APPLICATIONS OF GIS IN COMMUNITY-BASED FOREST MANAGEMENT IN AUSTRALIA (AND NEPAL)

By
Himlal Baral
B. Sc. (Forestry), Master Degree in Social Science (TU, Nepal)

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School of Forest and Ecosystem Science
Institute of Land and Food Resources
The University of Melbourne

Abstract

Community forestry is now a popular approach in forest management globally. Although local communities have previously been involved in forest management in various minor ways, community-based forestry is very new in the Australian context. Because of the multiple interests of forest users and other community interest groups, a wider range of up-to-date information is being requested in community forestry, than has been used in ‘conventional’ government-based forest management in the past.

The overall aim of this research was to explore the potential and constraints for the application of Geographic Information System (GIS) technology in community forest management in Australia and to relate the results also to Nepal. Specific objectives were to: (i) review the applications of GIS in forestry and community forestry worldwide, (ii) determine stakeholders’ views on their requirements for the use of GIS in community-based forest management, (iii) prepare and demonstrate various practical applications of GIS requested by community groups in the Wombat State Forest, (iv) identify the strengths and limitations of GIS in community forestry, and (v) relate findings on GIS applications in Australia to community forestry in Nepal.

This study involved a combination of three approaches: review of global literature on GIS, use of GIS and related technologies, and participatory action research. A wide variety of spatial information was identified through community groups as important for community forest planning and management. Two approaches for making GIS and such information available to Wombat Forest communities are outlined, the one being the process followed by the researcher for this thesis. The outcomes of the GIS applications developed as part of this research were made available to the community in the larger and linked Victorian Government GIS project.

Review of global literature on GIS applications showed high potential and growing use of GIS in community forestry. Some practical applications of GIS considered to be useful by community groups involved in management of the Wombat State Forest were

developed with participation by community members. The outcomes of some of those GIS applications are currently being utilised by stakeholder groups (e.g., weed maps for preparing an integrated weed management plan). Other applications being used in forest management planning include rainfall isohyet mapping, mapping of wetlands and of historical sites.

Some of the findings of this study appear to be relevant to developing countries and could be applied, with some modifications, to local situations in Nepal. For example, community mapping of weeds and the development of partnerships between communities and universities or research institutions. It is suggested that in some parts of Nepal GIS databases could be developed within a 'Range Post' (or *Ilaka* forest office) in a cooperative manner with a number of community forest user groups. The extension of electricity and other services to rural regions and support from outside agencies would be crucial for the future development of GIS in community forestry in Nepal.

The findings of this study clearly indicate that GIS and related technologies have high potential for use in community-based forest management. The integration of GIS with participatory action research can help to identify community's requirements for information, collect and incorporate local knowledge into community-based GIS databases, and for local forest resource planning and management activities. GIS technologies are only a means to identity and solve problems, and need proper planning and basic resources to allow their potential to be realised.

Declaration

This is to certify that the thesis comprises only my original work except where indicated in the preface; due acknowledgement has been made in the text to all other material used; the thesis is 30,000 words in length, inclusive of footnotes, but exclusive of tables, maps, appendices and references.

(…………………)
Himlal Baral
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List of Acronyms Used in Thesis

AAT	Arc attribute table
AGD	Australian geodetic datum
AMG	Australian map grid
ANG	Australian national grid
ASCII	American standard code for information interchange
BOM	Bureau of Meteorology (Melbourne Office of Australian Bureau)
CAD	Computer-aided design
CBFM	Community-based forest management
CD-ROM	Compact disk-read only memory
CF	Community forestry
CFM	Community forest management or Collaborative forest management
CFUG	Community forest user group
CGIS	Canada geographic information system
CGM	Computer graphics metafile
Ci-GIS	Community integrated geographic information system
COGO	Coordinate geometry
CPU	Central processing unit
CSU	Colorado State University
DBMS	Database management system
DEM	Digital elevation model
DoF	Department of Forests (Nepal)
DPI	Department of Primary Industries (Victoria)
DSE	Department of Sustainability and Environment (Victoria)
DTM	Digital terrain model
EOS	Earth observation satellite
ESRI	Environment system research institute
FAO	Food and Agriculture Organization of the United Nations
FUG	Forest user group
GDA	Geocentric datum of Australia

GIS	Geographic information system
GKS	Geographic knowledge system
GPS	Global positioning system
GRASS	Geographical resource analysis support system
GUI	Graphical user interface
HTML	Hypertext transmission protocol
INGO	International non-government organization
IPMS	Integrated pest management system
LAN	Local area network
MCA	Multi-criteria analysis
MSS	Multi-spectral scanner
NCGIA	National Centre for Geographic Information Analysis (USA)
NGO	Non-government organization
PAR	Participatory action research
P-GIS	Participatory geographic information system
PP-GIS	Public participation geographic information system
PRA	Participatory rural appraisal
RDBMS	Relational database management system
RMS	Root mean square
RRA	Rapid rural appraisal
RS	Remote sensing
SA	Selective availability
SCFC	South Carolina Forestry Commission (USA)
SCSI	Small computer system interface
SEI-Y	Stockholm Environment Institute
SPOT	Systeme probatoire de I’observation de la tree
SPS	Standard positioning service
TAT	Text attribute table
TIFF	Tagged interchange (image) file format
TIGER	Topologically integrated geographic encoding and referencing
TIN	Triangulated irregular network

