





Forest Cover Change Analysis in the Mopane (*Colophospermum mopane*) Ecoregion in Zambia 1975 – 2010

Patrick W. Matakala, Jackson Mukosha, Wamunyima Sitwala and Abel Siampale

May, 2016

ACKNOWLEDGEMENT

The project that forms the subject of this report was sponsored by the German Federal Ministry of Education and Research under promotion number (01LG1201M). The author is responsible for the content of this publication. The Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) through the National Remote Sensing Centre (NRSC) as the National Executing Agency (NEA) on behalf of the Ministry of Higher Education supported the Centre for Environmental Research, Education and Development (CERED) to carry out this research. The author is sincerely grateful to the German Federal Ministry of Education and Research, SASSCAL and the Zambian Ministry of Higher Education.

LIST OF ACRONYMS

CERED	Centre for Environmental Research, Education and Development
CIDA	Canadian International Development Agency
DBH	Diameter at Breast Height
FAO	Food and Agriculture Organization of the United Nations
GMA	Game Management Area
GPS	Global Positioning System
GRZ	Government of the Republic of Zambia
Ha	Hectare
ILUA	Integrated Land Use Assessment
M^3	Cubic Metre
NP	National Park
NR	Near Infrared
NRSC	National Remote Sensing Centre
PF	Patriotic Front
PGR	Private Game Ranch
SAG	Sectoral Advisory Group
SAR	Synthetic Aperture Radar
SASSCAL	Southern African Science Service Centre for Climate Change and Adaptive Land Management
SPH	Stems Per Hectare
SWIR	Short-wave Infrared
TCP	Technical Cooperation Programme
TIR	Thermal Infrared
TM	Thematic Mapper
TOR	Terms of Reference
UTM	Universal Traverse Mercator

EXECUTIVE SUMMARY

The Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) through the National Remote Sensing Centre (NRSC) engaged the Centre for Environmental Research, Education and Development (CERED) in 2013 under Task 221 to undertake research on forest cover change analysis in the Mopane Ecoregion of Zambia predominated by *Colophospermum mopane* over a 35-year period (1975-2010).

The review describes forest cover change from one epoch to the other: 1975 – 1990, 1990 – 2000 and 2000 – 2010 by showing maps (forest and non-forest) supported by narrative descriptions of what changes took place highlighting the changes in statistical terms. Based on the generated statistics of forest cover change, a description is given of the current status of mopane forests in the different biomes analyzed (including stocking levels) including specific recommendations on how to sustainably manage the mopane forests in Zambia in the future.

The land area of Mopane Ecoregion as classified on 1975 Landsat TM satellite imagery is in extent of approximately 4,428,000 hectares or 5.9% of the land area of Zambia. The distribution of mopane woodland is in Central, Eastern, Muchinga, North/Western, Southern and Western provinces.

The total change during the period under review from 1975 to 2010 indicates a reduced hectarage of mopane woodland at approximately 781,000 hectares or an annual rate of 22,000 hectares primarily due to conversion of forest cover to agriculture and fuelwood production (cutting for firewood and charcoal production). The change from 1975 to 1990 and from 2000 to 2010 was negative and the period 1990 to 2000, the change was positive. These phenomena could be attributed to seasonality of satellite imagery used in the classification or the potential of mopane woodland to regenerate or coppice if the affected area is not exposed to permanent agriculture and late bush fires.

The most common tree species in the mopane woodland in Zambia are eight (8) with *Colophospermum mopane* forming the dominant species with more than 85% of the stocking per hectare and in good drained soils forms pure stands.

The analyses have further revealed that in 2010 the total Mopane Ecoregion in Zambia forest cover stood at 3,461,000 and non-forest at 970,341 hectares. The mean stems per hectare for all species at +/- 150 and diameter class volume of 46 cubic metres. The estimated stocking in 2010 from stems (dbh) =/+ 5cm and above) for all species was approximately 519,150,000 with volume above ground of 159,206,000 cubic metres.

The area as large as the Mopane Ecoregion in Zambia needs a lot of field visitation at different periods of the year especially when dealing with remote sensing satellite imagery data to avoid misclassifications.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

1. BACKGROUND

The vegetation of Zambia is presented in the map compiled by A.C.R Edmonds, scale 1:500,000 in 1976 (Edmunds, 1976) from field data generated on aerial photos of 1975. The vegetation color key and types were based on the system adopted for Central Africa at Yangambi, in 1957. A detailed account of the vegetation types is documented in Forest Research Bulletin No. 7; "The Vegetation of Zambia", published by Government Printers in 1971.

The 1976 Vegetation Map of Zambia is grouped into five major types as follows (Edmunds, 1976):

(i) Dry Evergreen Forest

This is a three-storeyed forest with a closed evergreen or semi-deciduous canopy 25 to 27 metres high with occasional taller emergents, a discontinuous evergreen understory 9 to 15 metres high and dense evergreen shrub-scrambler thicket 1.5 to 6 metres high. It occurs on three distinct sites; (a) plateau, (b) the Bangweulu lake basin, and (c) northern Kalahari basin; always on level or gently undulating ground. The disturbance of these forests by fire and permanent cultivation results in their degradation to miombo woodland or Kalahari woodland or Chipya. The types that form the Dry Evergreen Forest are Parinari, Marquesia, Lake Basin Chipya, Cryptosepalum and Kalahari Sand Chipya.

(ii) Dry Deciduous Forest

This is a two-storeyed forest having an open or closed over wood, usually deciduous, and an under wood shrub layer of deciduous or partly evergreen thicket. The disturbance of this type of forest by fire and cultivation results in almost the same degraded types of woodland or chipya as the case with the dry evergreen forests. The types that form the Dry Deciduous forest are *Baikiaea* (Zambezi teak) and *Itigi.*

(iii) Moist Evergreen Forest

This is a variable three-storeyed forest sub-divided into montane, swamp and riparian types. Destruction of this type of forest leads to biotic grassland or reed beds. The types that form the Moist Evergreen Forest are Montane, Swamp and Riparian.

(iv) Woodland

This is a one-storeyed or two-storeyed structured with a dense ground cover of suffrutices and grasses. The miombo woodland is probably derived from degraded type 1 and 2, the Kalahari woodland from type 4 and 6. The types that form the woodland are Miombo woodland, Hill woodland, Kalahari woodland, **Mopane woodland** and Munga woodland.

(v) Other Vegetation Types

All types of vegetation, i.e. forest, woodland, thicket, scrub and grassland can be found on or around the bases of termitaria. They have been classified by habitat rather than by vegetation type, because to some extent the one limits the other. The types that form other vegetation type are Termitaria vegetation and bush groups and Grasslands.

1.1 Rationale

The advent of space borne satellites, data capture for various applications have improved. The launch in 1972 of Landsat 1 (One) and later the Landsat improved family, Spot, Aster, and now Ikonos provide the user with very recent images taken of the earth, also the improvement in the resolution of latest sensors enables the user to extract some information needed for various applications, such as land cover change over a period of time, monitoring for example of fires and deforestation, etc.

The space borne remote sensing data offers most update information of the earth, since the satellite cover the earth periodically. In Landsat case, it takes approximately 16 days to cover the same area, in Spot case it takes about 26 days to cover the same area. While in the case of Synthetic Aperture Radar (SAR) sensor there is a great advantage in terms of its ability to produce earth data in all weather conditions, day and night with good resolution.

This analysis will therefore provide the information of the mopane forest cover in the ecoregion of Zambia based on low resolution satellite imagery over a time span of 35 years.

1.2 Objective

The objective of this analysis is to provide baseline information on estimated *Colophospermum mopane* woodland cover change over a 35 period from 1975 – 2010 using low resolution satellite imagery.

1.3 Terms of Reference

The specific Terms of Reference (TORs) for the study are as follows:

- Conduct an integrated baseline assessment of the mopane forest resource cover in the ecoregion over a 35-year period (1975-2010) based on low resolution satellite imagery, geographically focused high resolution images and extensive ground–trothing (including explanation of methodology and approaches taken, maps and baseline inventories for each epoch);
- Describe the key threats and drivers of deforestation in mopane woodlands within the ecoregion (and the current status including stocking levels);
- Describe the socio-economic contributions of mopane woodlands to the local (community-level) economies in the ecoregion; and
- Recommend a monitoring system for mopane woodland conservation at national level to ensure sustainable forest management (including recommendations on how to sustainably manage the mopane forests in Zambia in the future.

Key Questions

-How much *Colophospermum mopane* woodland cover changed over time in Zambia?

-What are the main drivers of mopane woodland cover change?

2. LITERATURE REVIEW

In recent times, the forest woodland in Zambia has been under tremendous human induced pressures and natural changes. Changes in the forest cover generally imply either a conversion or a modification (Mather, 1987). These processes are described as deforestation and forest degradation, respectively. Despite growing concerns and the recognition of the ecological, social and economic importance of forests, disagreements exist about the extent and mechanism of tropical woodland deforestation due to differences in estimation and definition (Serneels, 2001).

Human intervention in forest environments as they struggle to satisfy basic livelihoods demands are generally accepted as the main trigger behind forest conversion in tropical areas (CIDA, 2001; Mertens, 1999; Myers, 1991). The rate of deforestation is alarming. According to the Global Forest Resources Assessment Report (FAO, 2015), Africa and South America had the highest net annual loss of forests in 2010-2015, with 2.8 and 2 million hectares respectively, but the report notes how the rate of loss has "substantially decreased" from the previous five year period. Since 1990 most deforestation has taken place in the tropics. In contrast, net forest area has increased in temperate countries while there has been relatively little change in the boreal and subtropical regions.

Though it is difficult to produce accurate figures of deforestation in Zambia, the Integrated Land Use Assessment (ILUA 1) project 2005 – 2008 have pointed to an alarming rate of forest cover change of between 250,000 – 300,000 hectares.

The importance of investigating land cover dynamics as a baseline requirement for sustainable management of natural resources has been highlighted by many researchers involved in global change studies (Brandon *et al*., 1998; Chen, 2002; Jansen *et al*., 2002; Mertens, 1999; Mertens *et al*., 2000; Petit *et al*., 2001; Primack, 1993; Read *et al*., 2002; Serneels, 2001; Serneels *et al*., 2000). These scientists have argued that a more focused management intervention requires information on the rates and the impacts of land cover change as well as the distribution of these changes in space and over time.

2.1 Colophospermum mopane Ecoregion in Zambia

The Know Your Trees Book on some of the common trees found in Zambia compiled by A.E.G. Storrs (1979), described *Colophospermum mopane* as a deciduous shrub or tree with a heavy, rounded, but occasionally narrow crown, which can reach a height of 21 metres.

