GLOBAL TECHNOLOGY INFLUENCE ON THE MANAGEMENT OF COMMON PROPERTY IN SOUTHERN AFRICA

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Abstract

Geographical Information System (GIS) technology is becoming one of the most widely used tools in the management of Common Property today. However in the developed world, trends change rapidly while in the developing world, particularly, Southern Africa, there is a technology lag. The availability of GIS systems and Internet today now offers the most advanced solutions to our tools for managing common property resources cheaply and reliably. In this paper, GIS technology applications in forest conservation, wildlife management, pastures, water resource management and atmosphere are reviewed on the basis of both spatial and non-spatial data. The benefits for integration to users are analysed. The efficiency and effectiveness in making well-informed decisions using visual aids, 3dimensional models that simulate the environment and other tools are determined. Finally, the seamless link of GIS with the TCP/IP based Internet communication technology make universal access and remote management possible.

Key words: Geographical Information Systems, GIS Seamless connection; resultant impact; digital innovations and innovative research.

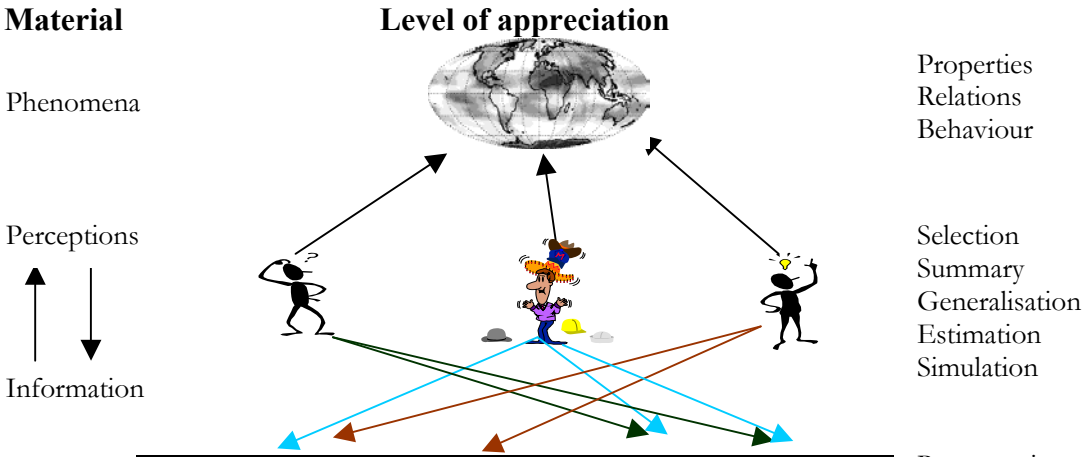
INTRODUCTION

The future of environment management in Southern Africa lies in the hands of the population whose average growth rate is above 3% *(SARDC 1994)*. In its normal form, nature is stable, and is disturbed by human factor for example, mismanagement (cultivating marginal lands), and natural disasters (e.g. drought, floods). As attested by a number of agreement and protocols e.g. Protocol on shared watercourses (see Chikowore in this volume) Southern Africa has realised the need to protect the common property resources. A neglected aspect of common property management problems is the geometrical representation, spatial location and relationships to the population it serves. This is a result of the complexity of modelling spatial reality without advanced technology and the value of technology. In this regard the role of technology cannot be overemphasized. Improved diffusions of technology innovations have made it possible to include computerised systems in managing private property or common or otherwise in the developed world. However, Southern Africa, like many other developing regions is lagging in the adoption of information technology. This creates a 'digital divide' that threatens to further widen the social and economic gap between developed and developing countries. In recent times the role of technology and the impact of global information society on the management of common property has improved the preservation and conservation techniques. Unfortunately Southern Africa suffers from lack of research funding for innovative technologies, although there are immense benefits that can accrue in cost saving from a significant technology leap. This paper examines

the applicability of GIS technology in forest conversation, wildlife management, pastures, water resource management and the atmosphere.

THE NATURE OF GEOGRAPHICAL INFORMATION SYSTEMS (GIS) TECHNOLOGY

Taylor (1991) saw definitions as more than just an exercise of semantics. They are important to focus attention on what a discipline sees as its major focus. GIS developed from the concept of a map. A map allows relationships between a wide variety of both quantitative and qualitative data to be organised, analysed, presented, communicated and used in a way no other product can match (Taylor 1991). To define GIS, one needs to understand what GIS hopes to represent (the Earth) and how people (users) perceive it. Cassettari (1993) views GIS as a tool to integrate spatial dimension with other information handling technologies. This has been the problem of the cartographer for years.