TM	Thematic mapper
UoM	University of Melbourne
USCG	United States Coast Guard
USDoD	United States Department of Defence
UTM	Universal Transverse Mercator
VDOF	Virginia Department of Forestry (USA)
WCFM	Wombat Community Forest Management
WSF	Wombat State Forest
WWW	World wide web

1 INTRODUCTION AND OBJECTIVES

1.1 Background

Forests are important renewable natural resources and have a significant role in preserving an environment suitable for human life. In the past 60 years forest management practices in many countries were driven mainly by economics; measuring forest growth and volume, calculating allowable cut and maximizing timber harvest or profit (Holloway 2000). Today forestry professionals have to understand the interconnectedness of, and the need to balance, the environmental and economic benefits that forest ecosystems provide (Warnecke *et al.* 2002). Organising, analysing, and presenting relevant information to policymakers, planners and managers are also responsibilities of modern foresters (Grove and Hohmann 1992) who need to address the interests and priorities of local communities and involve them in decision making (Jordan 1998). Therefore forest resource management in today's ever-changing world is becoming more complex and demanding to forest managers (ESRI 2003a). Geographic Information Systems (GIS) is suggested in this thesis as a potential means of dealing with this complexity.

1.2 GIS Technology in Forest Management

Geographical Information Systems(GIS) is an information technology that has been used in public policy-making for environmental and forest planning and decision-making over the past two decades (Bassole *et al.* 2001). GIS and related technologies provide foresters with powerful tools for record keeping, analysis and decision making. GIS can be established to provide crucial information about resources and can make planning and management of resources easier, e.g., recording and updating resource inventories, harvest estimation and planning, ecosystem management, and landscape and habitat planning. Nowadays, with improved access to computers and modern technologies, GIS is becoming increasingly popular for resource management (see Box 1-1).

Box 1-1: Reasons for the increasing trends towards GIS use by forestry professionals

- Reduced cost of computer hardware and software
- Technological advances in computer hardware and software
- User friendliness of software
- Availability of trained manpower
- Save time and money, although initial set up cost may be higher
- Trustworthiness of technology
- Ease to update (forest is ever-changing).

(Ammerman 1997; Bettinger and Wing 2004; Jordan 1998; Korte 2001; Warnecke *et al.* 2002)

Since foresters have to deal with numerous objectives from a single patch of forest (e.g., annual allowable cut, maintenance of biodiversity, conservation of soil and water) a wide variety of spatial information is required (see Section 4.2) and sources of reliable data are a prerequisite for developing a GIS in forest management. The trend towards community-based forest management has added new dimensions and potential to the use of GIS in forest management.

1.3 Community-based Forest Management

There is increasing recognition in developing countries that forest resources cannot be sustainably managed without active involvement of local communities. Although the concept of community forestry emerged mainly in developing countries it is also becoming common in industrialized nations. In Australia this concept is very new but communities surrounding Victoria's Wombat State Forest are developing a collaborative partnership with the government and gaining greater access to the decision making process (MUNR 2003). The terms collaborative (or community-based) forest management are becoming increasingly popular because of the role that local stakeholders are taking in forest planning and management. Community-based forest management is defined here as a working partnership among stakeholders in planning and management of forest resources.

Although different terms are used in different countries (e.g., community forestry, social forestry, joint forest management, village forestry), the common principle of community-based forest management (CBFM) is to involve local stakeholders in developing a process for the management of forests. There are many reasons that communities become involved in forest management, such as impact of forest on their livelihood, equity and social justice, importance of indigenous knowledge and skills, and pressure from environmental organisations. Cost-effectiveness, biodiversity conservation, development philosophy, and good governance have also been considered as important factors in driving CBFM (Brown 1999; Petheram *et al.* 2004).

The priorities of stakeholders in managing forest differ widely with the local situation, and on people's requirements from the forest, and their traditional norms and values. Table 1-1 shows some main concerns of communities in managing forest in the case of communities in Nepal and Australia.