Mopane occurs mainly on the heavy clay soils of the Lower Zambezi, Kafue and Luangwa valleys and their tributaries where it forms extensive pure woodlands, but it is also found in small pockets in miombo, munga and riparian woodland and thickets and on termitaria in areas adjacent to valleys.

It is a valuable browse species for both cattle and game, even the fallen leaves being eaten, and it is so liked by elephants that some areas of mopane woodland in the Luangwa valley are being devastated; the elephants push over the trees to make the leaves more accessible. The tree is host to the mopane caterpillar which is wildly eaten and sold at household level mostly in rural areas of Zambia.

The Wood Consumption and Resources Survey of Zambia conducted by the Forestry Department through the support of FAO/TCP/ZAM/4491 project in 1984 characterized Zambia's vegetation and forest types (Table 1 – only showing forest types and numbered). The objective was to give, by province, the area of each of the forest types based on the "Vegetation Map of Zambia", compiled by Edmunds (1976) by province (Table 2).

The validity of this analysis depended on the basic material used; the "Vegetation Map of Zambia" produced by Edmunds in 1976, and basic analytical inputs were from the years 1973 – 1975 (Figure 1).

Table 1: The Vegetation Map of Zambia (1976 based on 1973-1975 data)

ID Vegetation Type	Forest Type
DRY EVERGREEN FOREST	
Type 1.	Parinari Forest
Type 2.	Marquesia Forest
Type 3.	Lake Basin Forest
Type 4.	Cryptosepalum Forest
Type 5	Kalahari Forest
DRY DECIDUOUS FOREST	
Type 6.	Baikiaea Forest
Type 7.	Itigi Forest
MOIST EVERGREEN FOREST	
Type 8.	Montane Forest
Type 9.	Swamp Forest
Type 10.	Riparian Forest
WOODLAND	
Type 11.	Miombo Woodland on plateau
Type 12.	Miombo Woodland on hills
Type 13.	Kalahari Woodland
Type 14.	Mopane Woodland
Type 15.	Munga Woodland
OTHER VEGETATION	
Type 16.	Termitaria vegetation and bush groups
Type 17.	Grasslands
Type 18.	Inland waters, lakes, dams etc

Table 2: The Vegetation of Zambia (A country analysis by province)

Unit 1000 hectare

Vegetation Type	Central Province	Copperbelt Province	Eastern Province	Luapula Province	Lusaka Province	Northern Province	North Western	Southern Province	Western Province	Total Zambia
Dry Evergreen Forest										
1.	0	13	0	0	0	0	29	0	0	42
2.	0	0	0	0	0	43	0	0	0	43
3.	171	128	4	524	0	740	58	0	0	1 625
4.	0	0	0	0	0	0	952	0	812	1 764
5.	0	0	0	0	0	0	0	2	140	142
Sub-Total	**171**	**141**	**4**	**524**	**0**	**783**	**1 039**	**2**	**952**	**3 616**
Dry Deciduous Forest										
6.	71	0	9	1	48	4	50	222	438	843
7.	0	0	0	16	0	139	0	0	0	155
Sub-Total	**71**	**0**	**9**	**17**	**48**	**143**	**50**	**222**	**438**	**998**
Moist Evergreen Forest										
8.	0	0	0	0	0	0	4	0	0	4
9.	0	2	0	0	0	2	149	0	0	153
10.	11	0	64	1	3	1	3	1	8	92
Sub-Total	**11**	**2**	**64**	**1**	**3**	**3**	**156**	**1**	**8**	**249**
Woodland										
11.	5 715	2 376	3 904	2 939	1 215	9 517	5 886	3 295	440	35 287
12.	17	0	6	3	324	11	5	0	0	366
13.	36	19	0	0	0	0	2 513	823	6 370	9 761
14.	587	0	1 638	0	0	1 008	17	1 019	159	4 428
15.	811	1	920	1	468	81	28	1 044	373	3 727
16.	411	64	73	39	7	659	525	197	798	2 773
Sub-Total	**7 577**	**2 460**	**6 541**	**2 982**	**2 014**	**11 276**	**8 974**	**6 378**	**8 140**	**56,342**
Total Wooded	**7 830**	**2 603**	**6 618**	**3 524**	**2 065**	**12 205**	**10 219**	**6 603**	**9 538**	**61 205**
Other Vegetation										
17.	1 586	528	292	1 094	122	2 284	2 362	1 677	3 071	13 016
In Land Water Bodies										
18.	24	2	0	437	2	307	0	247	31	1 050
Total Land Area	**9 439**	**3 133**	**6 911**	**5 054**	**2 189**	**14 779**	**12 582**	**8 528**	**12 640**	**75 261**

Figure 1: The Vegetation Map of Zambia (1975) Scale: 1:500 000

The vegetation map of Zambia was compiled by A.C.R. Edmonds, Forest Department of the Government of the Republic of Zambia (1976). Scale 1:500,000. The map was printed by Institute for Angewandte Geodesy, Frankfurt, Germany under the auspices of the Federal Republic of Germany in its Programme for Technical Co-operation with the Republic of Zambia in 1976.

In terms of C. mopane distribution in the country, Muchinga Province accounts for more land area followed by Eastern and Southern provinces; the least occurs in North-western province (Table 3).

Table 3: *C. mopane* distribution in Zambia by province

No.	Name of Province	Area Covered by Mopane Ecoregion in Hectares
1	Central	587,000
2	Eastern	1,028,000
3	Muchinga	1,618,000
4	North-western	17,000
5	Southern	1,019,000
6	Western	159,000
Total Area		**4,428,000**

2.2 Species Diversity

Fanshawe (1971) found the diversity of the most common woody species in various vegetation types of Zambia as tabulated below (Table 4): A total of 1,706 of different species were documented. In the Mopane Ecoregion 88 species or 5.2% of species diversity were recorded (Table 4).

Table 4: Species diversity in the various vegetation types in Zambia

	Number of Species						
Vegetation Type	**Canopy Species**	**Under-story Species**	**Shrubs**	**Thickets**	**Climbers**	**Total**	**% of Species**
Dry evergreen forest	12	19	56	-	22	109	6.4
Lake basin (Chipya)	40	38	114	-	8	200	11.7
Baikiaea forest	21	-	20	43	8	92	5.4
Itigi forest	28	-	51	-	13	92	5.4
Montane forest	38	35	41	-	23	137	8.0
Swamp forest	23	13	31	-	12	79	4.6
Riparian forest	46	35	63	-	30	174	10.2
Miombo woodland	23	34	83	-	3	143	8.4
Kalahari woodland	20	23	102	-	9	154	9.0
Mopane woodland	16	26	38	-	8	88	5.2
Munga woodland	51	46	110	-	23	230	13.5
Termitaria	47	31	89	-	41	208	12.2
Total	**365**	**300**	**798**	**43**	**200**	**1,706**	**100**

Source: Species diversity - Fanshawe (1971)

As a consequence of increased forest cover change in some localized parts of the Mopane Ecoregion, natural forests and soils are damaged. In some areas there is a serious decline in the availability of forest products, such as fuelwood, building poles and other wood products. Due to the scarcity of forest products, local communities in the Mopane Ecoregion spend a lot of time looking for the necessary forest products. This in turn hinders their participation in other developmental activities. Also land degradation takes place through soil erosion, which causes a reduction in soil fertility and therefore decreasing the agricultural crop productivity. Most local communities in the Mopane Ecoregion fail to participate in nursery establishment, tree planting, woodlots and natural forests management due to limited extension services and local level capacity.

The poor rural communities, in particular, tend to be the hardest hit by environmental degradation and the least well equipped to protect themselves, yet at the same time, they cause much of the damage out of short-term necessity and lack of alternative income generating sources. Therefore, empowerment of local communities with knowledge and skills to take care of their forests is fundamental to securing local livelihood systems that conserve the local natural resource base. The change detection in the Mopane Ecoregion aims at valuing and developing local people's knowledge and skills, and provide them with appropriate information to achieve self development.

3. METHODOLOGY

3.1 Land Cover Change Detection, Qualification and Quantification

Land cover change detection is the process of identifying differences in the state of an object in this case forest cover by observing it at different times. Essentially, land cover change detection involves the ability to quantify temporal effects using multitemporal datasets. Remotely sensed data obtained from earth orbiting satellites is an important data source for land cover change detection because of repetitive coverage at short intervals and consistent image quality.

The objective of analyzing the spatio-temporal dynamics of land cover in this project is to monitor the evolution of the natural vegetation cover in the Mopane Ecoregion of Zambia. This is based on post classification comparison of independently classified land cover maps: 1975-1990; 1990-2000; and 2000-2010 by showing forest and non-forest. Land cover changes are investigated for the period 1975-2010. This is done in order to determine if there is a difference in the rate, the trends and factors that cause land cover change in the stated period. The spatial data collection required to estimate from the historical spatial analysis of forest change and non-forest in the Mopane Ecoregion that have been most affected by deforestation since 1975.

3.2 Approach used in Preparation of Landsat Satellite Data

A total of 18 segments of Landsat TM satellite image colour composite images were used in analysis of forest cover change. The colour composite images were made of band 4 in near-infrared; band 5 in mid-infrared; and band 3 in visible part of the electromagnetic spectrum.

The false colour satellite images were geometrically corrected and projected to UTM Coordinate System, Datum WGS 84. The choice of bands 4:5:3 for the colour composite images was needed to better detect forest cover. The colour composite images were clipped using the mopane forest type boundary to generate the images for the Mopane Ecoregion for each year, i.e. 1975, 1990, 2000 and 20010. The software applied in the process of image analysis and data computation was ENVI 4.7 and QGIS 1.8.0.

3.3 Forest/and Non Forest Cover Map Generation

The classification of Landsat satellite images covering the Mopane Ecoregion was applied using the ENVI 4.7 software. The classification method adopted was supervised classification using the Maximum Livelihood Classifier. The computer was trained using pixels values of forest and non-forest areas. A total of eighteen (18) forest and non-forest thematic maps were generated for each epoch period. The final stage was the seamless forest/non forest cover maps then converted to vector from raster format to enable querying for area statistics in the Mopane Ecoregion.

3.4 Forest/Non Forest Cover Validation Maps

The map validation was done by collecting GPS points indicating forest and non-forest (agriculture areas, settlements, open areas, water, etc.) in selected parts of the ecoregion (Annex

2). Local expert knowledge was also applied in determining the extent of mopane areas in Zambia.

The Global Position System (GPS) coordinates were applied to create a forest and non-forest point map to which the forest parameter attributes of forest or non-forest were assigned. The validation was further checked with Google earth imagery and field experience during the Integrated Lands Use Assessment (ILUA II) project field work covering the whole country.