Country	Area (km²)	Population (millions)	Density (per km²)
Botswana	581883	1 501 000	2.5
Lesotho	30 354	1 971 000	64
South Africa	1 219 411	43 327 000	36
Swaziland	17 367	1 032 000	59
Malawi	118 515	9 609 000	81
Mozambique	812 593	18 165 000	22
Namibia	825 336	1 727 000	2
Zambia	752 813	9 350 000	12
Zimbabwe	390 860	11 723 000	29

Processes

Figure 1 illustrates how people view specific themes depending on their interest, background and level of education (*knowledge base*). Their perception of the same 'earth' resultantly differs. With such diverse views, there is therefore no universally accepted definition of GIS. Several closely related terms are used namely Environmental Information System, Pollution Information Systems, Automated Mapping/Facilities Management and Resource information System. In this paper, GIS is taken in its broad and complex reality that comprise **tools** for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes (Burrough 1990, Taylor 1991, Cassettari 1993, Kennedy 1996). Tools include everything that gives humans the ability to alter a system (human creativity, money and labour) in order to achieve predetermined goals. Thus, the tools are more than just the technology (Savory 1991), as one of the most important component is human resources. GIS is a tool and differs with computer science, Cartography, Surveying, and Geography that are disciplines. GIS's purpose is for managing common property resources in a global perspective.

GIS as used in common property research, is generally under-utilised particularly for environmental research in Southern Africa. This is mainly due to lack of awareness of

Figure 1: Differing interest about the same 'Real world' *(Modified from Laurini & Thompson 1994)*

potential of GIS, location of digital data and the myth of a difficult technology. Technology has brought about an information revolution such that formerly remote land can be accessed without physical visiting it. Not only is the Windows environment on which most GIS software today user friendly, expertise in GIS is also becoming locally available. These developments are resulting in historical disciplines being merged, redefined or disappearing, thereby generating benefits to the community in a way not formerly perceived.

THE COMMON PROPERTY RESOURCES AND THE GLOBAL VIEW

Common property resources (CPRs) are important components of the natural resource endowment of rural communities in developing countries. Unlike in developed countries, CPRs in developing countries continue to be a significant component of the land resources base, which makes them vulnerable. This vulnerability is more pronounced in the relatively drought prone, low productivity areas such as the arid and semi-arid regions of Southern Africa where the majority of the population tends to be concentrated. Since all property, movable or otherwise is referred to the earth, and is therefore spatial in nature. Consequently existing management solutions have tended to generalise the spatial component while concentrating on descriptive information to solve the resource problems. This has made it difficult to resolve spatial relationships and their influence on the global resources.

In Southern Africa, land resources are held in various forms such as private, public (government) and traditional. In this contribution, Ingerson's (1997) definition of common property as private property owned and managed by a group of people in a specific 'right' way is used. It evolves from public (group) goods that can be privately consumed and depleted. This differs from open access where everyone has access and incentive to abuse it. Rational management of common property depends on availability of necessary information as well on the wisdom of the decision-makers *(Phillips 1986)*. Technology is utilised in CPR to manage data in order to ensure informed decisions and conclusions. However ownership patterns of land determine how technology can be applied since technology operates in a social setting and not a vacuum.

The management of resources has increasingly taken a global perspective because of developments in technology and the availability of the global data. GIS as a technology has largely been driven by technical developments, not by social needs (Cassettari 1993). Hence it has developed more rapidly than applications, and software or hardware developments (Davis 1989). The challenge is enormous as world population continues to increase while corresponding resources continue to decline with increased extraction. The need to manage resource from a global view has become necessary as resources become more and more commercialised in this age of globalisation. Most technologies tend to originate from the developed world, giving local researchers the sense of alien affinity to the technology. This explains the seeming delay in our African counterparts in adoption of the new GIS tool. With the challenge of, sustainable natural resource management it is impractical to ignore modern tools in managing our common property resources.

THE SEAMLESS CONNECTION OF GIS TECHNOLOGY AND COMMON PROPERTY RESOURCES

Since time immemorial, technology has increasingly used (generalisation) in order to represent the complex earth resources. Decisions are then arrived at with minimum conceivable detail gathered with a plethora of assumptions. Today, there is a need to integrate abundantly available information from various sources. With GIS technology, essential information about the resources and the environment is readily available (Phillips 1986) and integrated for decision making. The technology is employed at several levels before information is available for planning and management purposes.

1. Acquisition of common property resource information

In the 1980s, the major problem was obtaining sufficient information. However, with information revolution of the 1990s, there is now an explosion of data (Taylor 1991). Common property acquisition tools include field surveys (spatial and questionnaires), Global Positioning

Systems[1] (GPS) (figure 2), Remote Sensing and Photogrammetry[2], existing maps, reports and publications. This results in more informed common property management decisions. Within the acquisition group, space technology[3] has registered its dominance, particularly Remote Sensing and GPS as we drift from an age of photogrammetry and terrestrial surveys. GPS is another complex system that is easy to *use* (Kennedy 1996). Space platforms are providing the unique capability of seeing and interacting with large parts of the earth simultaneously, thereby taking a global study of resources. Furthermore, there is significant increase in the speed of acquisition and repetitive coverage, but with minimal loss of accuracy (resolution). Utilisation of Remote Sensing in developing countries was limited by lack of ground receiving stations (Phillips 1986), but recent coverage has extended to the the world over with a broader spectral sensitivity[4] and temporal resolutions[5]. Spectral sensitivity, a function of wavelength of propagated wave, affects the features that can distinctly be studied in a single scene, while temporal resolution allows researchers to monitor changes over time. Scenes have recently been availed (CCRS, NASA) for civilian, research and management use at reasonable cost.

Figure 2: GPS a popular acquisition tool in the common property domain.