Table 1-1 Community priorities in managing forest in Kavre (Nepal) and Wombat State Forest (Australia)

Nepal (Kavre District)	Australia (Wombat CFM, Victoria)
Fuel wood Fodder supply Small poles Construction timber Medicinal and aromatic plants Conservation – soil and watershed and Biodiversity (in some cases). (Source: Community Forest Operational Plans of various CFUGs in Kavre District, sighted at DFO in 2002)	Water conservation Wildlife habitat conservation Recreation (bushwalking, horse riding, orienteering) Natural heritage conservation Forest restoration Fuel wood. (Source: Various community meetings with Wombat CFM July- November 2003 and Petheram *et al.* (2002)

Table 1-1 shows that priorities in Nepal are concerned mainly with daily needs whereas in the Wombat Forest they are oriented more towards conservation and recreation. Even though timber and fuel wood demand were not mentioned as major priorities in the community forums in the Wombat Forest it is well known that firewood (and timber) are very important priorities for sectors of that community (G. McIntosh [Daylesford Landcare] pers. comm. December 2003). Of the numerous stakeholder groups identified in the Wombat State Forest in early discussions on community management (Petheram *et al.* 2002), some primary ones were local residents (town and rural), Department of Sustainability and Environment, environmentalist groups (local and national), timber industry (small scale and large scale), and local governments (4 shires), catchment management authorities, recreation and tourism and other organisations

1.4 Emergence of Community-based GIS

It has been stated that conventional GIS has seldom fully addressed social issues. Weiner *et al.* (1995) state that GIS practitioners have created digital representations of social and natural phenomenon that best reflect their expert viewpoint. However, Cinderby (1999) criticises the conventional uses of GIS in forest and natural resource management for being part of a top-down approach (not democratic) and avoiding the social and cultural aspects of forest management. Over the last decade a range of new computer map-based tools, termed participatory geographic information systems, have been developed to investigate the options for sustainable livelihoods and to strengthen people's role in decision-making.

People usually claim to know their local area more intimately than outsiders and can reasonably be expected to provide valuable insights in to local phenomena that are not available in ordinary GIS datasets. Incorporation of local knowledge is clearly a major strength of participatory approaches and may go some way towards providing the Geographical Knowledge Systems (GKS) proposed by Taylor (1990) and Carver (2001). Participatory GIS can help to merge community knowledge and outside expert’s, information in CBFM.

GIS is becoming recognised as a tool that can be applied to involve local people in the decision-making process, thus enhancing communication and understanding, and incorporating local people's perceptions regarding resources and their management. In this study, an attempt was made to combine GIS technology with ideas from participatory research, as much as was feasible in working over a short period of time (8 months) with some stakeholder groups that expressed interest in the use of GIS in their areas. These groups were invited to seek assistance or advice on use of GIS in mapping or for other purposes. All participation was voluntary.

1.5 Research Problem, Aim and Objectives

The emerging role of GIS and related technologies in forestry and the global trend toward community-based forestry have been mentioned. However, the potential benefits of GIS in CBFM have seldom been realised for a range of reasons:

- Local communities have poor access to computers and GIS software (Shah 2001; Weiner *et al*. 2002)
- People trained in GIS and related technologies are not readily available (Abbot *et al*. 1998; Shah 2001)
- There is lack of trust by government authorities – in making data available (Cinderby 1999; Jordan and Shrestha 1999)
- Social scientists think GIS is too technical for use by local communities (Cinderby 1999)
- Little is known by GIS technicians about ways to integrate GIS with needs of particular forest stakeholders (Abbot *et al*.1998; Carver 2001).

While this study was conducted in Australia the findings may have relevance for community forestry in Nepal and other parts of world.

The overall aim of the study is to explore the potential and the constraints for the application of GIS technology in community-based forest management in Australia and Nepal. The research objectives are to:

1. Review the applications of GIS in forestry and community-based forestry worldwide
2. Determine stakeholders' views on their requirements for the use of GIS in CBFM in the Wombat State Forest (WSF)
3. Prepare and demonstrate various practical applications of GIS requested by community groups in the WSF, and gauge response and problems
4. Identify the strengths and limitations of GIS applications in community forestry
5. Relate findings on GIS applications in Australia to Community Forestry (CF) of Nepal.

1.6 Approach, Methods and Study Area

The approach and methods for this thesis can be divided into three categories: (i) review of literature on GIS applications in forestry and community-based forestry, (ii) 'action research' with community members in defining the needs for GIS and data collection for CBFM, and (iii) use of GIS, GPS and related technologies in developing GIS applications for CBFM.

Thus, although technical skills and methods from GIS and related technologies were essential in the research method, this study also involved modern approaches to social research conducted with community members in a participatory framework.

The area chosen as a research site for this study was the Wombat State Forest in Victoria (see Figure 1-1). This was selected because it is the only community run forest in southern Australia and there is strong interest among stakeholders in using GIS in local forest management. The approach and methods used in this thesis are discussed further in Chapter 3.

