Paper 1943
GIS as a tool in Managing and Monitoring Timber Concessions

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Abstract

It is the duty of the Forestry Commission of Ghana to effectively manage the forest resources in the country. This paper looks at how GIS can be used as a tool in managing and monitoring timber concessions in the country. Five species of trees were selected for an in-depth study. These species were digitized to obtain their positions (X,Y) from a stock map. The analysis of the spatial distribution of these trees, their diameter at maturity, and their growth rate among other attributes were the basis for our study. This was used to create a model that the Forestry Commission can use as a basis for determining and projecting the yield of any species at any time and a basis for creating regeneration and reforestation programs.

Chapter 1: Introduction

A number of factors have, over the period of a century, contributed to the depletion of Ghana's forest resources. These factors include over exploitation of timber resources, bad farming practices, bush fires, mining activities to mention a few. In 1900, Ghana could boast of about 8.2 million hectares of forest. Between 1982 and 1983, it was estimated that approximately 50% of the forest resources was destroyed by the operations of timber operators. This loss has been incurred as a result of the lack of the right tools and resources needed to effectively manage the forests.

Fortunately, with the advent of geographic information systems technology, it has become easier to represent the situation as it is in the real world, make decisions and analysis based on this representation as well as to predict to a fair degree the situation as it would be in the future.

The objective of this paper is to outline how GIS can be used to help the Forestry Commission of Ghana to effectively manage the forestry resources of Ghana with respect to allocating timber concessions. The activities the paper discusses are

1. the creation of a tree inventory with their geographic positions.
2. the provision of data on yield species at any given time using such factors as the growth rate of the species.
3. the development of principles of regeneration for reforestation and species conservation purposes.

The Bia North Forest Reserve was used to undertake this study and five species of trees that are of commercial value were used. These are Wawa, Otie, Ofram, Kyereye and Onyina.

The basic questions that the GIS will help answer

The following outlines the most common questions that are asked for the effective management of forest reserves and how GIS helps make the answering of these questions easier than traditional methods of paper maps.

Where? : The question of location

The geographic positions of tree species are very important. These help the manager of the forest know where exactly they can find mature species for harvesting and where trees need to be planted to replace harvested ones. The manager can also get information as to where he can find the spatial distribution of certain species.

How? : The question of condition

At any point in time, the forester can get an idea of the condition of the forest. He can query the GIS to know how many species are ready for harvesting and where they are. This may therefore become a form of tree inventory. This can be used to estimate the economic value of the forest or a spatial area of the forest. With this inventory, the

condition of the forest with respect to particular tree species can also be determined. This will help the forester to know which tree specie need to be replanted.

The question of Trends and patterns
From the GIS, trends and patterns of the condition of the forest can be attained. These can be scientifically interpreted to deduce a model which can be used to predict the condition of the forest based on a number of factors. Such factors may include soil type, altitude, rainfall pattern, density of trees and rate of logging of tree species.

What if? The question of "What if?"
The whole forestry system can be used to create a scientific model that can be used in what if analysis. A buffer can be used to estimate the extent of damage that will be caused by bush fires, illegal and unplanned felling of trees and flooding.

Current Practices of the Forestry Commission
The Forestry Commission of Ghana currently uses paper maps and log books to store the tree inventory data. There are three different paper maps of each forest area. These are the

1. Forest reserve map showing the outline and landmarks of the forest reserve.
2. concession maps showing both mature and immature trees. This map is also referred to as the Stock Map.
3. the yield map. This map shows only the mature trees that are ready for harvesting.

These three maps are usually superimposed to get a complete picture of what is on the ground.
In addition, the forestry commission has log books that contain information about mature and immature trees and their approximate (X, Y) coordinates in log books. These books are checked when timber concessions are given out. The mature trees are then plotted on a map for the timber contractor to use in the reserve.