2. Storage and management of common property resource information

The proliferation of data as experienced today normally results in several problems:

- redundancy and inconsistency from multiple source of data
- accessing data by users who are not familiar with locations of required data
- data isolation in order to select suitable data for an application
- concurrent use for faster response time
- security problems results in all data that lacks privacy, e.g. available over the Internet and
- Integrity problems such as predefined constrains are not verified.

The database component of a GIS is a structured collection of related spatial and non-spatial information that attempts to solve these problems. The sets of tools ensure safe and efficient access to the data stores and subsequent display of solutions. The essential

[1] **Global Positioning Systems** is a data acquisition technique that uses a constellation of 24 satellites orbiting the earth while broadcasting data to users to determine their spatial locations.

[2] **Remote Sensing and Photogrammetry** is the science and art of acquiring information on the earth without coming into contact with the earth, object or phenomenon. Photogrammetry is a subset of remote sensing that uses only visible and near visible part of the electromagnetic spectrum, while remote sensing covers all wavelengths.

[3] **Space technology** is system that use satellites launched above and orbiting the earth

[4] **Spectral sensitivity** is the range of the electromagnetic spectrum wavelength that can be used.

[5] **Temporal resolution** is the rate at which data of the same area is reacquired.

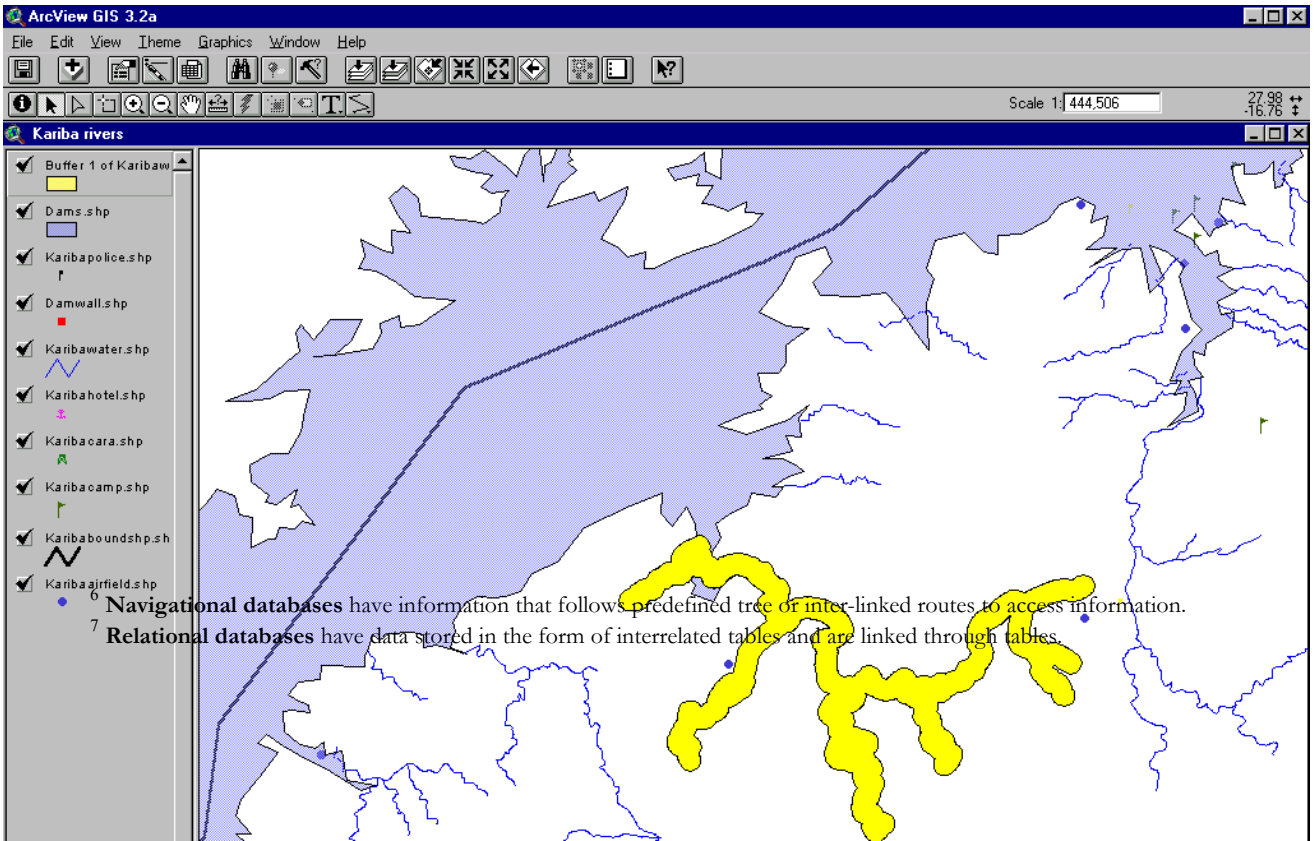
components allow definition of content, modify/insert/delete of data, query (select) content as management tools *(Star and Estes, 1990)*. Systems developments have made database technology a common tool for common property applications as it aims to structure new information.

Several management technologies exist today from the historical navigational databases[6] (network & hierarchical) of the 1980s, relational databases[7] of the 1990s, to the object oriented models of today's world. Relational databases have established themselves as the de facto standard in the region and most established GIS system operate on them.

