).

Ademiluyi, *et al.,* (2008) said rapid urbanization/industrialization and large scale agriculture and major changes in human activities have been identified as the major causes of the dramatic changes in land cover and land use patterns globally. Urban centers in Nigeria are facing the problems of over-stretched infrastructures, environmental degradation,

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seasonal flooding, destruction of natural vegetation, all resulting from increase in population (Joel, 2006).

The movement of people from rural to urban cities in search of better livelihood lead to an expansion of urban areas and increase in social and economic activities along flood plains thus increasing the risk of urban dwellers and infrastructures to natural disasters such as floods (Akinbami, Akinwumi and Salami, 1996; Ishaya, Ifetimehin and Okafor, 2008). The need for quantitative information on the environmental consequences of expansion of cities in Nigeria provided the basis for this study.

The aim of this study is to corroborate the increasing problem of urbanization on other land uses. The study explored the implications of the increasing urban expansion, spurred up by population growth, for environmental sustainability especially in Nigeria. Needless to state that the attainment of sustainable development will remain a mirage in Gombe in particular and Nigeria in general, if the current rate of urban population growth (such as natural increase and migration) and increasing environmental decay are not matched with proportionate economic growth and environmentally friendly development practices.

II. Materials and Methods

The study area is Gombe town and, it is located on latitude 10^0 13'and $10^0$20'N and longitude $11^0$02'and $11^0$16'E. The study area is limited to the urban area and environs. Some 9km radius around the town has been arbitrarily demarcated for the study with Union Bank round about, along Biu Road being the centre point (Fig.1).Gombe is located within the sub-Sahara climatic zone. It is characterized by two distinctive seasons, that is, dry season (November-April) and wet season (May-October). The dry season comes with the north-east trade winds over the region originating from Sahara belt. The wind is dry and dust laden accompanied by low pressure system. The wet season comes with the south-Westerly wind which is moisture laden, and originates from high pressure zone over the Atlantic Ocean to the low pressure zone over the Sahara. The rainfall here averages 907 mm. The vegetation of Gombe is within Sudan/Guinea savannah. This is characterized by shrubs and scattered trees with a different species of grasses. The soils are highly ferruginous, formed as a result of intensive weathering of the basement rocks.

a) Methodology

The datasets used in this study were mainly derived from Lands at imageries acquired in 1976, 1996 and 2016Theses imageries were sourced from one of the USGS websites; (https://glovis.usgs.gov/). The characteristics of the images are shown in Table 1. The Geo-information software used includes; IDRISI version 18 and Arc GIS, 10.0. The IDRISI Terrset was used in the image processing and analysis, while the Arc GIS was used for visualization of the processed images. Area of Interest (AOI) was extracted from the four (4) Lands at scenes using the "Window" tool in IDRISI. False Colour Composite (RGB) of the three bands for each of the selected dates was made in order to increase the pictorial quality for easy visual interpretation and identification of features on the images. The images were further subjected to geometric correction using the "Resampling" technique. This is carried out in order to co-register the images as suggested. The images were classified using the Maximum Likelihood algorithm into six classes (settlements, bare surfaces, undisturbed and sparse vegetation, rocky outcrops and farmlands).