The forest/non-forest point feature maps were over-laid with each of the forest/non-forest forest cover maps for 2010 to generate a cross table from which error matrices were created. Following this process, the overall accuracy statistical was computed. The overall accuracy was computed by way of dividing the correctly classified points by total number of points multiplied by 100 percent using the Kappa statistic formula; K = (po – pe), where K is the kappa statistic, "po" is the observed proportion of the correctly classified outcomes; "pe" is the correctly classified cases expected by chance also referred to as chance agreement. Note that an overall accuracy of 75%; kappa of 0.5 and above is statistically acceptable.

3.5 Generation of Statistics, Forest Cover Change Analysis

The forest and non-forest cover maps in the vector format were analyzed to determine the changes in forest cover between the years 1975 – 1990; 1990 – 2000; and 2000 – 2010. The outcomes of the analysis were statistics which show either an increase or decrease in forest cover. The statistics on forest cover were generated for each difference years. Change maps were generated to show change of forest cover to non-forest and non-forest to forest cover for the periods 1975, 1990, 2000, and 2010 (Annex 2).

3.6 Drivers of Deforestation and Forest Degradation

The drivers of deforestation and forest degradation were inferred from earlier work undertaken by the team in the ecoregion. The principal drivers and threats in order of ranking are:

- Agricultural extensification or expansion necessitated by poor soil fertility. To meet agricultural yields mainly for subsistence purposes, communities are inclined to convert forests (still rich in soil nutrients) to agricultural lands which they will cultivate for 2-3 years after which the nutrients are exhausted and forced to convert more virgin forests to agricultural lands; and

- Fuelwood collection. This includes both firewood and charcoal both sold on the market. Mopane charcoal or firewood is regarded as of high value due to the wood's high density and high calorific value compared to other natural species in the country. This has tended to push demand higher for both firewood and charcoal derived from mopane resulting in both deforestation and forest degradation.

Other proximate drivers include:

- Increased land demand for settlement resulting in high rates of in-migration principally driven by foreseen opportunities to sell fuelwood of high value charcoal and firewood;

- Late bush fires affecting natural regeneration of C. mopane;
- Infrastructure development such as hydro-dams and infrastructure associated with mineral exploration, settlement and service provision to potential labour force (roads, health facilities, education facilities, etc.); and
- Natural disasters. The Mopane Ecoregion occurs mainly in lowland areas or valleys that are highly prone to floods which affect the regenerative capacity of *C. mopane*. They are also regularly prone to droughts thus forcing local communities to exploit the forests as the only viable source of income generation to meet their subsistence needs due to inherent agricultural failure.

3.7 Satellite Imagery Related Factors

There are four image-related factors that should be considered when determining what imagery is most suitable for a given application (www.geoimage.com.au). These factors are spatial resolution, spectral resolution, temporal and radiometric resolutions. The factors are briefly explained below:

3.7.1 Spatial resolution

The spatial resolution is the smallest picture element of the image (pixel size) and is related to the smallest object the image can detect. Each image is made up of a grid of pixels which when viewed together create an image. Spatial resolution will affect the detail that you can see and the map scale that an image can be reproduced and still maintain clarity.

3.7.2 Spectral resolution

The spectral resolution of the imagery is the "colour" range of the image. Images record different parts (bandwidths) of visible and invisible light and hence will have different applications and interpretations (Table 5). When red light is passed through one bandwidth, green through another, and blue through another a colour image is created. Different bandwidths will show different information about the vegetation, soil and water.

Table 5: Different bandwidths and their applications

Bandwidth (micro-metres)	**Application**
0.45-0.52 (visible blue)	Differentiation of soil from vegetation, affected by haze
0.52-0.60 (visible green)	Vegetation vigour assessment
0.60-0.69 (visible red)	Vegetation cover discrimination
0.76-0.90 (NIR)	Determining biomass content and delineation of water bodies
1.55-1.75 (SWIR)	Vegetation and soil moisture content
2.08-2.35 (SWIR)	Discrimination of soil type
10.40-12.50 (TIR)	Vegetation heat stress analysis, soil moisture discrimination

NIR = Near Infrared, SWIR = Short-wave Infrared, TIR = Thermal Infrared

3.7.3 Temporal Resolution

The temporal resolution of the imagery is the time between satellite revisits of the same area. Using different dates will show different conditions of vegetation and soil over time (for example, variation in a crop over time, or seasonal pasture composition).

3.7.4 Radiometric Resolution

Radiometric resolution refers to the number of brightness levels in the image. This can range from two levels (black and white), which can be obtained using high contrast photographic film, to 256 gray levels for an 8-bit image. Higher radiometric resolution produces a continuous tone image and may make it easier to detect different types of features in the image. Figure 2 summarizes the steps taken in the change analysis process.

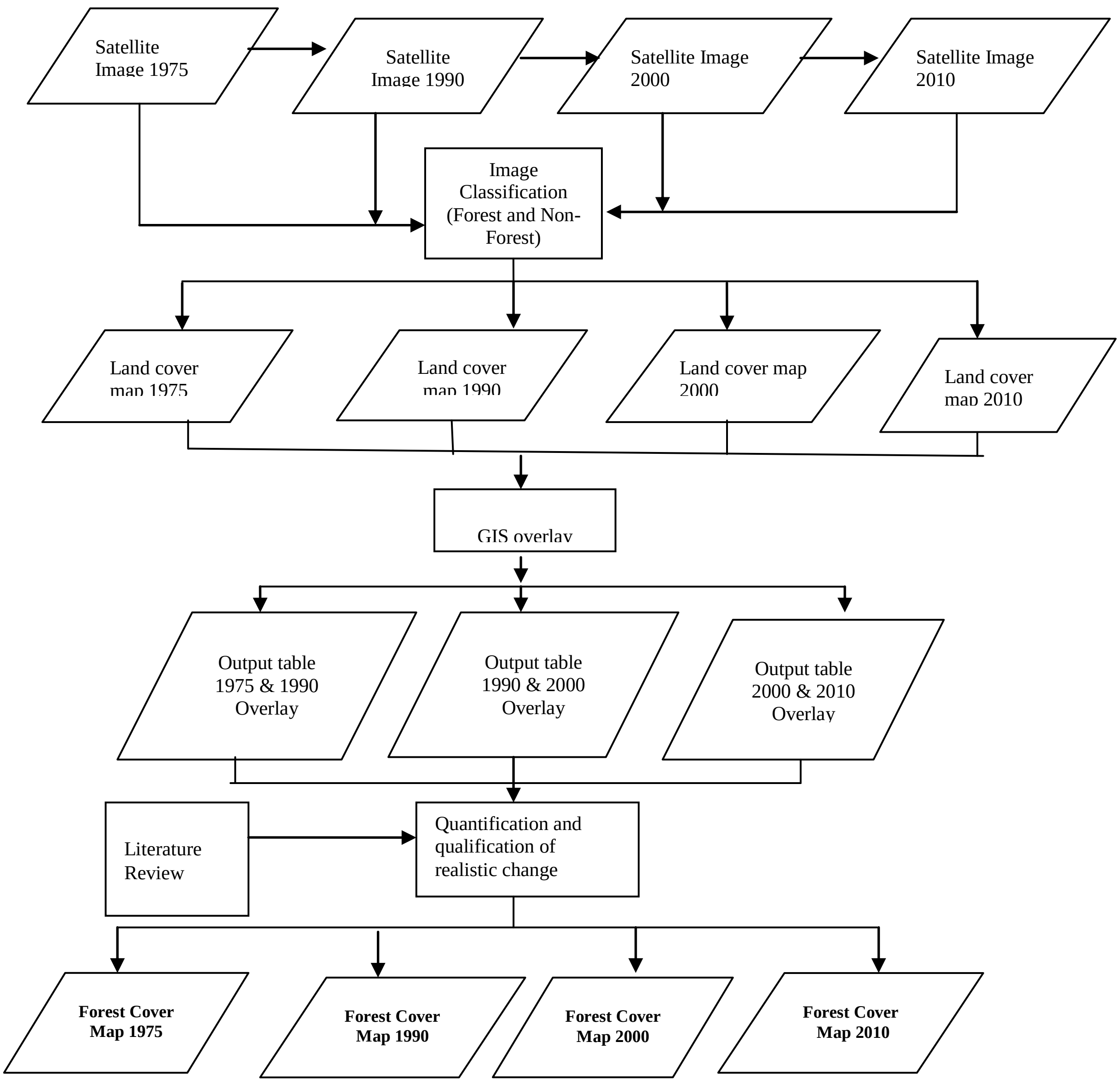


Figure 2: Flowchart showing steps taken during the change analysis process

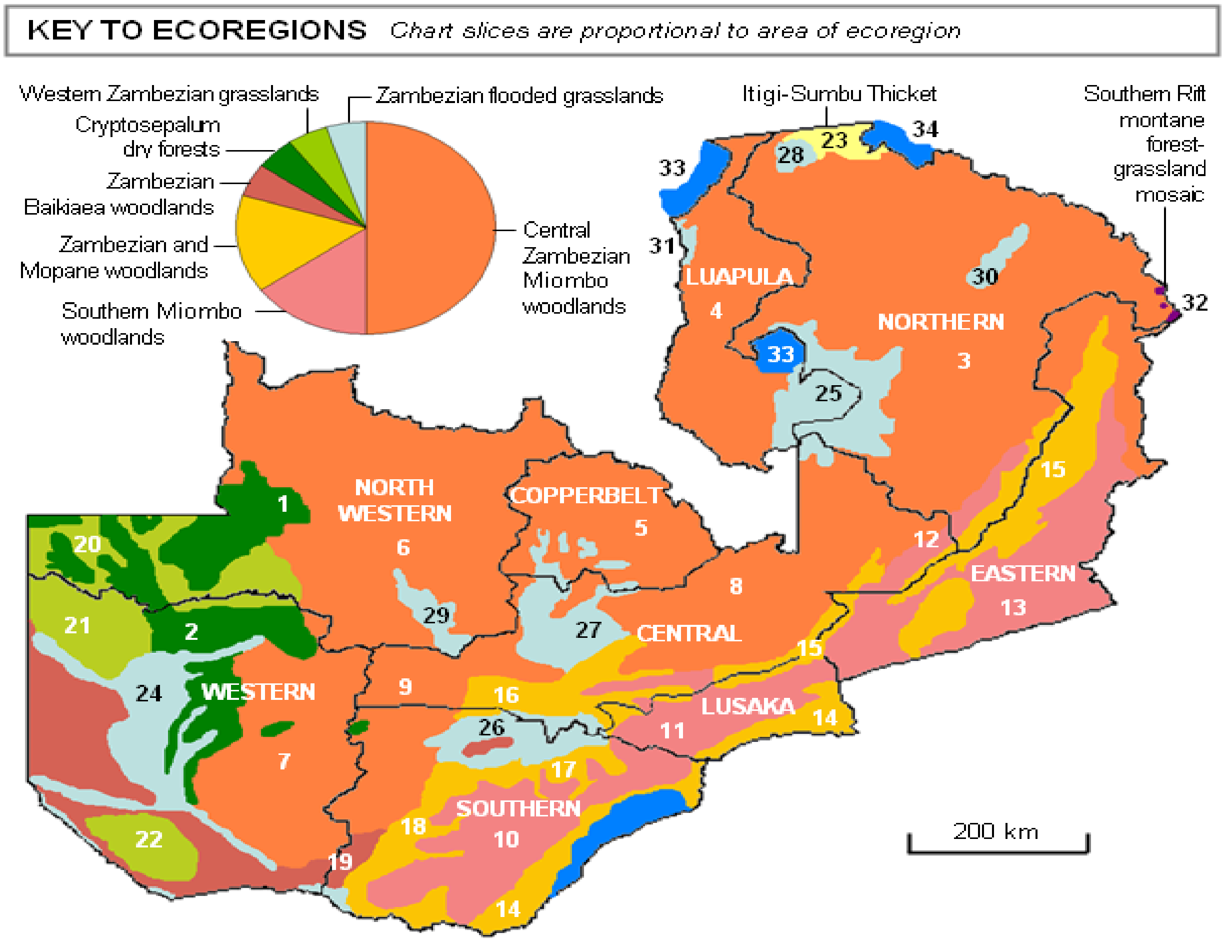


Figure 3: The Mopane woodlands Ecoregion (Source: Ecoregion of Zambia – Wikipedia, the Free Encyclopaedia)