3. Analytical tools in common property management

The complex decisions at a regional view (large scale) require that information be structured in order to shape the world (user view). Both scientific and social uncertainties constrain decision making in assessment, planning, and remediation projects confronted by common property managers with vast amounts of data. The quality of their decisions, which have wide-ranging impacts, depends on the analytical tools at their disposal. In a GIS, individual maps, composite maps, or spatial overlay, analyses are produced to meet unique requirements. Each map produced with GIS software is actually a layer of information. The different layers are displayed on the same map in combinations or individually giving the user the ability to display relevant information on request. As Mather (1993) noted, data collected in the field by different methods, when integrated together on the same geographical base, provide spectacular added value.

Reclassification and Aggregation: Manipulation tools allows the user to select and reselect subsets of data for display (Cassettari, 1993). This results in the isolation of resources of a common attribute or uniting two resources that share an attribute. In a study to isolate areas that were susceptible to erosion along a river network, a buffer of 5 kilometres was seen ensuring more management activity within the zone (Figure 3).



[6] **Navigational databases** have information that follows predefined tree or inter-linked routes to access information.

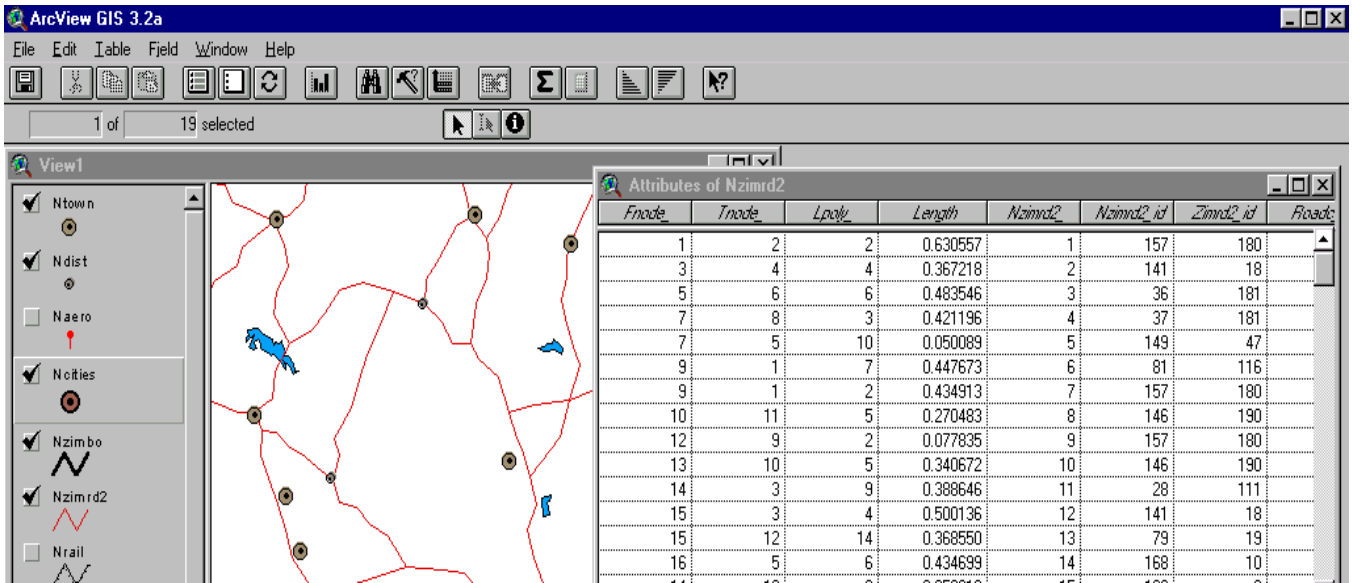
[7] **Relational databases** have data stored in the form of interrelated tables and are linked through tables.

Figure 3: Analytical technique buffering extend of influence of a river within a five-kilometre radius in the Kariba area, Zimbabwe

In this area, it is necessary to look at other influences such as slope and vegetation by integrating with buffered zones to effectively manage erosion.

Geometrical operators: Geometrical operators, including union *(sum)* and intersection *(minus),* are used to analyse the effects of integrating and overlaying different spatial datasets. Further, quantitative operators such as angular, distance (length) and area measurements are critical in managing the resource.

Spatial operators: Spatial operators provide the bridge that links fundamental data models to GIS technology, with the result that applications are enhanced and research findings are broadened and deepened. Together with attribute operators, they allow interrelation and maximum analysis of the character of point line and area features that constitute common property (Figure 4).