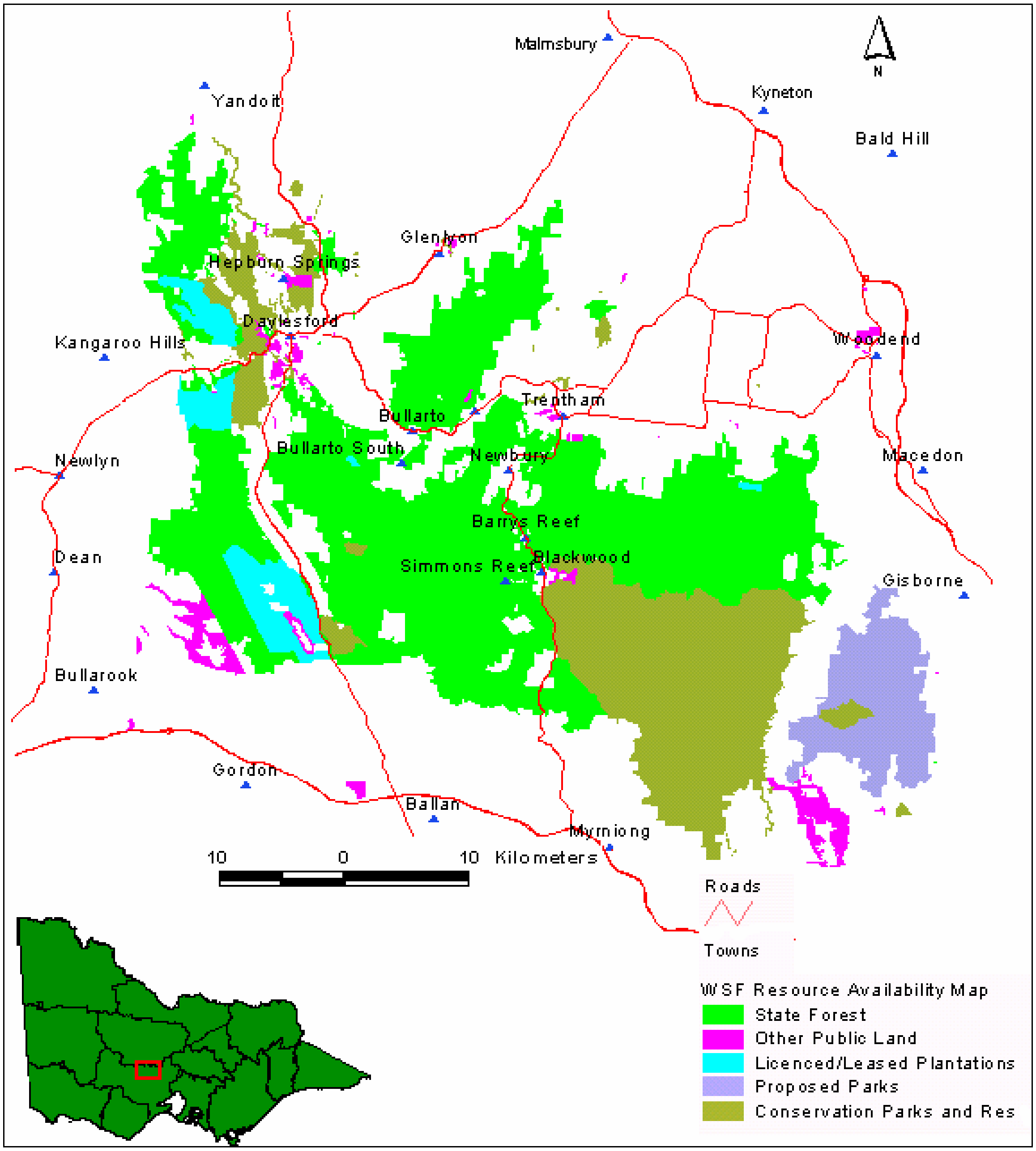


Figure 1-1 Map of the study area: the Wombat State Forest, Victoria

1.7 Summary Outline of the Thesis

Chapter 2 gives an overview of the principles and concepts of GIS, its components and functions. Since the focus of this thesis is on the applications of GIS in CBFM, the technical information provided in this chapter is very limited. Chapter 2 also includes a brief introduction to concepts of GIS-related technologies appropriate for this thesis, i.e., Global Positioning System (GPS) and remote sensing (RS).

Chapter 3 outlines the methods used for this research project and the methodological framework in which GIS technologies were combined with participatory action research and a wider review of worldwide literature on GIS.

Chapter 4 discusses various applications of GIS and related technologies in forestry and especially in community forestry. Chapter 4 concludes with a brief introduction to free GIS and GPS software available on the Internet and their value to community forest user groups.

Chapter 5 deals with the development of community-based GIS in the Wombat State Forest. It starts with various issue-based working groups associated with CBFM and their spatial information requirements. Two models for community-GIS and their development for the WSF are outlined. Some international case studies regarding community-based GIS are reviewed, and lessons are drawn for the Wombat State Forest.