The Mopane tree, *Colophospermum mopane*, is in the family of legume and grows in hotter locations of Zambia than the miombo species, and so Mopane woodlands replace southern Miombo woodlands at lower elevations in valleys in the south of the country, principally:-

Key to the above map:

14 - Along the Zambezi and Kariba valleys
15 - Along the bottom of the Lunsemfwa and Luangwa valleys
16 - In a strip running north of the Kafue Flats in Central Province
17 - In a strip running south of the Kafue Flats in Sothern Province
18 - In a strip running from the Kafue Flats crossing into Namibia
22 - Misclassification as plains instead of Mopane forest Shangombo district of Western Province

4. RESULTS AND DISCUSSION

Land cover change detection in the Mopane ecoregion of Zambia is the process of identifying differences in the state of the cover of mopane forest by observing it at different times. Essentially, land cover change detection involves the ability to quantify temporal effects using multitemporal datasets.

The change analysis was drawn on the defined area boundary and clipped from the Forest Vegetation Map of Zambia of 1975 as the historical and base source map. The forest and non-forest maps for the periods 1975, 1990, 2000 and 2010 were generated (Figure 4).

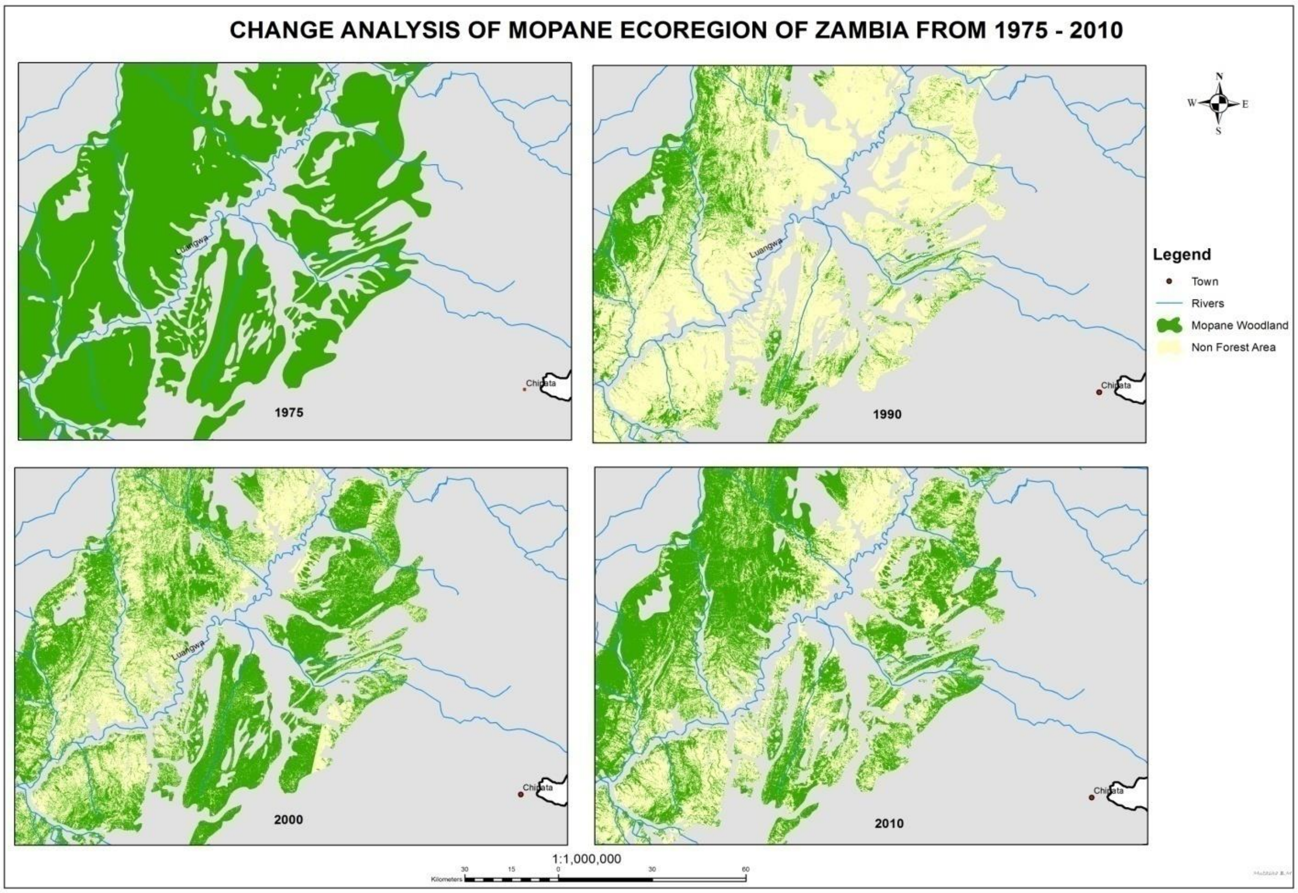


Figure 4: Clipped Mopane Ecoregion forest cover maps 1975, 1990, 2000 and 2010

The satellite imagery shape files for the periods 1975, 1990, 2000 and 2010 were overlaid on source map clipped from the 1975 vegetation map of Zambia compiled by Edmunds (1976). The Wood Consumption and Resource Survey of Zambia (GRZ, Technical Notes No.2, 1986) generated the total area of all forest types by province, and for the country, as well as the total area of all forest types by province, with a breakdown by district.

It must be noted that, the validity of the Wood Consumption and Resource Survey of Zambia results depended on the basic material used; the "Vegetation Map of Zambia" edited by Edmunds in 1976, and basic analytical inputs were from the years 1973-1975.

4.1 Comparison of the 1975 Vegetation Map of Zambia and the 1975 Landsat TM Satellite Map of Mopane Ecoregion of Zambia

4.1.1 Vegetation Map of Zambia - 1975

The Wood Consumption and Resource Survey of Zambia estimated the area of the Mopane ecoregion to be 4,428,000 hectares in 1975. (Table 6).

Table 6: The Vegetation of Zambia (A country analysis by province)

Unit 1000 hectare

Vegetation Type	Central Province	Copperbelt Province	Eastern Province	Luapula Province	Lusaka Province	Northern Province	North Western	Southern Province	Western Province	Total Zambia
Mopane	587	0	1 638	0	0	1 008	17	1 019	159	**4 428**

However, the distribution of the mopane (a country analysis by province) changed when the Patriotic Front (PF) Government realigned and split Northern Province in two provinces (Muchinga and Northern). The area of mopane in Chama district is now counted as part of Muchinga Province and the area of mopane that was counted under Northern Province in Mpika district is now added to Muchinga Province (Tables 7 and 8). In its natural form, the distribution of *C. mopane* occurs in Central, Eastern, Muchinga, North-western, Southern and Western Provinces

Table 7: The Mopane ecoregion distribution in Zambia (A country analysis by province including Muchinga Province)

Unit 1000 hectare

Vegetation Type	Central Province	Copperbelt Province	Eastern Province	Luapula Province	Lusaka Province	Muchinga Province	North Western	Southern Province	Western Province	Total Zambia
Mopane	587	0	1 028	0	0	1 618	17	1 019	159	**4 428**

Table 8: The Mopane ecoregion distribution (A country analysis by district)

District	**Province area in hectares**					
	Central	Eastern	Muchinga	North Western	Southern	Western
Chibombo	15,000	-	-	-	-	-
Mkushi	276,000	-	-	-	-	-
Mumbwa	11,000	-	-	-	-	-
Serenje	285,000	-	-	-	-	-
Sub-Total	**587,000**					
Mambwe	-	264,000	-	-	-	-
Lundazi	-	347,000	-	-	-	-
Petauke	-	417,000	-	-	-	-
Sub-Total		**1,028,000**				**-**
Isoka	-	-	11,000	-	-	-
Mpika	-	-	997,000	-	-	-
Chama	-	-	610,000	-	-	-
Sub-Total			**1,618,000**			
Mufumbwe	-	-	-	12,000	-	-
Kasempa	-	-	-	5,000	-	-
Sub-Total				**17,000**		
Gwembe					705,000	-
Kafue Flats	-	-	-	-	40,000	-
Kazungula	-	-	-	-	202,000	-

Livingstone	-	-	-	-	17,000	-
Siavonga	-	-	-	-	55,000	-
Sub-Total					**1,019,000**	
Shangombo	-	-	-	-	-	45,000
Senanga	-	-	-	-	-	68,000
Sesheke	-	-	-	-	-	46,000
Sub-Total						**159,000**
Total - Mopane Ecoregion distribution (analysis by district 1975)						**4,428,000**

4.1.2 Landsat TM Satellite Vegetation Map 1975

Based on the Landsat TM satellite image, resolution of 30m x 30m of the same clipped vegetation map of Zambia, the satellite image of 1975 was classified and the outcome compared with the Wood Consumption and Resource Survey of Zambia report.

The area of the Mopane Ecoregion of Zambia based on the 1975 satellite imagery covering Central; Eastern; Muchinga; North/Western; Southern and Western provinces was clipped and computed as a block. The result of the satellite image map shows the status of the mopane forest cover in 1975 as follows (Table 9):

Table 9: The Satellite Mopane Ecoregion 1975 Map

Satellite Imagery (Year)	Mopane Forest area (ha)	Mopane Non-Forest area (ha)	Total mopane area (ha)
1975	4,242,000	189,341	4,431,341

The area of mopane ecoregion on satellite image map, compared with the Wood Consumption and Resource Survey Map, resulted in a difference of 3,341 hectares, more in the satellite image classification. The difference in size between the two assessments can be attributed to the basic materials used to generate the area of mopane in the 1975 Vegetation Map of Zambia and the resolution of the Landsat TM satellite image map and training pixel values used in the supervised classification whether the sample sites were evenly distributed from the generated shape files.