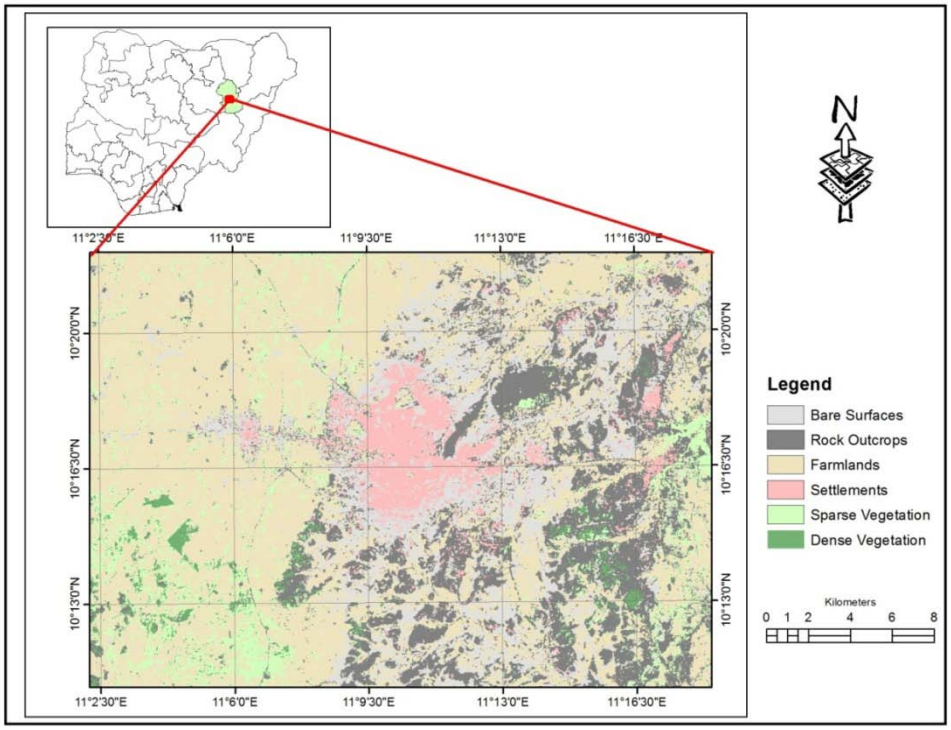

Figure 1: The Study Area

b) Procedure for Data Collection

The characteristics of the satellite images used in this study are contained in Table 1.

Table 1: Characteristics of Satellite Imageries

Date of acquisition	Type of satellite image	Spatial resolution (m)
1976	Landsat Multi Spectral Scanner (MSS)	30
1996	Landsat Thematic mapper (TM)	30
2016	Landsat Thematic mapper (TM)	30

The remote sensing and the geographic information system (GIS) technology and applications were applied in the determination of the land cover changes. The interpretation and classification of satellite images involved subsetting and other pre-processing steps including georeferencing, colour composite and unsupervised classification; ground truthing, screen digitization of some features, supervised classification and change detection. Subsetting consisted mainly in selecting and extracting the study area from the full scene images. Colour composite and unsupervised classification enabled us to establish major land cover classes before ground truthing to match the reality in the field with the classified image. After ground truthing, the supervised classification enabled to proceed on land cover map composition for each image.

c) Data Analysis

The obtained result was analyzed using tables and maps. The size and area of the land cover changes were calculated and represented in hectares. The rationale for these was based on the total size of the study area.

III. Results and Discussion

Sequel to the general objective of this study, it was observed that there was an exponential growth in the city which have led to the quest for land, housing and other facilities/infrastructures that have given rise to changes in land cover, thus, reduction and loss of other land uses.

Figures 1, 2 and 3 present the LULC of the study area during the study period. The statistics of the land use/land cover distribution for each study year as derived from the imageries is presented in Table 2.

Table 2: Land-use/Land Cover Distribution

Land use classes	1976 (hectares)	%	1996 (hectares)	%	2016 (hectares)	%
Undisturbed vegetation	21374.37	23.75	6052.50	6.70	1235.52	1.37
Sparse vegetation	33986.25	37.76	18373.77	20.42	8721.90	9.69
Settlements	324.45	0.36	978.84	1.09	3615.03	4.01
Farmlands	22327.56	24.81	38697.12	43.00	46112.94	51.24
Rock outcrops	1962.45	2.18	13916.34	15.46	15286.95	16.99
Bare surfaces	10024.92	11.14	11981.43	13.31	15027.66	16.70
Total	90,000	100	90,000	100	90,000	100

The supervised classification system using the maximum likelihood classifier as explained in the methodology was used for the analyses of the imageries. Figures 1, 2 and 3 shows the classified maps adopted in this study.