Comparing current practices to a GIS solution

Creating and storing data

The process of plotting the maps on paper is quite tedious. Apart from the fact that it requires highly-skilled human resources that are knowledgeable in cartography, it is prone to errors since approximations are carried out throughout the whole process. A certain degree of human error is thus introduced. Another disadvantage is that data is stored on paper which is not so durable due to the climatic conditions of the country.

GIS Solution

Creating the data with ArcView GIS is very straightforward since the software plots the points once the X, Y coordinates are specified. This does not require much expertise and the process is fast. This goes in a long way to increase the efficiency of the Forestry Commission. Storage of data is also not a problem since backups of data can be done anytime for long term storage. There is no requirement for a clean room to store maps. One added advantage is that, with a GIS, the system can easily be integrated with GPS technology such that data can be captured in the field and just be imported into the GIS.

Updating data

Updating the data in the office to reflect the current situation in the reserve is also a very difficult process. It is not possible to erase trees that have been harvested from the map. Changes in the reserve are therefore recorded and at the end of the year, new maps are drawn for the same area. This means that maps are drawn and discarded continuously. Since the drawing of maps is an intensive process, the end result is that Forestry Commission staff are always burdened with drawing maps just to update the data. This makes the whole data update process very time-consuming.

GIS Solution

Updating GIS data is very easy. If a tree is harvested, all that needs to be done is to delete the corresponding feature in the GIS map. This does not involve getting the map from the map cabinet, marking the map for future updates when the area is being drawn again.

Querying and Analysis

Performing queries and analysis of the data is very difficult. Lookups have to be done between log books and maps continuously to arrive at the answer to a query. The Forestry Commission is therefore limited to very simple queries since complex ones are very time consuming and the result of such a query might not be correct to a larger degree.

GIS Solutions

With a comprehensive GIS, most of these problems can be solved. One can easily query the GIS database with a few mouse clicks. Complex analysis can also be performed by the GIS. With the advantage of the computing power of the computer, such analysis can be performed within a very short time. Locating specific trees, tree species and other

queries are just performed and the results are printed on-the-fly. Thus, creating maps that answer specific queries is also easier.

Needed Expertise

The current system requires a high-degree of expertise related to the operations of the Forestry Commission. Most existing employees gain such expertise through years of work experience with the Commission. New employees have to understudy existing staff most times for a period not less than a year before they get acquainted with the Commissions' operations and procedures.

GIS Solution

It is a fact the learning curve for learning ArcView GIS is very **gradual.** A new employee with tertiary education level, irrespective of his/her course of specialization, will within a month be up to level on the use of ArcView GIS. The software is quite intuitive and user-friendly. ArcView also comes with a lot of documentation and learning material that makes learning ArcView GIS very easy.

Chapter 2: Methodology

Assembling Data
The project involved three major steps. These steps are outlined below;

1. Gathering available data
2. Processing the data with ArcView GIS to get the map
3. Scanning and scaling the concession area maps.

Step I
Data was collected from the Commission in the form of the Permanent Sampling Plot. This is a method of inventory where a sample of reserve is surveyed to find the various trees making up the forest, their geographic positions with respect to a local coordinate system and other attributes of the tree species such as the diameter at breast height (about 1.3m from the ground) and its estimated age.

Step II
The data from the Permanent Sampling Plot is plotted with the X, Y coordinates. The remaining data such as age, diameter, and growth rate of a species was entered into ArcView GIS.

Step III
The maps for the concession areas were scanned and on-screen digitizing was done to acquire these features. These features were then scaled to the correct scale.