4.1.3 Mopane Ecoregion Forest Cover and Cover Change Statistics

The result of Landsat TM satellite imagery indicates change in the Mopane Ecoregion of Zambia. The statistics of mopane cover change vary from one epoch period to the other. The mopane forest is under growing threat mainly due to agricultural expansion, increased demand for fuelwood (charcoal and firewood), increased demand for land for settlement, infrastructure development, mineral exploration and late forest fires.

Statistics for the mopane forest cover change and non-forest cover for the target years 1975 as historical year, 1990, 2000 and 2010 were generated. The mopane forest cover was classified to determine the spatial extent of forest and non-forest cover from 1975 to 2010. Figure 5 shows the distribution of Mopane Ecoregion in Zambia as classified from satellite imagery.

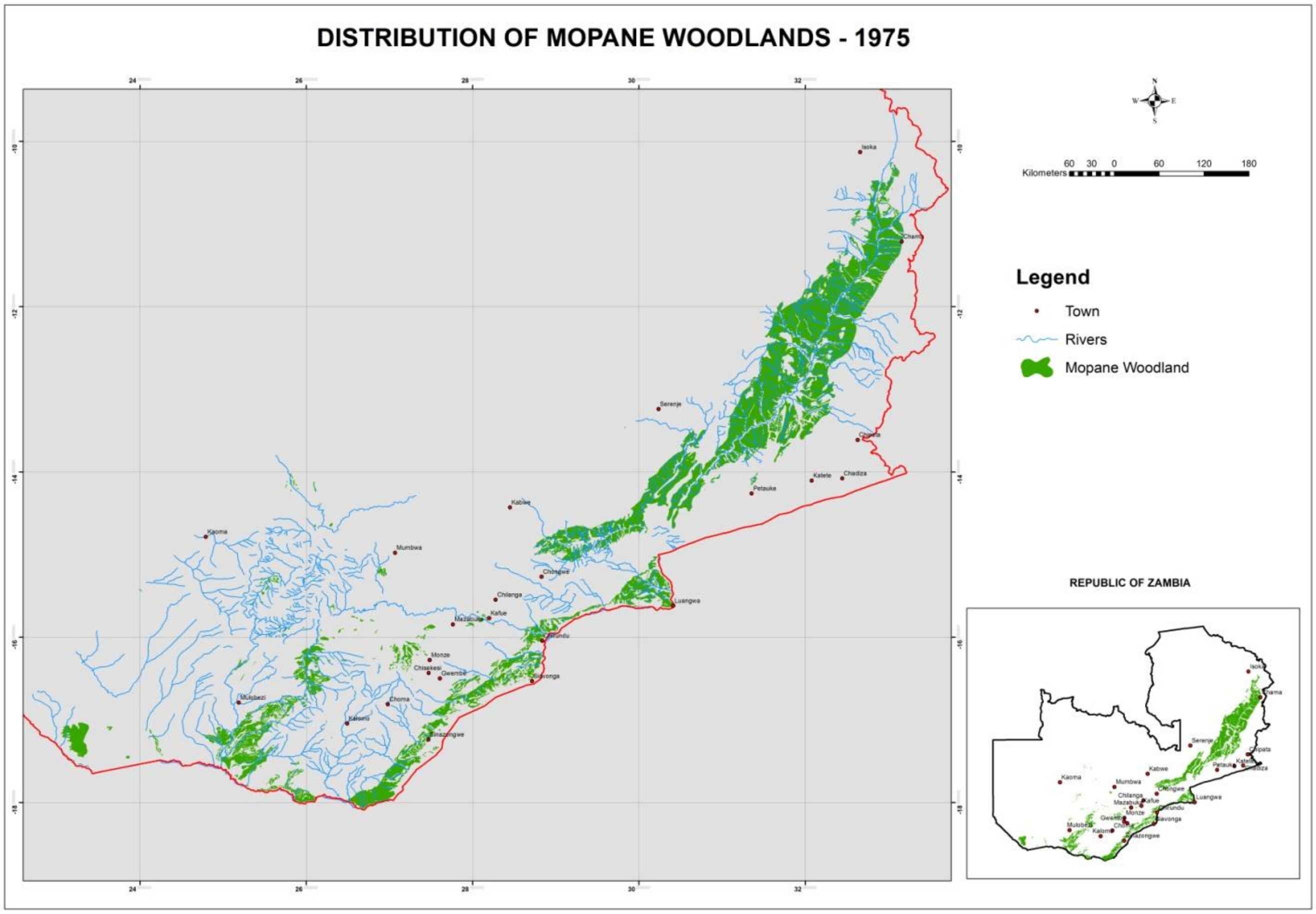


Figure 5: Landsat TM Satellite Imagery 1975 Map of Mopane Ecoregion

The Mopane ecoregion forest cover and non-forest statistics were generated from respective satellite images using shape files for the periods 1975, 1990, 2000 and 2010 clipped from each full epoch period satellite map (Figure 4). Table 10 shows the mopane forest cover change statistics generated from full maps of the periods under review.

Table 10: Mopane Ecoregion Forest Cover Change (1975 – 2010)

Forest Type	Year	Forest (ha)	Non-Forest (ha)	Loss (ha)	Gain (ha)	Total Forest (ha)	Annual Change (ha)
Mopane	1975	4,242,000	189,341	-	-	4,431,341	-
Mopane	1990	3,397,000	1,034,341	845,000	-	4,431,341	56,333
Mopane	2000	3,528,670	771,001	-	131,670	4,431,341	13,167
Mopane	2010	3,461,000	902,671	67,670	-	4,431,341	6,767

- The results in Table 9 indicate that there is some loss and gain in the Mopane Ecoregion in Zambia. For the period 1975 to 1990 (15 years) the total change or loss was 845,000 hectares with an average annual rate of loss of approximately 56,333 hectares.

- For the period 1990 to 2000 (10 years) the total change or gain was 131,670 hectares with an average annual rate of increase of approximately 13,167 hectares mainly from natural regeneration and coppicing as well as late fire management.

- Between 2000 and 2010 (10 years) the total change or loss was 67,670 hectares with an average annual rate of loss of approximately 6,767 hectares possibly due to population increase and improved road network resulting in increased in-migration and demand for agricultural land and settlement as well as fuelwood harvesting.

- The total change (loss) in the Mopane ecoregion in Zambia from 1975 to 2010 is approximately 781,000 hectares at an annual rate of 22,000 hectares. From the satellite analysis, most of the change is occurring in southern parts of the Mopane ecoregion in Chirundu/Siavonga, Gwembe, Kazungula, and Mwandi/Sesheke districts.

- In the northern part of the Mopane ecoregion, the annual change is estimated at 36.4% or 8,000 hectares of the total annual rate in areas covering Chama, Lundazi and Mpika districts as much of the areas are under Game Management Areas (GMAs), National Parks (NPs) and Private Game Ranches (PGRs) and thus already receiving some form of protection.

1. Pure mopane forest in Chama District

2. Field assessment in mopane forest – Chama District

3. Assessment team in Chama District – mopane forest

4. Pure mopane forest - north of Lundazi District

Figure 6: Un-disturbed pure stands of mopane forest in the Northern part of Zambia

5. CURRENT STATUS OF MOPANE ECOREGION IN ZAMBIA

5.1 1975 Vegetation Map of Zambia

Based on the 1975 vegetation map of Zambia, it is estimated that the total wooded land area of Zambia in its natural distribution without any encroachment is approximately 61,205,000 hectares or 81.3%., grassland 13,016,000 hectares or 17.3% and inland water bodies 1,050,000 hectares or 1.4% of total land mass area of 75,261,400 hectares or 752,614 square kilometres.

The vegetation map of Zambia was compiled by A.C.R. Edmonds, Forest Department of the Government of the Republic of Zambia (1975). Scale 1:500,000. The map was printed by Institute for Angewandte Geodesy, Frankfurt, Germany under the auspices of the Federal Republic of Germany in its programme of Technical Co-operation with the Republic of Zambia in 1976.

The Mopane Ecoregion of Zambia based on the 1975 vegetation map out of the total wooded land area covers approximately 4,428,000 hectares or 7.2%. This is 5.2% of land mass of the country.

5.2 Landsat TM Satellite Imagery Classification of 1975, 1990, 2000 and 2010

The Mopane Ecoregion of Zambia based on Landsat TM satellite imagery classification, wooded area clipped from the 1975 to 2010 added up to 4,431,341 hectares or 7.24%. This is 5.8% of land mass of the country with (error comparison of the two 0.6%). The total change is approximately 781,000 hectares or annual rate of 22,000 hectares during the period 1975 to 2010.

5.3 Use of Mopane Woodland in Zambia

Mopane woodlands provide valuable hard timber with strong resistance against termites. For this reason mopane timber has long been used for building houses and fences, as railway sleepers and as mining pit props. It is also good for parquet flooring and as a decorative wood. Recently, mopane is heavily exploited to satisfy Asian markets, particularly China, where it is used to manufacture woodwind musical instruments such as bagpipes, clarinets, flutes, etc. Other wood products include poles for construction, firewood and charcoal for energy needs. All these wood products are on high demand and are commercialized.

Mopane woodlands provide critical habitat for Zambia's wildlife. It is particularly a preferred habitat for elephants which browse on *C. mopane* leaves. Other wildlife species common in mopane woodlands includes buffalo, eland, warthog, common duiker, lion and monkey/baboon thus contributing to ecotourism and local employment opportunities in the Mopane Ecoregion. The mopane tree (*Colophospermum mopane*) is also a major food source for the mopane worm, the caterpillar of the moth *Imbrasia belina*. The caterpillars are rich in protein and are eaten by people, and the sale of roasted or dried mopane worms contributes significantly to rural household economies (about 50% of household income in-season) and to food security (about 70%) in the Mopane Ecoregion.

The woodlands are a key source of many non-wood forest products which local communities depend on for their subsistence and income generation. These include honey, medicines, wild fruits such as baobab (*Adansonia digi*tata), tubers, fibers, mushrooms, rich pastures for both wildlife and livestock including water reservoirs for fish and animals. Catfish or bubble fish is a very common fish species associated with Mopane woodlands especially in the southern and western parts of the Mopane Ecoregion following floods when water levels recede. This provides a major source of income and food security.