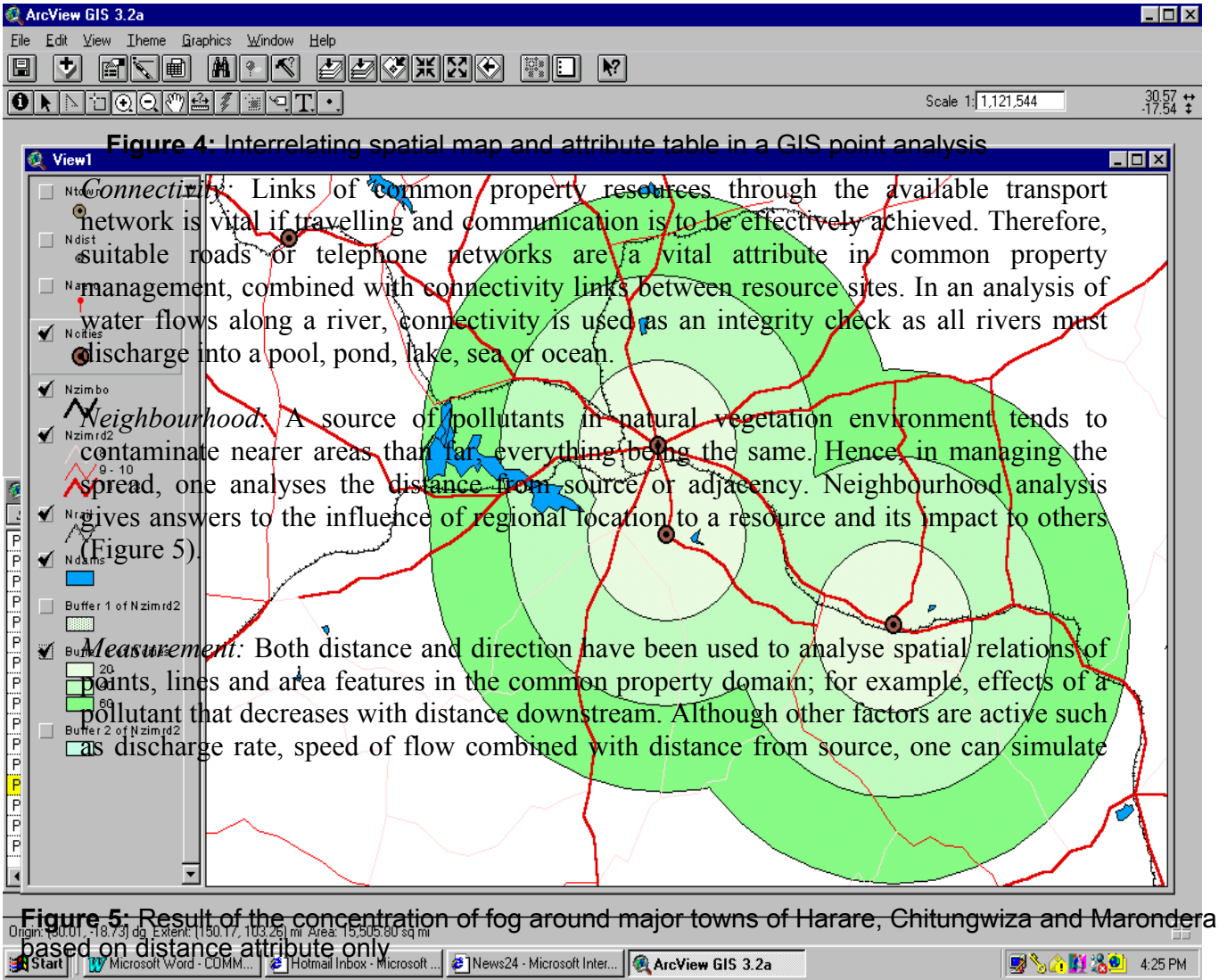


Figure 4: Interrelating spatial map and attribute table in a GIS point analysis

Connectivity: Links of common property resources through the available transport network is vital if travelling and communication is to be effectively achieved. Therefore, suitable roads or telephone networks are a vital attribute in common property management, combined with connectivity links between resource sites. In an analysis of water flows along a river, connectivity is used as an integrity check as all rivers must discharge into a pool, pond, lake, sea or ocean.

Neighbourhood: A source of pollutants in natural vegetation environment tends to contaminate nearer areas than far, everything being the same. Hence, in managing the spread, one analyses the distance from source or adjacency. Neighbourhood analysis gives answers to the influence of regional location to a resource and its impact to others (Figure 5).

Measurement: Both distance and direction have been used to analyse spatial relations of points, lines and area features in the common property domain; for example, effects of a pollutant that decreases with distance downstream. Although other factors are active such as discharge rate, speed of flow combined with distance from source, one can simulate

Figure 5: Result of the concentration of fog around major towns of Harare, Chitungwiza and Marondera based on distance attribute only

the range of influence. It becomes possible to confirm whether a community 100km downstream would be affected should they use the water for domestic use.

Statistical Analysis: Having postulated a null hypothesis that a spatial attribute affects common property management negatively, it is proven in a GIS using scientific facts. The validity of the hypothesis can be based on attribute data while visual result presentations can be easily understood. The probability and the extent of reliability of the results are computed and tested against known models. Samples representative of each area are then acquired and compared with the simulation.

Modelling: Cartographic modelling (overlay) is a common tool used to integrate various datasets (Figure 6). It is used to combine data areas, provide options and redefine new classes in the combined results. Its use has been mainly in modelling suitability studies for siting, planning and other activities.