Geodatabase design for Forestry Management GIS

The software used for the project was ArcGIS 8.1 from ESRI. A personal geodatabase was created in ArcCatalog. The geodatabase contained three main feature classes and one table. The structures of these tables are shown as follows;

Areas	
Field	**Description**
Feature Type	Polygon
Name	Identity of concession area

Rivers	
Field	**Description**
Feature Type	Polyline
Name	Name of river

Trees	
Field	**Description**
Feature Type	Point
Tree species	The species of the tree
Age	Approximate of the tree
Diameter	Diameter of tree at breast height

Species	
Field	**Description**
Name	Name of tree species
Growth rate	Rate of growth of species in cm/year
Diameter at maturity	Approximate diameter of species at maturity

Customization of ArcGIS

Further customization of ArcGIS was done with Borland Delphi and VBA. ArcObjects which form the building blocks of ArcGIS is based on Microsoft's Component Object Model (COM) technology. This makes it possible to perform customizations with any COM-aware programming language. Borland Delphi was chosen because of its object oriented nature and ease of use compared to Visual C++.

Chapter 3: Project Results

Classification of trees

With the GIS data, the trees can be classified on the map according to three important criteria; species, age and diameter. These can easily be printed.

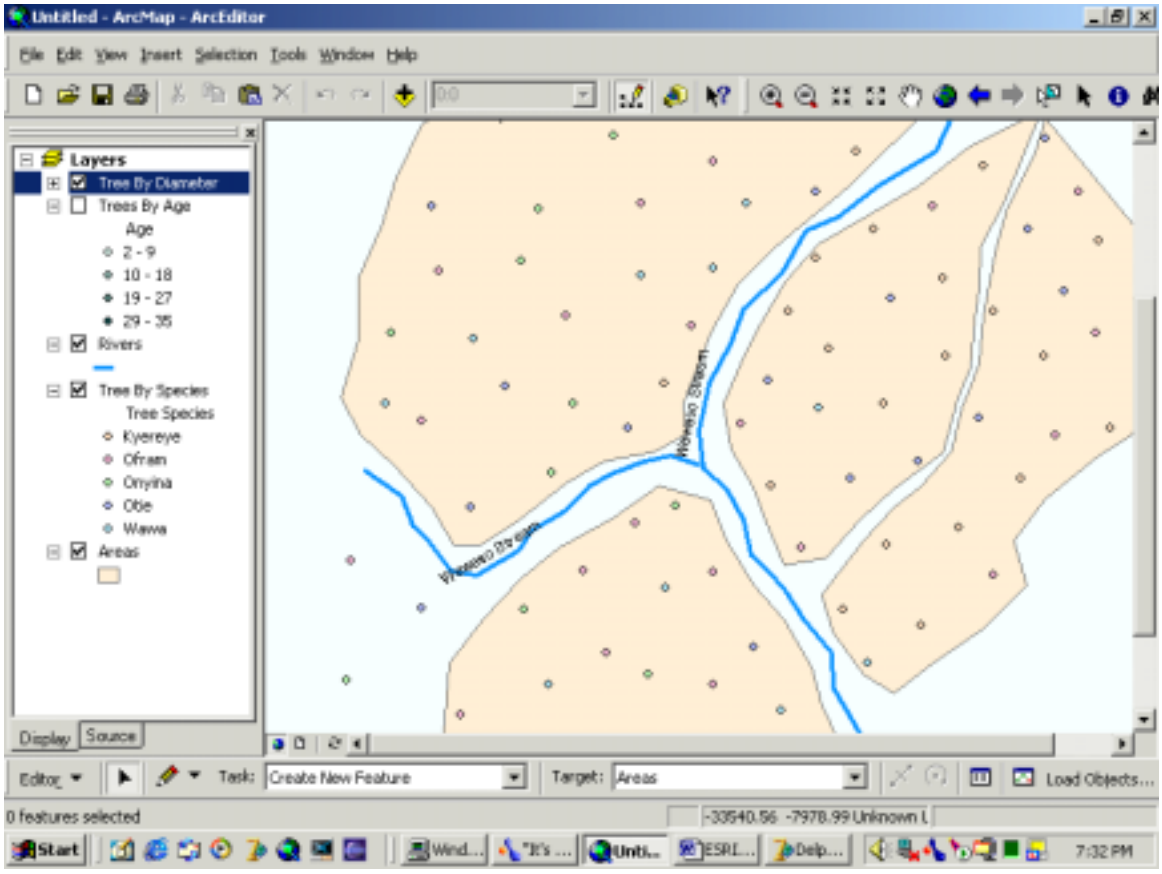

Fig 1. Map showing classification based on tree species

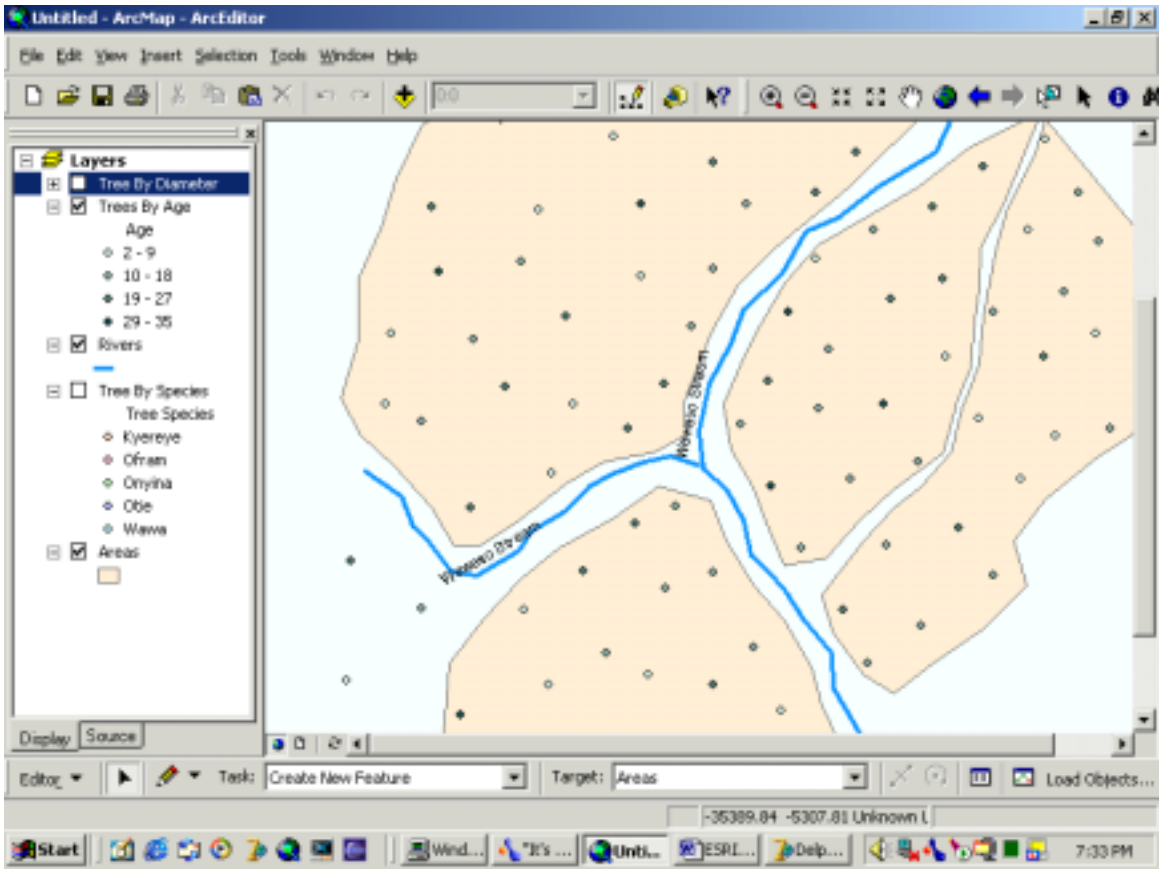

Fig 2 Map showing classification based on age range of tree.