Farming is the most prominent livelihood activity practiced by almost every household in the ecoregion. The seasonal calendar for farming in the ecoregion starts from November and ends in May. Charcoal production, firewood collection, pole harvesting and fishing are other important livelihood activities in the ecoregion for sustained livelihoods and income generation. Other livelihood activities undertaken throughout the year include livestock rearing, gardening, beer brewing, shop keeping, poultry and labour in ecotourism lodges.

5.4 Stocking, Density, Volume and Diameter Distributions in Mopane Woodlands

- Stocking levels of common species in the Mopane Ecoregion per hectare

Based on the localized field inventory in the mopane woodland across Mopane Ecoregion, the most common tree species is the *Colophospermum mopane which in most cases in good drained soils forms pure stands followed by Acacia nigrescens and Adansonia digitata.* The Stems per hectare is in the range of 145 – 155.

Table 11: Stems per Hectare

Name of specie	**Stems Per Hectare (SPH)**
Acacia nigrescens	8
Adansonia digitata	4
Colophospermum mopane	130
Combretum imberbe	2
Combretum molle	1
Commiphora mollis	2
Lannea stuhlmannii	2
Lonchocarpus capassa	1
Total	**150**

- Mopane Ecoregion Volume Diameter Class Distribution/Hectare

Based on the localized field inventories conducted in the mopane woodland across the eco-region, the mean volume per diameter class per hectare for all species tabulated in Table 12 is (+/-) 46 cubic metres.

Table 12: Volume Diameter Class Distribution per Hectare

Species Name	Diameter Class Range						Total Volume (M^3)
	5-9	10-14	15-19	20-29	30-39	40+	
Acacia nigrescens	0.1	0.1	0.1	0.1	0.0	0.0	0.4
Adansonia digitata	0.0	0.1	0.0	0.1	0.2	4.0	4.4
Colophospermum mopane	0.3	0.1	0.7	7.2	12.0	16.0	36.3
Combretum imberbe	0.0	0.0	0.0	0.4	0.0	3.7	4.1
Combretum molle	0.0	0.0	0.1	0.2	0.0	0.0	0.3
Commiphora mollis	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lannea stuhlmannii	0.0	0.	0.0	0.0	0.0	0.0	0.0
Lonchocarpus capassa	0.0	0.0	0.1	0.1	0.0	0.3	0.5
Total Volume for all Species	**0.4**	**0.3**	**1.0**	**8.1**	**12.2**	**24.0**	**46.0**

- Standing volume in the Mopane Ecoregion from one epoch to the other

Using the two parameters, the means stems 150 and volume per hectare for all species in the Mopane Ecoregion, the standing stems and volume in each epoch is shown in Table 13.

Table 13: Table 12 Standing Volume in the Mopane Ecoregion from one epoch to the other

Forest Type	Year	Forest (ha)	All species/stems	Vol/M^3
Mopane	1975	4,242,000	636,300,000	195,132,000
Mopane	1990	3,397,000	509,550,000	156,262,000
Mopane	2000	3,528,670	529,300,500	162,318,820
Mopane	2010	3,461,000	519,150,000	159,206,000

This computation does not include stems below 5cm diameter at (dbh)

6. CONCLUSIONS

From this analysis, the following conclusion can be made, that Landsat TM satellite imagery is an important source of data for mapping the dynamics of land cover change in the Mopane Ecoregion. However, cloud cover can limit the useful of this important data because as high as 23% in most cases of the information can be obscured by cloud coverage. Therefore, any possible limitation of Landsat TM satellite images in mapping land cover and cover change in the Mopane Ecoregion is the effect of clouds.

The availability and use of time series satellite images permits the detection and quantification of land cover change in the Mopane Ecoregion in the operational technical unit by making reference to a number of materials and publications. This has been useful in improving the understanding of the past and present changes in the Mopane Ecoregion. The land cover change cannot be assumed to be a process that takes place at a constant rate in time. The rate varied between the periods, but the factors responsible for Mopane Ecoregion change were consistent in all periods.

The key threats and drivers of deforestation and forest degradation in the Mopane Ecoregion include unsustainable timber harvesting (illegal timber, poles, firewood and charcoal), agricultural expansion through shifting cultivation practices, increased demand for land for settlement, infrastructure development and mineral exploration, late forest fires and natural disasters especially floods. These proximate drivers are in turn driven by indirect drivers such as poverty, population growth, weak enforcement of the policy, legal and regulatory framework, and lack of incentives and benefit sharing mechanisms for community participation in the sustainable management of mopane woodlands.

Addressing these drivers requires a multi-stakeholder and multi-sectoral approach as well as policy coordination with the understanding that most of the drivers and the solutions sought predominantly lie outside the forest sector (e.g., agriculture, energy, land use and infrastructure development, mining, population increase and distribution, policy and institutional causes, cultural causes, etc.)

Hence, the institutional arrangements to address the key threats and drivers of deforestation and forest degradation in the Mopane Ecoregion should include government and traditional institutions working side by side with donors, private sector, NGOs, CSOs and local communities in the planning, implementation, monitoring and evaluation of activities.

7. RECOMMENDATIONS

The Mopane Ecoregion of the *Colophospermum mopane* tree species has potential to regenerate and coppice naturally as long as some silvicultural activities such as fire management through controlled early burning is conducted regularly. To manage the Mopane Ecoregion woodland in Zambia in the future the following must be considered:

- The promotion of alternative livelihood options with direct linkages to *C. mopane* conservation such as sustainable agricultural practices including agroforestry and conservation farming, alternative energy sources, beekeeping, domesticated production and commercialization of viable non-wood forest products.

- The creation of Community Forests in line with the new Forests Act No. 4 of 2015 should be encouraged in the Mopane Ecoregion in areas outside protected national forests. For communities that are in the Mopane Ecoregion near or surrounding local forests, by new Law, such forests can be declared as community forests.

- Administration of permits to harvest mopane woodland resources needs to be shared with the local communities through Joint Forest Management (JFM) interventions in order to promote and encourage a sense of ownership of mopane woodland by the communities residing in such areas. The new Forests Act of 2015 allows for the declaration of Joint Forest Management areas and benefit sharing.

- There is need for the Forestry Department and its sector partners to increase investment and funds for research and development in order to promote sustainable use and management of the Mopane Ecoregion areas in the country.

- There is need to link the research results of this study to other similar work to be undertaken in neighbouring SASSCAL-funded countries, e.g., Angola, Botswana and Namibia.

- There is a need to capacitate Forestry Officers for them to promote awareness among the general public in particular the rural communities about conservation and importance of the Mopane Ecoregion areas in order to enhance compliance with the Forest Laws.

- There is need for improved coordination in the Mopane Ecoregion management among line sectors in order to avoid overlapping of responsibilities. This could be achieved through common platforms such as Sectoral Advisory Groups (SAGs).

8. REFERENCES

Edmunds, A.C.R. 1976. The Vegetation Map of Zambia. Printed by Institute for Angewandte Geodesy, Frankfurt, Germany.

Fanshawe, D.B. 1971a. Species diversity in various vegetation types of Zambia. Forest Department, GRZ.

Fanshawe D.B., 1971b. The vegetation of Zambia, Forest Research bulletin No. 7 Forestry Research, Zambia.

FAO. 1997. Tropical woodland forest cover change. FAO publications, Rome, Italy.

FAO. 1995. Tropical woodland forest cover change. FAO publications, Rome, Italy.

FAO. 2015. Global Forest Resources Assessment Report 2015. FAO, Rome, Italy.

Forest Department and FAO. 2005. Integrated Land Use Assessment (ILUA I) Report, 2005-2008.

Forest Department and FAO. 2016. Integrated Land Use Assessment (ILUA II) Preliminary Report, 2016.

Forest Department.. 1986. Wood Consumption and Resource Survey of Zambia. Technical Notes No. 2. Government of the Republic of Zambia.

Mather, M. 1987. Change in forest cover by conversion or modification.

Mukosha, J.M. 2003. Identifying of Tree Resources Outside Forests, using sensors of different satellite imagery. ITC, Thesis Report, 2003.

Mukosha, J.M. 2013. ILUA II quality control field reports of Mopane ecoregion. Forest Department and FAO of the United Nations, Zambia.

Satellite Imagery Related Factors (www.geoimage.com.au)

Serneels, T. 2000 Investigation of land cover dynamics, global change study.

Serneels, T. 2001. Estimation of deforestation in tropical woodland.

Siampale, A. 2014. The Mopane ecoregion inventory report. Task 221, SASSCAL report.

Sitwala, W. 2015. Landsat TM shape files of Mopane ecoregion, 1975, 1990, 2000 and 2010. Task 221, SASSCAL report.

Status of Forest Resources in Zambia (www.fao.org/docrep/005/AC455E/ac455e02.htm)

Storrs, A.E.G. 1979. Know Your Trees. Forest Department, Government of the Republic of Zambia.

Use of Mopane woodland resources and associated woodland management challenges in Rural Areas of South Africa (www.ethnobotanyjournal.org/vol10/i1547-3465-10-369.pdf)

Walker, R. 2002. Global carbon cycle and biodiversity.

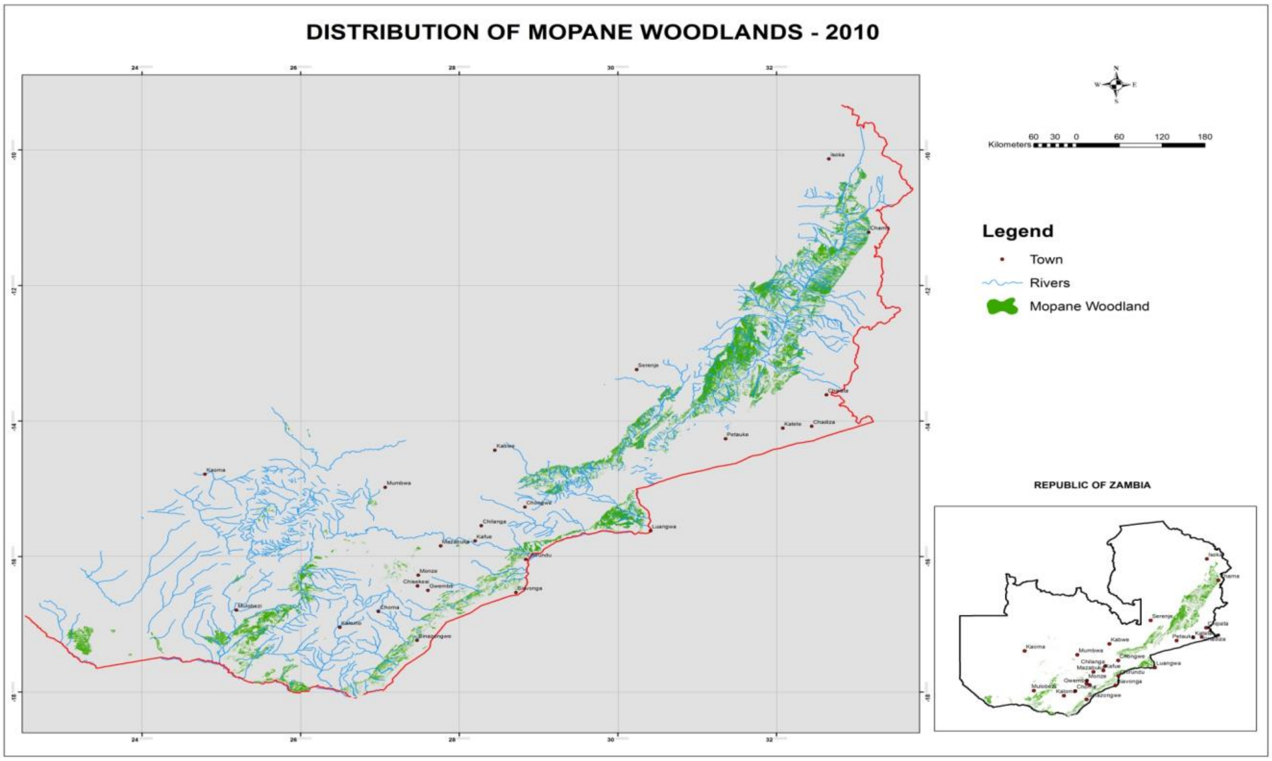
Wikipedia, the free encyclopedia Eco-regions of Zambia.