Chapter 6 deals with some practical applications of GIS developed with community groups in the Wombat State Forest. Examples are given of specific applications of GIS requested by community groups involved in forest management, such as community weed mapping using GIS with the Blackwood and Barrys Reef Community. The major strengths and limitations of community-based GIS are also covered.

Chapter 7 synthesizes key findings from the previous chapters and discusses the contribution of GIS in addressing the community's spatial data requirement in the WSF.

It also discusses the relevance of the findings in the WSF to the Nepalese context. Some conclusions are drawn and suggestions made to guide the future development of community-based GIS in the WSF generally, and in this study area.

2 OVERVIEW OF GIS AND RELATED TECHNOLOGIES

2.1 Introduction

This chapter introduces some basic principles and concepts of GIS and related technologies that are relevant for this thesis and that can be used in developing some practical applications for use by groups involved in community forest management in the Wombat State Forest.

GIS has emerged as a very powerful tool in the management of spatial information and has become a topic of intense interest for many academic disciplines, government organizations, as well as commercial enterprises. Although GIS has existed since the 1960s (Delaney 1999), its applications have grown phenomenally during the last two decades (Apan 1999). The development of cheap and powerful personal computers and user friendly, readily available GIS software has increased the use of GIS technologies in almost every field (Apan 1999; Berry 1994; Burrough and McDonnell 1998; Chrisman 1997). Davis (2001) reports that GIS is a highly dynamic field, growing as the same very rapid pace as the change in information technology. Sound understanding of the capabilities of GIS by users, managers, and decision makers is crucial to the appropriate and effective use of the technology (Aronoff 1989).

It is not possible within the space of this thesis to discuss the theory and practice of GIS in detail, so interested readers are referred to some especially useful background texts on GIS, such as Aronoff (1989), Bettinger and Wing (2004), Burrough and McDonnell (1998), Chang (2002), Chrisman (2002), Davis (1996), Longley *et al.*, (1999), Lo and Yeung (2002) and Mitchell (1999).

2.2 GIS Definitions

Various definitions of GIS have evolved in different areas and disciplines (Maguire *et al.* 1991) so it is difficult to select one definition that suits all the purposes and concepts of GIS applicable to this thesis. Some main definitions from the literature are shown in Box 2-1:

Box 2-1: Some definitions of Geographic Information System (GIS)

Definition 1: GIS as a toolbox
“a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes” (Burrough and McDonnell 1998 p. 11).

Definition 2: GIS as an information System
“an information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is both a database system with specific capabilities for spatially referenced data, as well as a set of operations for working /analysis with the data” (Star and Estes 1990 p. 2-3).

Definition 3: GIS plays a role in society
“organised activity by which people measure and represent geographic phenomena, and then transform these representation into other forms while interacting with social structures” (Chrisman, 1999 p.13).

From the definitions in Box 2-1, some people see GIS as a toolbox that has a number of different roles and capabilities, while others view GIS as a decision-support system for policy making, planning and management (Apan 1999; Maguire *et al.* 1991). The following definition was developed by consensus among 30 GIS specialists from various disciplines (Durker and Kjerne 1989, cited in Chrisman 2002 p.12).

"GIS is a system of hardware, software, data, people, organization, and institutional arrangement for collecting, storing, analysing, and disseminating information above areas of the earth."

Wright *et al.* (1997) claim that for most users, GIS is a problem-solving tool.

2.3 Basic Components of GIS

Maguire *et al.* (1991) state that the four main components of GIS are software, hardware, data and people, whereas ESRI (2001) includes 'method' as a fifth component. All the components need to be in balance, if the system is to function satisfactorily.

Software

Software refers to computer programs that provide the functions and tools needed to store, analyse, and display geographic information. GIS vendors often advertise their products with special features (Chang 2002) and different GIS software packages can vary widely in cost, functionality and user friendliness (Delaney 1999). Some well-known GIS software packages, their developers and main features are shown in Appendix 2-1. A wide range of GIS programs have been used by forestry and natural resource management professionals (Bettinger and Wing 2004).

The selection of a GIS software package for a particular project is usually based on criteria such as price, database availability and types, and the capability and flexibility of the software (Bettinger and Wing 2004). The selection of GIS software for this research project is discussed in Section 3.5.

Hardware

Hardware refers to the computer components on which a GIS operates. The central processing unit (CPU) is the core part of computer hardware that performs all the data processing and analysis tasks. Today, GIS software runs on a wide range of hardware types, from centralized computer servers to desktop computers used in stand-alone or networked configurations (Lo and Yeung 2002). Hardware capabilities affect processing speed, ease of use and the types of output available (Bettinger and Wing 2004). Hardware components for GIS can be categorized into four major types (Apan 1999, p. 29):

- Input devices, which includes digitiser, scanner, keyboard
- Storage devices includes, hard disc, CD ROM, floppy disc
- Processing devices or processor, and
- Output device includes printers, plotter, and monitor.