To find the tree population in a given area

The user just has to select the area within which he wants to conduct the study and GIS selects the population and statistics of the various tree species. There is a customized form that shows the statistics of the chosen area.

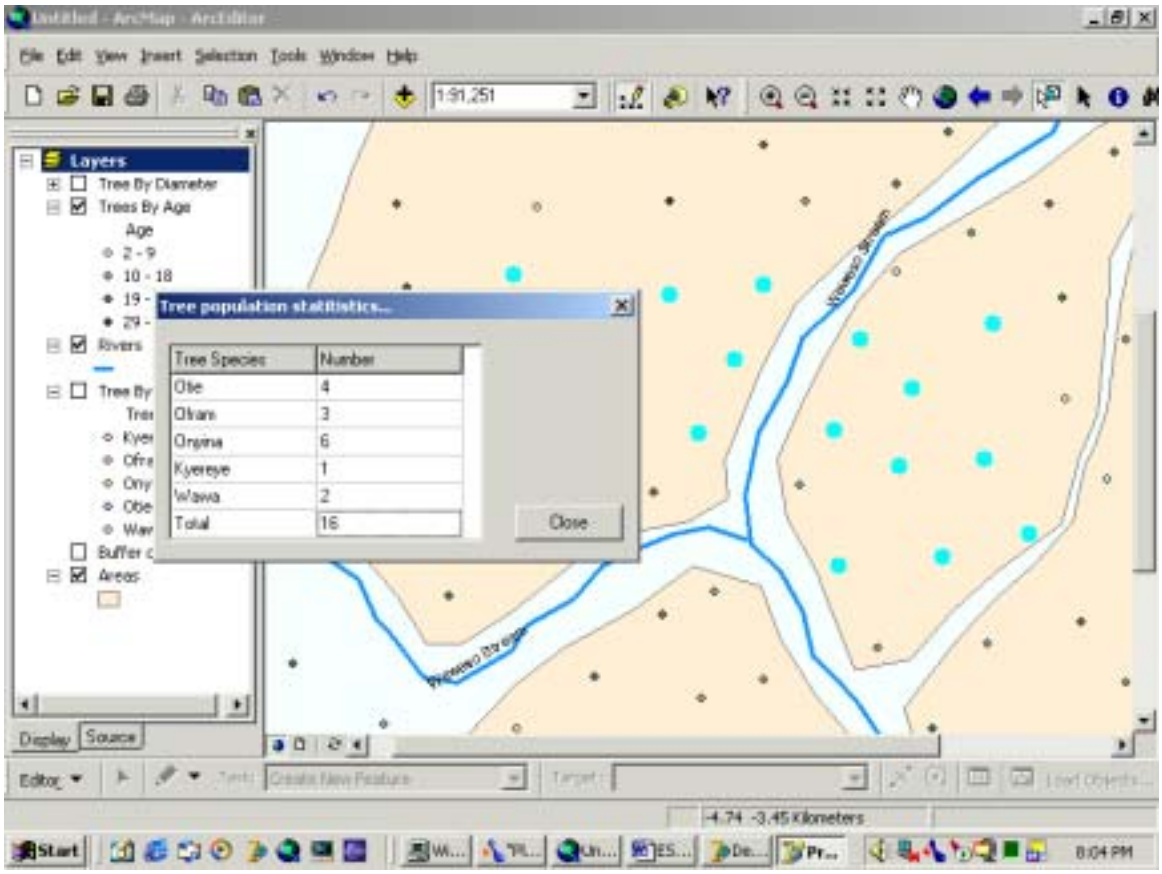

Fig 3. Map showing the tree statistics of selected trees

To find mature (harvestable) trees in a given area

With the help of a VBA macro, trees that are mature for harvesting can be selected. This is done by selecting for each tree species, the trees that have reached the diameter at maturity for that species.