Annex 1: Mopane Sawn Timber

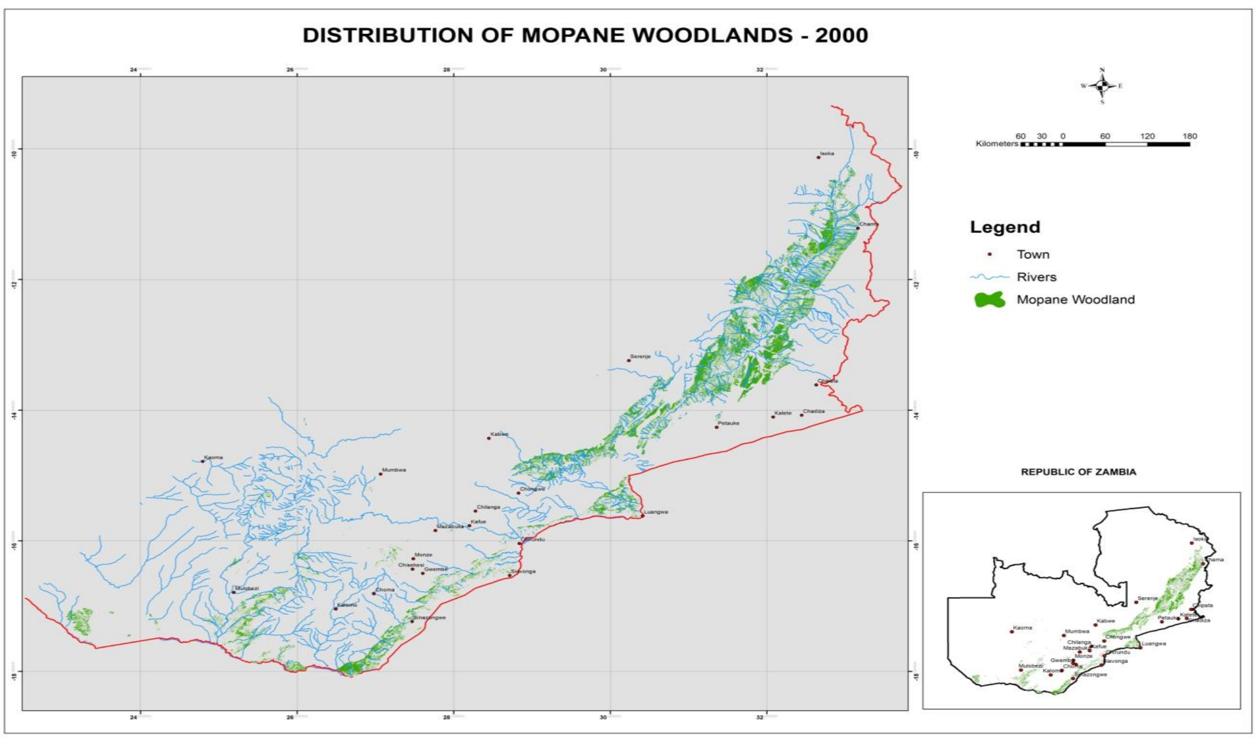
In the picture below, Mopane tree is prepared into blocks for timber house construction. It is acknowledged that Mopane is very good timber and is only next to the Zambian Teak (*Baikiaea plurijuga*) in terms of durability.

Annex 2: Maps showing *Colophospermum mopane* cover change from 1975 -2010

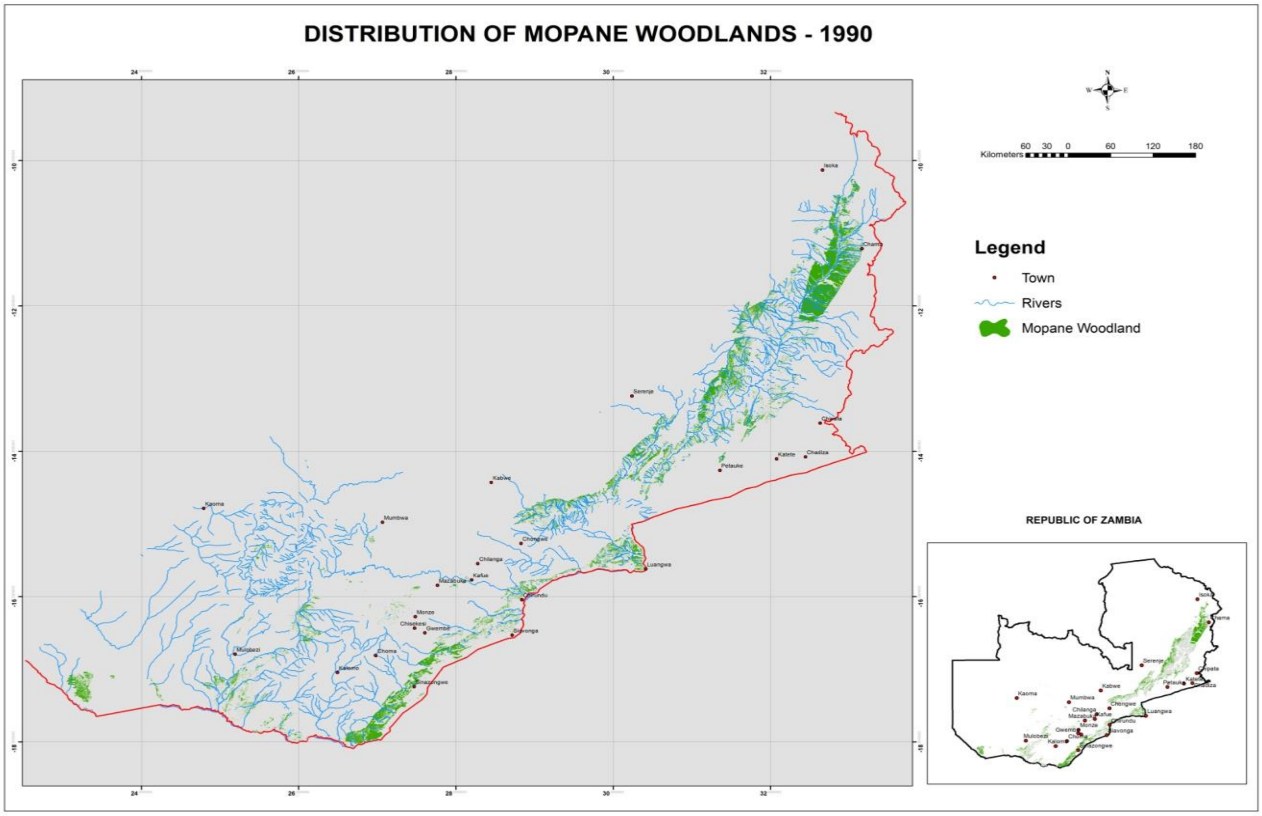
MOPANE ECOREGION 2010



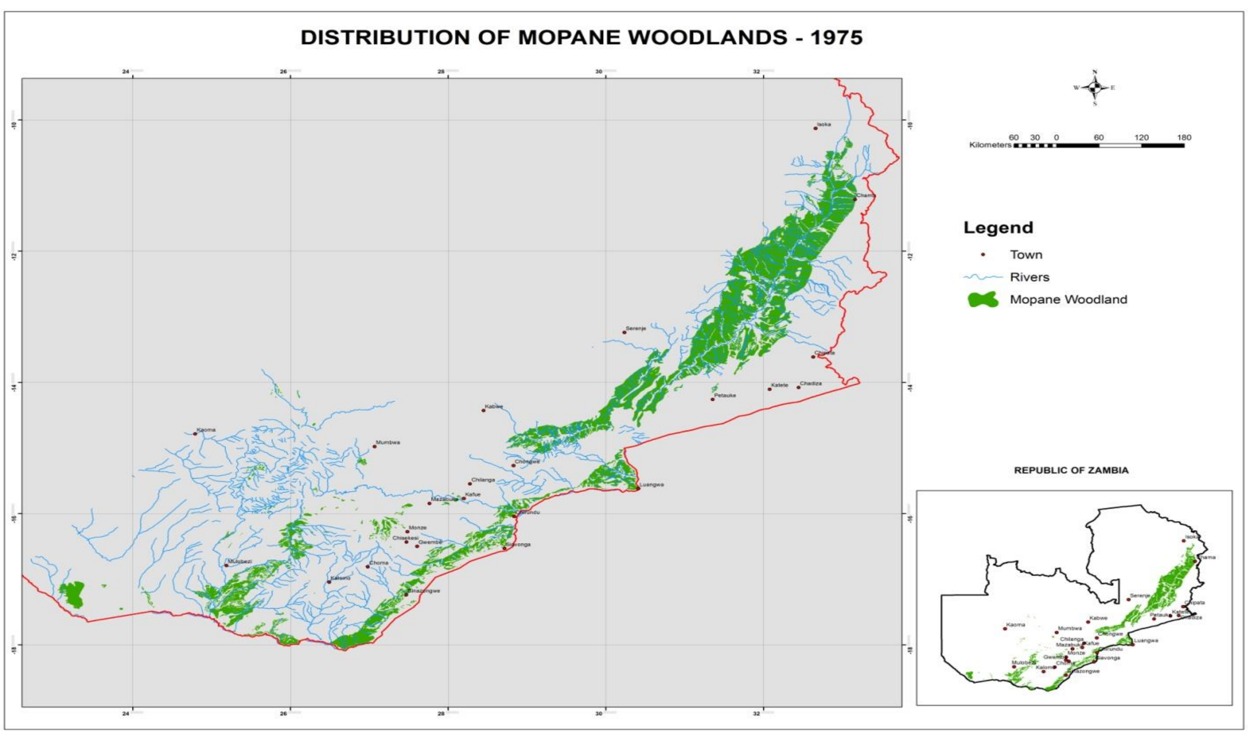
MOPANE ECOREGION 2000



MOPANE ECOREGION 1990



MOPANE ECOREGION 1975



Annex 3: Distribution of Mopane Woodland Ecoregion in Zambia Coordinates
(UTM Coordinates below were generated and used in the orientation and quantification of Mopane ecoregion forest cover change 1975 – 2010)