Initially, GIS facilities were very expensive and were therefore only operated and managed by high level management authorities. As GIS has developed for use with personal computers its applicability and accessibility has been ever-increasing (Lo and Young 2002). The US National Centre for Geographic Information Analysis (NCGIA) chair, Professor Goodchild stresses that the first and foremost factor that contributed to the evolution of GIS over the last 40 years is the decreasing cost of hardware. He further explains the change in cost and power of computer hardware since the early 1960s:

> *Early GIS was very expensive. The world's first GIS, the Canada Geographic Information System (CGIS) required a large, dedicated mainframe computer costing several millions of dollars in the mid – 1960s. The power of the multimillion-dollar computer used by CGIS is now very much exceeded by the average laptop. Most advanced GIS applications now run on computers costing less than 2000 dollars and this cost is continuously decreasing (Craig et al. 2002).*

This declining cost and increasing power of computer hardware made GIS affordable by many organisations including field level forestry projects and community-based organisations, in industrial and now in some lower-income countries.

Data

Locations and other characteristics of natural features and human activities on, above and beneath the earth's surface are recorded as geographic data for GIS (Lo and Yeung 2002). There is wide variety of data sources – collected in house (by the operators- primary data) or purchased from a commercial data provider (secondary data) (Malczewski 1999). Primary and secondary data may have three modes or dimensions, i.e. spatial, temporal, or thematic (Heywood *et al.* 1988):

- Spatial: The spatial dimension of data can be regarded as various character strings or symbols that convey to the user information about the location of the feature being observed
- Temporal: The temporal dimension provides a record of when the data were collected (or the record to which data applies)
- Thematic/attribute: The thematic dimension shows the characteristic of a real world feature to which the data refer. In GIS, thematic data are often referred as non-spatial, or attribute, data.

Davies (2001 p. 29) refers to geographic data and information as the heart of the GIS process and therefore major emphasis in GIS operation is placed on data – from data input to data analysis and to the presentation of data.

People

GIS technology is of very limited value without skilled people to manage the system and develop plans for applying it to real-world problems (Congalton and Green 1992; Davis 2001). GIS users range from technical specialists who design and maintain the system, to those who use it to help them perform their everyday work. Juppenlatz and Tian (1996, p. 46) identified different human resource categories required for GIS technology:

- Operational staff: end-user, cartographer, data capturer, and potential user
- Technical professional staff: analyst, system administrator, programmer, database administrator, and super-operator, and
- Management personnel: manager and quality assurance coordinator.

Lo and Yeung (2002) classified GIS users into three categories – GIS viewers, general GIS users, and GIS experts – based on their information needs and the way they interact with the system (see Figure 2-1).

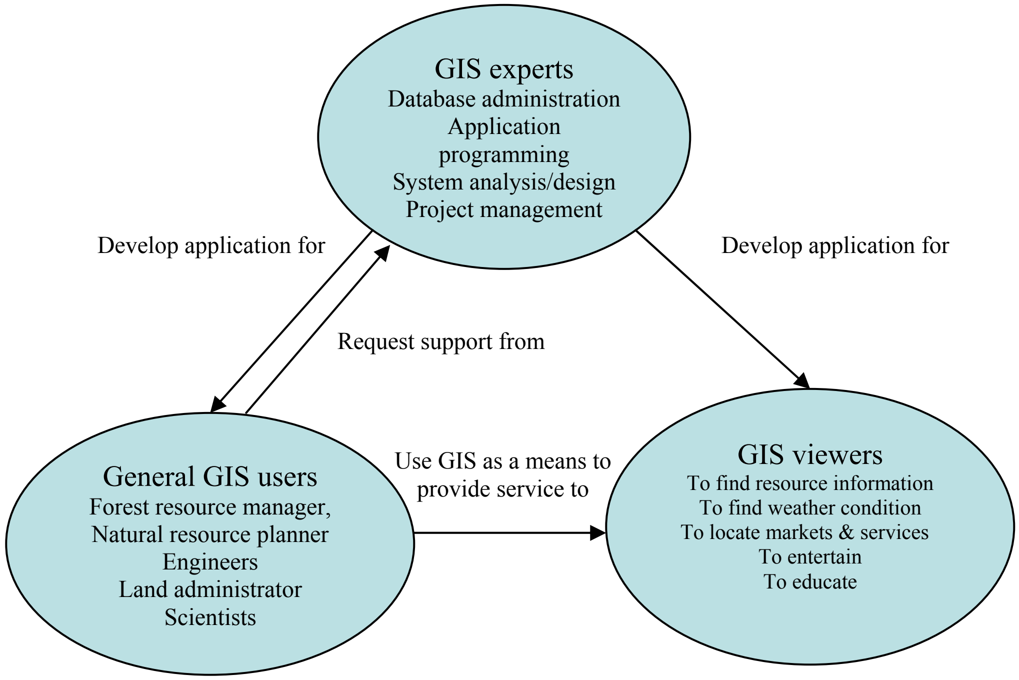


Figure 2-1 Relationships between GIS experts, users and viewers
(Adapted from: Lo and Yeung 2002 p. 14)