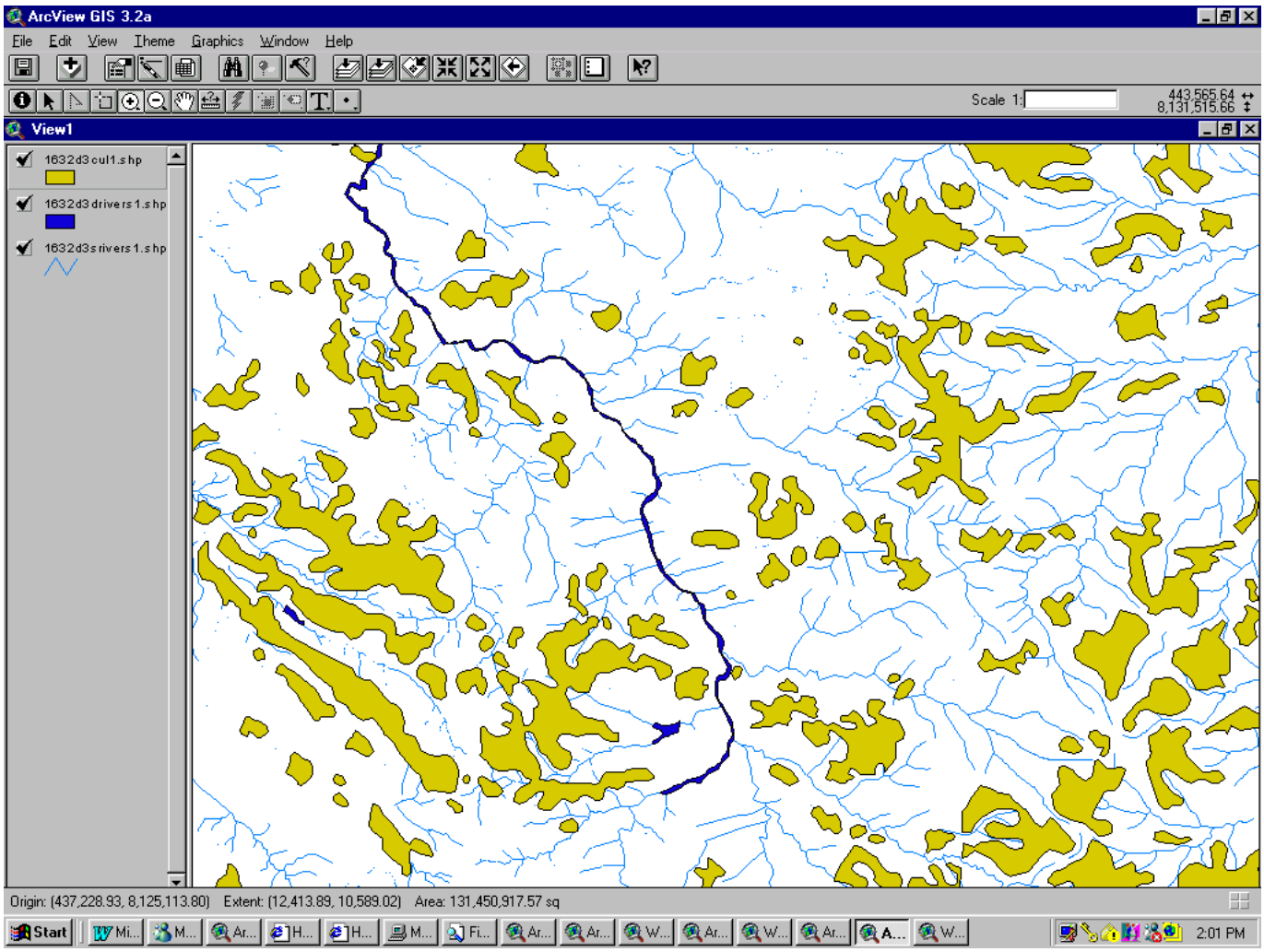
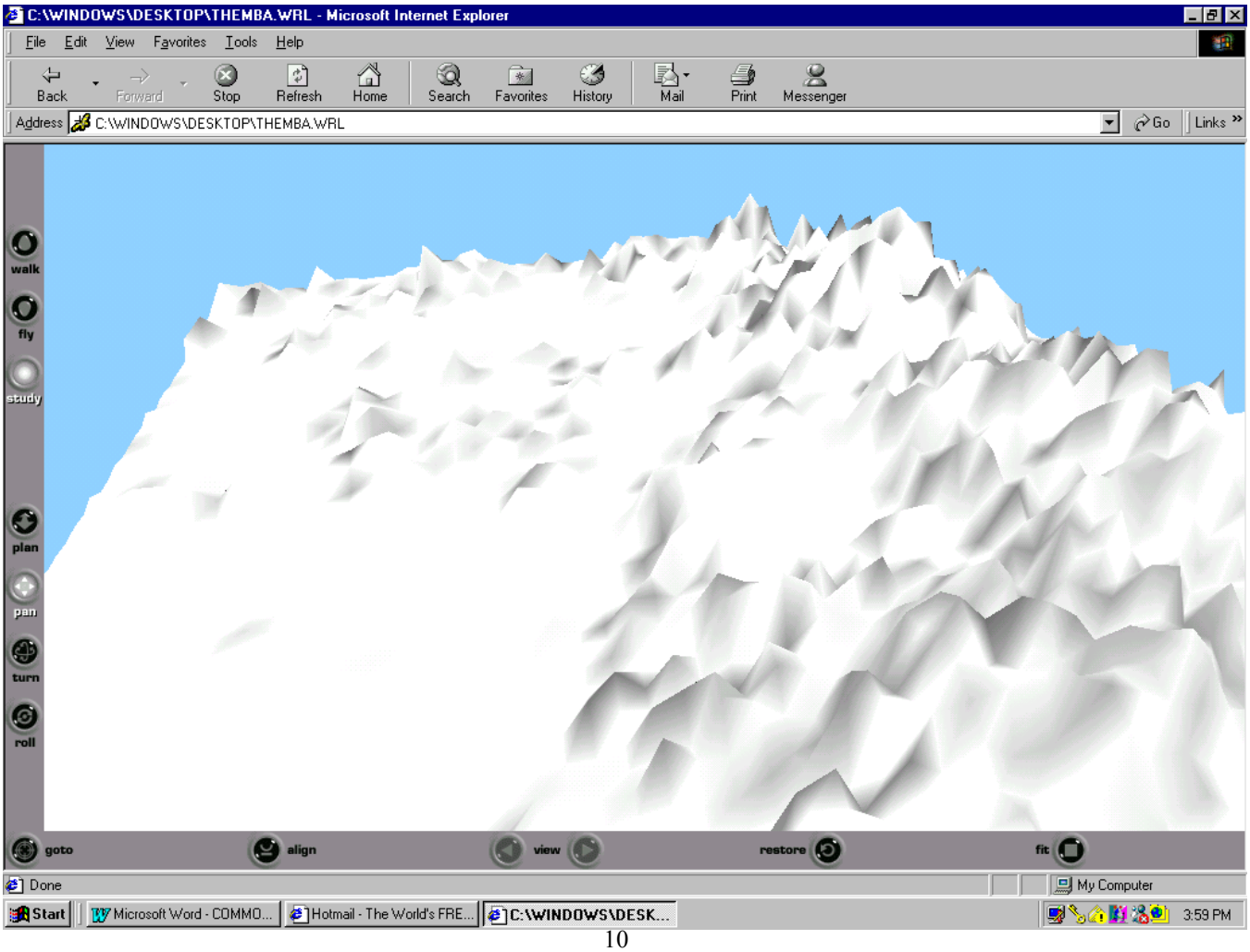