Projection	Province	District	X	Y
UTM-35	Southern	Livingstone	383529	8020459
UTM-35	Southern	Kazungula	394123	8020518
UTM-35	Southern	Kazungula	425903	8020663
UTM-35	Southern	Sinazongwe	478865	8020791
UTM-35	Southern	Sinazongwe	500050	8020803
UTM-35	Southern	Kazungula	330461	8031142
UTM-35	Southern	Kazungula	351664	8031312
UTM-35	Southern	Kazungula	415262	8031685
UTM-35	Southern	Kazungula	362111	8053519
UTM-35	Southern	Kazungula	308837	8075220
UTM-35	Southern	Gwembe	574601	8131300
UTM-35	Southern	Gwembe	595953	8142277
UTM-35	Southern	Siavonga	649395	8164097
UTM-35	Southern	Gwembe	596102	8175466
UTM-35	Southern	Siavonga	681498	8174916
UTM-35	Central	Mkushi	758253	8351268
UTM-36	Eastern	Mambwe	359411	8496060
UTM-36	Eastern	Mambwe	391870	8496213
UTM-36	Muchinga	Mpika	348402	8529186
UTM-36	Eastern	Lundazi	489214	8540669
UTM-36	Muchinga	Mpika	348279	8551310
UTM-36	Eastern	Lundazi	478370	8551722
UTM-36	Eastern	Mambwe	391803	8562901
UTM-36	Eastern	Lundazi	434984	8562712
UTM-36	Eastern	Lundazi	489180	8629137
UTM-36	Muchinga	Chama	434782	8651183
UTM-36	Muchinga	Chama	489168	8662311
UTM-36	Muchinga	Mpika	173535	8671916
UTM-36	Muchinga	Mpika	423846	8673274
UTM-36	Muchinga	Chama	445819	8673646
UTM-36	Muchinga	Chama	445599	8684380
UTM-36	Muchinga	Chama	500050	8695486
UTM-36	Muchinga	Chama	521920	8817109

Creator	x	y	ns1:ele	ns1:name7	ns1:sym
EasyGPS 4.96	-17.62729	25.94220	1089	001	Fishing Hot Spot Facility
EasyGPS 4.96	-17.62007	25.82305	1066	002	Fishing Hot Spot Facility
EasyGPS 4.96	-17.53297	25.64512	1030	003	Fishing Hot Spot Facility
EasyGPS 4.96	-17.48545	25.44223	965	004	Fishing Hot Spot Facility
EasyGPS 4.96	-17.54244	25.30911	956	005	Fishing Hot Spot Facility
EasyGPS 4.96	-17.56318	25.21345	950	006	Fishing Hot Spot Facility
EasyGPS 4.96	-17.01508	26.49114	1232	007	Fishing Hot Spot Facility
EasyGPS 4.96	-16.27851	26.90868	1080	008	Fishing Hot Spot Facility
EasyGPS 4.96	-17.90061	25.89447	1128	0890	Flag, Blue
EasyGPS 4.96	-16.28178	28.41714	995	CAMP TM2	Flag, Blue
EasyGPS 4.96	-16.02829	28.69495	474	SIAVONGA	Flag, Blue
EassyGPS 4.96	-16.25228	28.72462	457	PLT1	Flag, Blue
EasyGPS 4.96	-16.26004	28.72299	457	009	Flag, Blue
EasyGPS 4.96	-16.26246	28.72249	457	010	Flag, Blue
EasyGPS 4.96	-16.26493	28.72198	457	011	Flag, Blue
EasyGPS 4.96	-16.26648	28.72165	457	012	Flag, Blue
EasyGPS 4.96	-16.26812	28.72130	457	013	Flag, Blue
EasyGPS 4.96	-16.26985	28.72094	458	014	Flag, Blue
EasyGPS 4.96	-16.27210	28.72049	459	015	Flag, Blue
EasyGPS 4.96	-16.27345	28.72021	459	016	Flag, Blue
EasyGPS 4.96	-16.27437	28.72002	459	017	Flag, Blue
EasyGPS 4.96	-16.27588	28.71970	459	018	Flag, Blue
EasyGPS 4.96	-16.27755	28.71936	459	019	Flag, Blue
EasyGPS 4.96	-16.27955	28.71894	470	020	Flag, Blue
EasyGPS 4.96	-16.28059	28.71873	470	021	Flag, Blue
EasyGPS 4.96	-16.28217	28.71839	470	022	Flag, Blue
EasyGPS 4.96	-16.28372	28.71807	470	023	Flag, Blue
EasyGPS 4.96	-16.28578	28.71763	473	024	Flag, Blue
EasyGPS 4.96	-16.28764	28.71724	467	025	Flag, Blue
EasyGPS 4.96	-16.28975	28.71682	470	026	Flag, Blue
EasyGPS 4.96	-16.29296	28.71619	469	027	Flag, Blue
EasyGPS 4.96	-16.29550	28.71636	475	028	Flag, Blue
EasyGPS 4.96	-16.29808	28.71668	477	029	Flag, Blue
EasyGPS 4.96	-16.30098	28.71704	476	030	Flag, Blue
EasyGPS 4.96	-16.36359	28.72464	475	031	Flag, Blue
EasyGPS 4.96	-16.09846	28.70629	467	BTM RD	Flag, Blue
EasyGPS 4.96	-16.14853	28.67027	469	032	Flag, Blue
EasyGPS 4.96	-15.77014	26.02037	1018	033	Flag, Blue
EasyGPS 4.96	-15.83040	26.52806	1046	036	Flag, Blue
EasyGPS 4.96	-15.89792	26.55577	1018	037	Flag, Blue
EasyGPS 4.96	-16.43922	27.47879	1176	038	Flag, Blue
EasyGPS 4.96	-16.02741	27.97391	1287	039	Flag, Blue

EasyGPS 4.96	-15.99773	28.00232	1254	040	Flag, Blue
EasyGPS 4.96	-15.96502	27.61105	1021	041	Flag, Blue
EasyGPS 4.96	-17.45362	24.99780	937	KASAYA	Flag, Blue
EasyGPS 4.96	-17.45871	25.01692	955	042	Flag, Blue
EasyGPS 4.96	-17.45946	25.02010	956	043	Flag, Blue
EasyGPS 4.96	-17.46009	25.02274	956	044	Flag, Blue
EasyGPS 4.96	-17.46090	25.02563	954	045	Flag, Blue
EasyGPS 4.96	-17.46155	25.02764	948	046	Flag, Blue
EasyGPS 4.96	-17.46993	25.07969	961	047	Flag, Blue
EasyGPS 4.96	-17.47029	25.08182	962	048	Flag, Blue
EasyGPS 4.96	-17.47068	25.08424	961	049	Flag, Blue
EasyGPS 4.96	-17.47106	25.08659	962	050	Flag, Blue
EasyGPS 4.96	-17.47190	25.09152	961	051	Flag, Blue
EasyGPS 4.96	-17.47225	25.09372	961	052	Flag, Blue
EasyGPS 4.96	-17.47277	25.09694	962	053	Flag, Blue
EasyGPS 4.96	-17.47632	25.11866	950	054	Flag, Blue
EasyGPS 4.96	-17.47715	25.12114	950	055	Flag, Blue
EasyGPS 4.96	-17.47833	25.12288	953	056	Flag, Blue
EasyGPS 4.96	-17.49063	25.13798	959	057	Flag, Blue
EasyGPS 4.96	-17.49262	25.14042	959	058	Flag, Blue
EasyGPS 4.96	-17.49470	25.14297	960	059	Flag, Blue
EasyGPS 4.96	-17.49607	25.14465	942	060	Flag, Blue
EasyGPS 4.96	-17.49673	25.14546	946	061	Flag, Blue
EasyGPS 4.96	-17.49906	25.14837	954	062	Flag, Blue
EasyGPS 4.96	-17.50113	25.15094	949	063	Flag, Blue
EasyGPS 4.96	-17.51932	25.17207	964	064	Flag, Blue
EasyGPS 4.96	-17.52482	25.17661	944	065	Flag, Blue
EasyGPS 4.96	-17.52681	25.17827	951	066	Flag, Blue
EasyGPS 4.96	-17.57426	25.21249	957	067	Flag, Blue
EasyGPS 4.96	-17.57658	25.21319	959	068	Flag, Blue
EasyGPS 4.96	-17.58067	25.21545	958	069	Flag, Blue
EasyGPS 4.96	-17.63556	25.23911	950	070	Flag, Blue
EasyGPS 4.96	-17.48206	25.12746	945	071	Flag, Blue
EasyGPS 4.96	-17.48566	25.13187	944	072	Flag, Blue
EasyGPS 4.96	-17.48855	25.13543	942	073	Flag, Blue
EasyGPS 4.96	-16.61573	23.56672	987	074	Flag, Blue
EasyGPS 4.96	-15.70066	23.30513	1046	075	Flag, Blue
EasyGPS 4.96	-14.97541	24.29720	1117	076	Flag, Blue
EasyGPS 4.96	-14.59622	24.70514	1145	077	Flag, Blue
EasyGPS 4.96	-14.60074	24.70509	1144	078	Flag, Blue
EasyGPS 4.96	-17.46597	24.93325	929	079	Flag, Blue
EasyGPS 4.96	-17.45916	24.95138	931	080	Flag, Blue
EasyGPS 4.96	-17.45801	24.95442	935	081	Flag, Blue

EasyGPS 4.96	-17.45424	24.97617	934	082	Flag, Blue
EasyGPS 4.96	-17.45411	24.97993	939	083	Flag, Blue
EasyGPS 4.96	-17.45400	24.98304	939	084	Flag, Blue
EasyGPS 4.96	-17.45387	24.98675	932	085	Flag, Blue
EasyGPS 4.96	-17.45417	24.99793	931	086	Flag, Blue
EasyGPS 4.96	-17.45701	25.00973	923	087	Flag, Blue
EasyGPS 4.96	-17.49556	25.14399	937	088	Flag, Blue