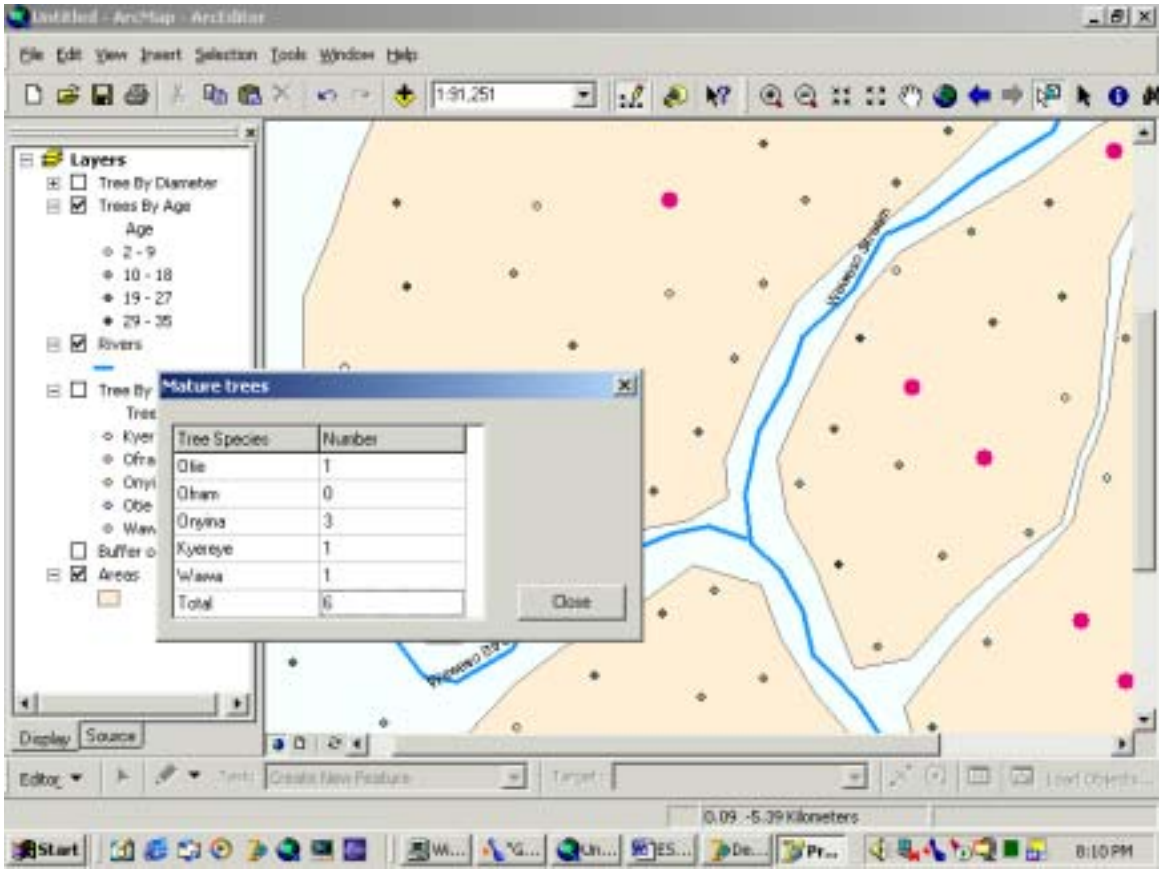

Fig 4. Map showing mature trees within an area and their statistics

To find the effects of bush fires started from one point

In the event of a forest fire, GIS may help in letting us know the extent of damage that will be caused. For this exercise, it was assumed that forest fires spread radial form in a circle. This can therefore be simulated with a buffer.