Figure 6: An analysis of the land under cultivation, drainage and communal pasture in rural Zimbabwe

In managing common property resources, the purpose is to improve the accessibility and equity of opportunities and services. GIS accommodates more sensitive configurations of economic activities and common property services. GIS capabilities for handling spatial data allow researchers to develop detailed representations and analysis of the spatial distribution of disadvantaged populations and their access to opportunities and services. GIS-based techniques for solving sophisticated and realistic location and distribution problems can allow these systems to be configured to maximize accessibility and equity.

4. Display and Visualisation tools for Common Property Management

GIS display components explores geographical visualisation techniques that are employed to monitor and manage common property resources in one up-to four dimension. The tools are developed and evaluated to ascertain their applicability for visualisation of data associated with specific regions and sites. The aim is to develop new products that improve the effectiveness of the transmission of information and better understanding of the process of communication (Taylor 1991). One dimension representation is typical of attribute databases, two dimension being the spatial map, three dimension displays include models while four dimensional display involve time series analysis of a 3D product. The most common graphical products of a GIS are maps of various kinds (Star & Estes 1990). Several other highly specialised displays have evolved, as models to systematically depict the earth such as digital elevation models



(2.5D) and Virtual Reality Models[8] (figure 7*)* became popular.

Figure 7: Three -dimensional visualisation of the Eastern Highlands in Zimbabwe at 500 vertical exaggeration *(Extracted from the Digital Chart of The World)*

Other graphical displays such as bar charts, line graph, scatter maps and summary statistic can enhance comprehension of the attributes and their spatial locations.

GIS technology has reached the point where non-technical people can comprehend complex data in a format with which almost everyone is comfortable: maps; making GIS, a perfect media for exchange of information among both technical and non-technical people alike. This has provided the key to critically comprehend applications of data benefiting subsequent analysis, processing or decision making. Of extreme importance is the 3D model of real life terrain with analytical tools of panning, walk through, fly by, measure and re-scale. Computer generated terrain are gaining acceptance as visualisation tools in most application areas (Raper 1989). As common property resources are generally 3D in nature, and an attempt to fit on 2D lacks accurate modelling, analysis and display, it is gaining acceptance in Southern Africa for common property resource management. This is particularly so for meteorology, hydrology ground water and hazard containment.

THE RESULTANT IMPACT OF THE TECHNOLOGY ON COMMON PROPERTY RESOURCE MANAGEMENT: A SOUTHERN AFRICAN PERSPECTIVE

The introduction of GIS technology in Southern Africa involves the complex process of managing change within environments typified with uncertainty, entrenched institutional procedures and little personal motivation. This has affected the opportunities for GIS solutions particularly for common property applications. However, the diffusion trend has seen increased acceptance, as the communities become more aware. The old trend of having the resources in the developed world well managed compared to the developing countries is slowly fading away. Not only can specialists in a distant country assist using modern GIS and Internet communication in the management of resources, qualified practitioners are becoming locally available. The TCP/IP technology (commonly known as Internet) allows remote access to local databases to specialists in Europe, USA and Canada to manage local resources in Southern Africa. The region has significant common property resource because of the nature of traditional land tenure systems as village communities who directly benefit from the resources thereon own most land. With the continued land redistribution anticipated, more land, and therefore resources would fall in the common property regime demanding more management resources. However technology has increasingly made it easy to plan land by few local specialists. We are entering an era of globalised management of resources.