Figure 2-1 illustrates that GIS experts develop applications for both general GIS users and GIS viewers. There is two-way communication between GIS experts and general GIS users, but the GIS experts do not take feed back from GIS viewers. This seems to represent a rather top-down approach to GIS and has been criticised by various authors (Elwood and Leitner 1998; Harris and Weiner 2002). Community-based GIS practitioners have shown that there are benefits in developing GIS in participatory ways, through involving GIS users from early stages of designing applications and even collection of data (see Section 6.2- 6.7).

2.4 Types of Spatial Data

In GIS, spatial data, e.g., features or landscape elements are classified into three main types (Davis 2001):

- Point: A point feature is a spot (or location) that has no physical or actual spatial dimensions. A point feature represented by a single coordinate and only has a geometric property of location.
- Line: A line is a one-dimensional feature having only length, no width. It is represented by series of points and has the geometrical properties of location and length.
- Polygon: A spatial feature that is represented by a series of lines and has the geometric properties of size and perimeter.

In a forestry database, an owl nest, a wombat hole or mineral springs, are represented by a point. In contrast, forest roads and watercourses are represented by a line feature, and timber stands, soil types and wildlife habitats are examples of polygon features.

2.5 Data for GIS

Geographic data can be represented in either of two formats – 'raster' or 'vector'. Raster uses a grid cell structure whereas vector is more like a drawn map (Davis 2001). These formats are explained below.

Vector data

In the vector data model the world is represented as a mosaic of interconnecting lines and points representing the locations and boundaries of geographical entities (Aronoff 1989). In vector data simple points, line and polygon entities are essentially static representation of phenomena in terms of *X, Y* coordinates and supposed to be unchanging and do not contain information about temporal and spatial variability (Burrough and McDonnell 1998 p. 22). Linear features, such as roads and rivers, can be stored as a collection of point coordinates. Polygonal features, such as forest stands and river catchments, can be stored as a closed loop of coordinates. The vector model is very useful for describing discrete features, but less useful for describing continuously varying features such as soil type or accessibility costs for services (Davis 2001).

Raster data

The raster (or grid-cell) data model has developed from aerial and satellite-imaging technology, which represents geographical objects as grid-cell structures known as pixels. The location of geographic objects or conditions is defined by the row and column position of the cells they occupy. The area of each cell defines a spatial resolution available. Thus in the raster approach, the space is populated by a number of regularly distributed cells, each of which can have a different value (Aronoff 1989). Both vector and raster data models have their merits and limitations, which are summarized in Table 2-1.

Table 2-1 Relative merits and limitations of raster and vector data models

Raster data model	Vector data model
Merits • simple data structure, and easy to understand and use • easy for overlay operations • the computer platform can be "low tech" and inexpensive because of the relative simplicity of raster formats • high spatial variability is effectively represented • more or less required for efficient manipulation and enhancement of digital images.	Merits • more compact data structure • more accurate and credible than the raster format • provides efficient encoding of topology, and as a result more efficient implementation of operations that require topological information, such as network analysis • better suited to supporting graphics that closely approximate hand-drawn maps.
Limitations • spatial inaccuracies are common • less compact data structures that data comparison techniques can often overcome this problem • topological relationships are more difficult to represent • output of graphics is less aesthetically pleasing because boundaries tend to have blocky appearance rather than the smooth line of hand-drawn maps.	Limitations • more complex data structure than the simple raster • overlay operations are more difficult to implement • the representation of high spatial variability is inefficient • manipulation and enhancement of digital images cannot be effectively done in the vector domain.

Table adapted from (Aronoff 1989; Burrough and McDonnell 1998; Congalton and Green 1992; Davis 2001; Lo and Yeung 2002; Malczewski 1999)

Raster data are useful for the analysis of the spatial relationship between data pertaining to different aspects of the environment, particularly at the regional and national levels (Lo and Yeung 2002). Some well-known examples include wildlife habitat studies, environmental impact analysis and study of biological diversity.

2.6 GIS Functions

GIS perform four basic processes or tasks: (i) data input, (ii) data storage and management, (iii) data manipulation and analysis and (iv) output.