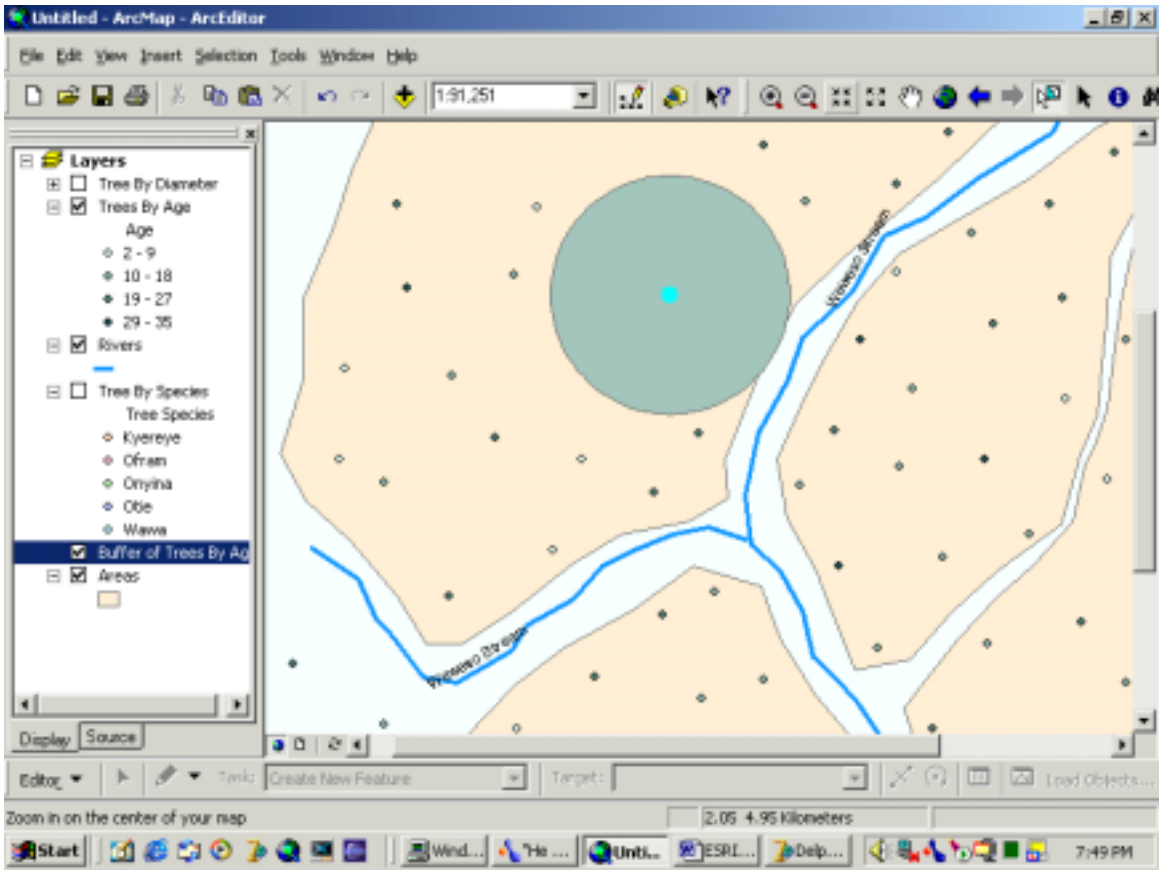

Fig 5. Map showing the extent of damage caused by a bush fire

To estimate the condition of the forest in a certain number of years

With the estimated growth rates available, it is possible to estimate the condition of the forest in the future. Given a number of years from now, y, the tree parameters can be calculated as follows;

New Age = Current Age + y
New Diameter = Current Diameter + (Growth Rate x y)

This information is used to create another tree feature class in the Forestry geodatabase with the computed values for the diameter and age. The feature layers in the map document are then set to display data from the new feature class. The various operations and analysis conducted earlier on can then be done with this new data. The figure shown below shows the operation being carried out for a projection of 6 years into the future.