[8] **Virtual Reality Model** depicts the surface/ object with the third dimension of height and spatial relationship incorporated. It allows the user to interact with the model through fly through, panning, rotating, zooming, walk through etc

The impact of information technology from the acquisition, management, storage and display results in highly informed decisions. With increased success in local GIS projects, the diffusion of the technology is gaining momentum making it the fastest growing technology in Southern Africa. With the expansion come several advantages including :

- GIS being an integrating tool allows varied source data to be analysed in a common platform. These results in more accurate predictions of future trends as they are modelled within a GIS system based on accurate information. This is more relevant to long term planning and management of common property resources.
- Spatial consistence is maintained through pre-defined links making data more effective and manageable. Not only are attribute based integrity constrains maintained, but also spatial relationships that are vital in the operational, tactical and strategic level are upheld.
- Integrated data gives an interdisciplinary perspective to common property resource management. Because several disciplines are involved in the management of common property, there is need to integrate varied source data and present it in a manner most professionals are comfortable in analysing, a map.

The basis of the benefits is greater awareness of the tasks being performed and range of information being used (Cassettari 1993). This is cemented by reduced duplication of data capture, manipulation and storage process.

COMMUNICATION AND SHARING OF THE RESULT

The Internet has become a reality even in third world countries. Although currently largely a privilege of well-to-do companies and research institutes, some businesses have gone to the extent of using Internet Cafes to tape on regional business. The links with major centres in the region are reliable and as a result provide specialists an opportunity to consult interactively on common property management. Coupled with the development of Internet GIS and Virtual Reality Modelling technology, the availability of the report in both spatial and 3D forms have resulted in increased diffusion of the results. The cost of sharing has greatly reduced and update is virtually on line. The use of local area networks and wide area networks has continued to contribute to a digital communication network thereby helping to disseminate results. There are a number of resources where this can be applied.

By the end of 1985, Thibault (1986) noted that 1.2 billion people living in developing countries did not have access to clean water. Drought continues to cause famine particularly in Southern Africa, hence the need to locate, develop, and efficiently manage water resources. Satellite Remote Sensing today has provided means for addressing global issues quickly and economically by characterising large areas for their capability to support a variety of human activities. The recent cost of satellite data seemed astronomical compared to meagre resources, unproven benefits and problems in feeding a population with a high growth rate. With the reduction in satellite data cost, projects in catchment management and modelling have increasingly been using GIS. This has resulted in improved understanding of issues by multidisciplinary teams managing the

resource. Notable examples have been Chivero, Mupfure, Manyame and Save catchments where this has been applied. The tool increased the understanding of our underground water resource in the hydrological unit 3 of Zimbabwe.

Much of Southern Africa falls in the Savannah type of vegetation, making it suited for pasture. Two thirds of Southern African land is suitable only for grazing (SARDC 1994). With increased population of animals, both wild and domestic, there has been increased need to understand the changes in vegetation over a period of time. A time series analysis of the kind is best undertaken from Remote Sensing imageries of the same area taken over a period of time.

Common property management of forests, pastures and wildlife are critical in Southern Africa, as the population is likely to exceed the capacity of the land soon. A project using GIS and remote sensing in a communal setting revealed alarming rate of depletion. No intensive reforestation would match the rate of consumption suggesting alternative sources of fuel as the sole solution. Coupled with a semi-arid climate, GIS was used to integrate the varied attributes in order to model and analyse trends.

THE FUTURE ROLE OF GIS IN COMMON PROPERTY MANAGEMENT

Our communication channels are increasingly becoming digital environments hence the need to adopt the digital innovations. Diffusion of innovative research and development improved tremendously when GIS was integrated with the Internet technology. The reduction in the cost of GIS as a technology has made it more appropriate in light of limited resources and needs. Thus more and more organisations are incorporating GIS as part of their business plan to ensure competitive edge.

The era when GIS served tasks and planning rather than more intellectually challenging strategic issues is coming to an end. Strategic targets are being achieved using GIS because of improved information management, better analysis and hence better choices. Not only can GIS be specifically modelled to respond to a given problem, it also allows easy interpretation by technical and non-technical people alike. This enhances the joint participation of local communities and specialised advisers in common property management in line with increased community participation in resource management.

The time span between commencement of GIS project and implementation has greatly reduced. The cost of data acquisition, a significant component in the cost recently, has also been reduced tremendously. The technology was developed in military circles. Civilian use therefore is only but supplementary use of the technology thus leading to the overall reduction of management costs in common property resource.

However, the problems of copyright and data ownership have continually hounded Southern Africa. The copyright laws meant to regulate the use and re-use of digital resources has not developed at the same pace as technological advancement and continually lags behind. The data that could be shared is usually re-acquired to ensure compliance to copyright laws. Save for data primarily used for research, which carries

limited restrictions, GIS, has failed to enter the commercial market at the expected rate. As a result, a lot of duplicate data acquisition has continued to increase the cost of new projects that could easily be avoided.

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