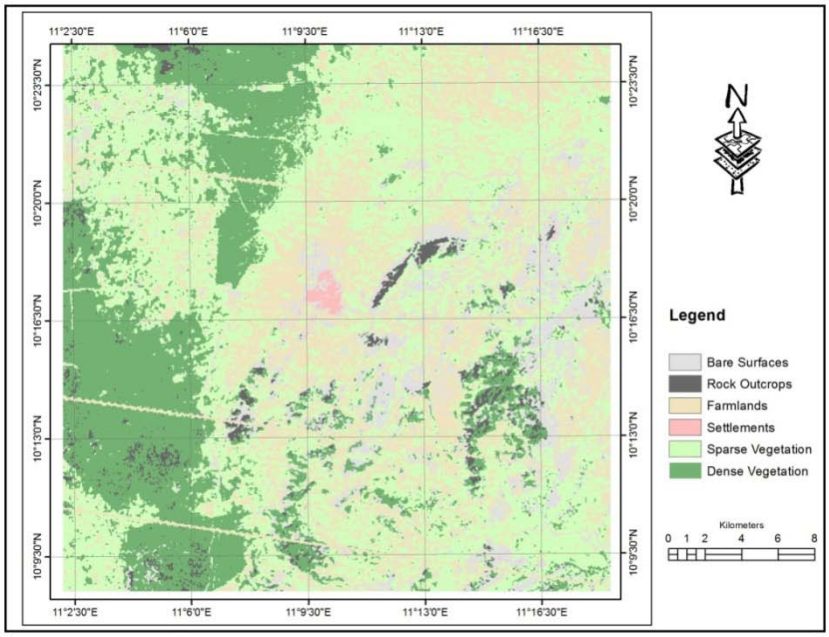

Figure 1: Classified Land Use Land Cover of 1976

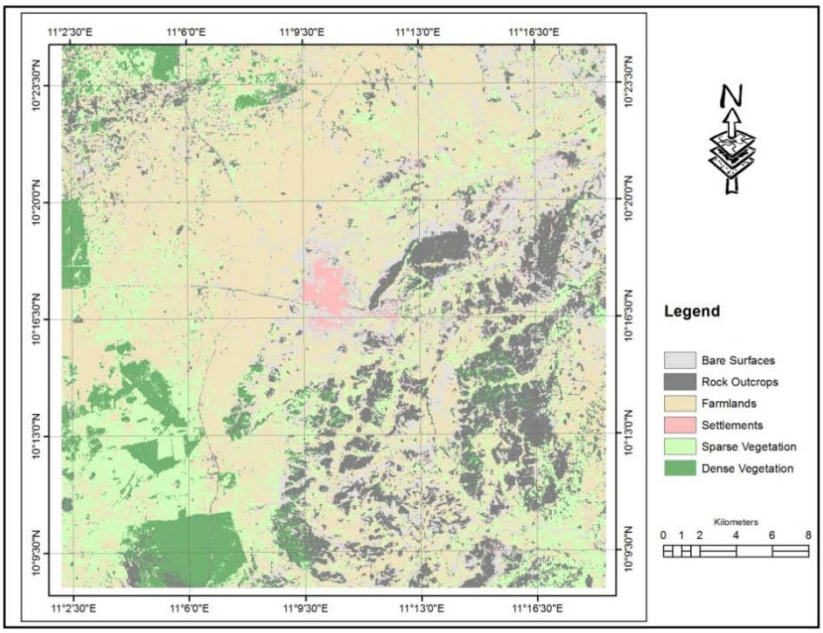

Figure 2: Classified Land Use Land Cover of 1996

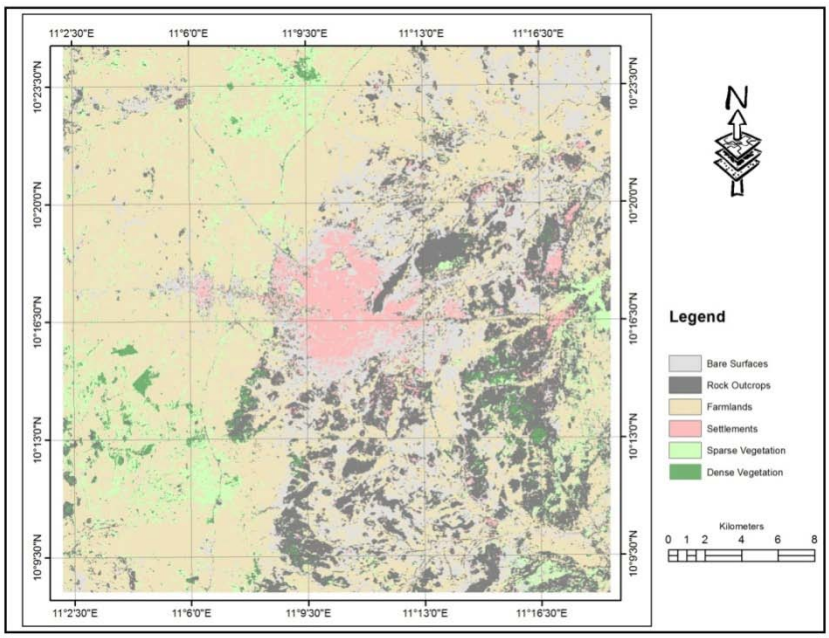

Figure 3: Classified Land Use Land Cover of 2016

As shown in Figure 4.4, the land-use/ land-cover distribution pattern in the year 1976 shows that sparse vegetation occupies 38% of the land-use category in the study area, followed by farmlands and undisturbed vegetation with a percentage of 25% and 24% respectively. This means that the vegetation as at then was readily abundant and there was available farmland with less competition on land uses. The bare surfaces had about 11% while rock outcrops had only 2%. The least of the land use was settlement which occupies about 0.4%.

The land-use/land-cover distribution for 1996 also shows that farmland occupies over half of the land-use distribution (43%) with almost two times increase from the 1976. This is followed by sparse vegetation 20% a decrease from 1976 land-use distribution, others on the increase are also rock outcrops, bare surfaces and settlements having 15%, 13% and 1% respectively. However, the undisturbed vegetation reduced to about 7% due to increase in settlements and farmlands.

In 2016, the land-use distribution shows increased in settlement which occupies 4%, while the farmlands occupied 51% of the land-use distribution making it the highest land-use/ land-cover category in the study area. Undisturbed vegetation showed a decrease occupying only 1% of the total area. The remaining land-cover categories of rock outcrop (17%) and bare surfaces (17%) showed an increase in these areas compared to the previous years except sparse vegetation that also showed a rapid decrease to 10% from 38% of 1976 and this is attributed to land-use conversion for other urban activities and increased population pressure. This conforms to the studies of Chigbu, *et al.,* (2011) who noted a significant disparity and trend in vegetation land cover due to rapid urbanization and socio economic activities. As well as Oluseyi, (2006) that discovered that the land use types that are subject to major changes are vegetal covers and sprawl development.

IV. Conclusion

Urbanization and ineffective legal frameworks had been discovered to be the major impediments to the ever growing land use changes in Nigeria. This has however contributed immensely to the poor economic structures and environmental degradation. The creation of Gombe State and Gombe as a state capital has attracted a lot of people to the area thus contributing to the physical expansion of the city.

Results of this study indicate that, supervised classification provided satisfactory results in terms of distinguishing settlements, bare surfaces, undisturbed and sparse vegetation, rock outcrops and farmlands. The main change observed for the time period of 1976 to 2016 was the decrease of undisturbed and sparse vegetation areas due to urbanization. Settlements are increasing in the study area as well as farmlands. Land use/land cover mapping and detection of changes shown here may not provide the ultimate explanation for all problems related to land use/land cover changes but it serves as a base to understand the patterns and possible causes and consequences of land use/land cover changes in the area.

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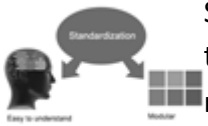

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11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.
Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

19. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

20. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

21. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

22. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

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Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

Index

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