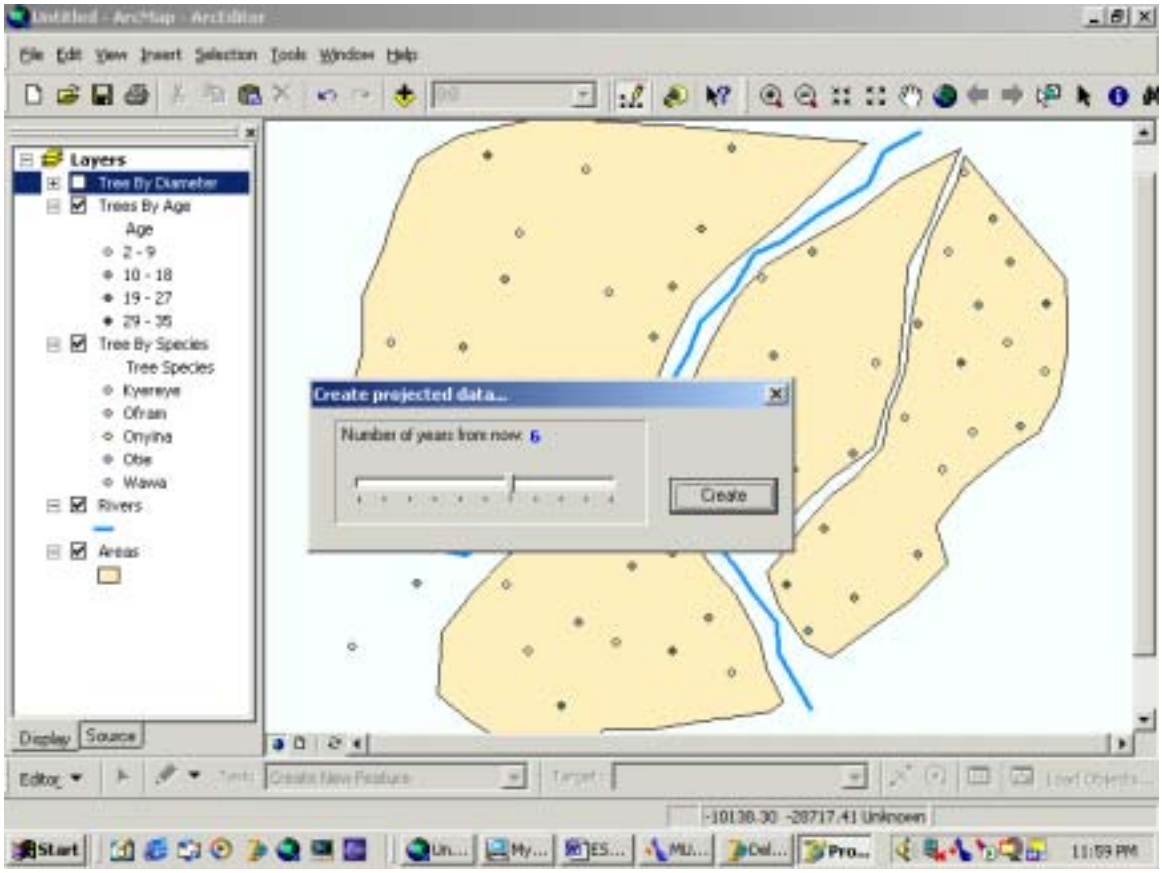

Fig 6 New feature class about to be created with a projection of 6 years.

Chapter 4: Conclusion

It can be seen that the benefits of using a GIS in the management of Forest Resources cannot be overestimated. The rewards are great and the advantages, numerous. This is just one of the many applications of GIS in forestry. Other factors such as analyzing soil types and using this analysis, together with rainfall patterns to determine the actual growth rates and the condition of the forest can be factored in.

On the whole, it can be concluded that GIS will provide a time and cost efficient system that can be implemented within the shortest possible time. This gives GIS a double advantage over the existing system. GIS can also be used as a tool in performing research into the correlation between the condition of the forest and natural factors such as rainfall and soil types.

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