Data input

Data input refers to the procedure of encoding data into a computer-readable form and writing the data to the GIS database (Aronoff 1989). This process involves acquiring, reformatting, geo-referencing compiling, and documentation the data (Malczewski 1999). The creation of an accurate and well documented database is the most important task of GIS (Chang 2002; Davis 2001). Before geographic data can be used in a GIS, the data must be converted into a suitable digital format. There are various data input methods:

- **Manual Digitising**: The process of converting data from paper maps into computer files using a digitising table and a pointing device is called digitising. Paper maps are fixed to a digitising table which enables the electronic encoding of the position of pointing device precisely. Known reference points on maps are identified using a ‘punk’ which sends a signal to the wire mesh on the table. As the map elements are traced with a pointer, the coordinate data generated from the digitising table are processed by the GIS. Descriptions of standard (or *tablet*) and on-screen (or *heads-up*) digitising with ArcView GIS 3.2 are provided in Appendix 6-1 and 6-2.
- **Keyboard entry**: Field observations and most attribute data are entered in digital form by typing data using a computer keyboard. This can be combined with manual digitising to enter the attribute information.

- **Scanning:** Scanning involves automatic digitising with a device that passes a photoelectric cell or eye over a paper document and records lines, points or text on the data source. It is a much faster means of data entry than manual digitising but often needs careful editing.
- **Importing**: This process involves importing data that are already in digital format.
- **Other tools**: Examples of other tools are remote sensing (RS) and the global positioning systems (GPS).

All data input methods outlined above were used in this study in the creation of digital databases, to prepare and demonstrate practical GIS applications with forest community groups, and are discussed in Chapters 5 and 6.

Storage and management of data

The process of storing and management of data includes those functions needed to store and retrieve data from the database (Malczewski 1999). The methods used to implement these functions affect how effectively the system performs operations with the data (Aronoff 1989). GIS store data in digital format, which can be much more efficient than using paper maps and survey sheets. Two basic data models for geographic data storage, i.e., vector and raster are described in Section 2.5.

It is likely that data types required for a particular GIS project will need to be transformed or manipulated in some way to make them compatible with the system. For example, geographic information is available at different scales (Malczewski 1999). Before such information can be integrated, it must be transformed to the same scale and format. This could be a temporary transformation for display purposes or a permanent one required for analysis. GIS technicians use many tools for manipulating spatial data and for weeding out unnecessary data (Aronoff 1989).

Manipulation and analysing data

GIS can provide both simple ‘point-and-click’ query capabilities and sophisticated analysis tools to managers and analysts (Aronoff 1989; Burrough 1993; Malczewski 1999). Geographic analysis usually involves more than one geographic dataset and requires the analyst to proceed through a series of steps to reach a result. Three common types of geographic analysis are:

- Proximity analysis: GIS can investigate the relationship of features in terms of nearness, connectivity or other properties of distance. It is also known as neighbourhood analysis (Davis 2001).
- Overlay analysis: The integration of different data layers involves a process called overlay. At its simplest, this could be a visual operation, but analytical operations require one or more data layers to be joined physically. This overlay, or spatial join, can integrate data on soils, slope, and vegetation, or land ownership with tax assessment.
- Network analysis: This type of analysis examines how linear features are connected and how easily resources can flow through them (ESRI 2001).

Davies (2001) states that these are only some basic categories and that many other analytical possibilities are available in GIS.

Data Output

Data output refers to producing an end-product and displaying results (Delaney 1999). For many types of geographic operation the end result is best visualized as a map or graph. Maps are very efficient at storing and communicating geographic information. While cartographers have created maps for millennia, GIS provides new and exciting tools to extend the art and science of cartography. Map displays can be integrated with reports, three-dimensional views, photographic images, and other output such as multimedia. Result of display can be output in a variety of formats, such as maps, reports and graphs.

2.7 Organising Spatial Data

A GIS can be used to organise and store information as a collection of thematic layers that can be linked by geography. Each layer contains features having similar attributes, like streets and cities that are located within the same geographic extent. This simple but extremely powerful and versatile concept (see example in Figure 2-2) has made GIS an invaluable means of solving many real-world problems related to forestry and natural resources management (ESRI 2001).

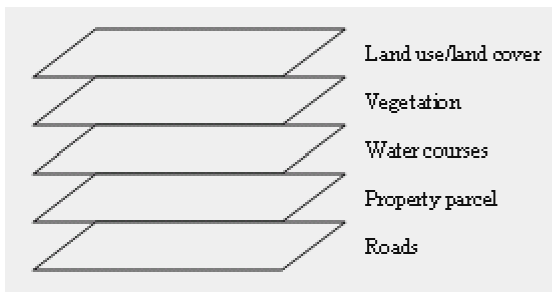


Figure 2-2 Examples of layers in a GIS – for use in forest management

A number of factors are used to organize layers in a geographic database and these differ with each application. Some of the most common considerations for organizing layers include feature types, logical grouping of features, and the intended uses for the geographic data (Aronoff 1989).

2.8 Map Scale, Projections and Coordinate Systems in GIS

Whenever comparisons are made between paper maps or computer generated maps, the map scale, coordinate systems and map projections should be taken into account.

Map Scale

A map 'scale' provides a comparative value of the distance between two points on map in relation to the distance between those same two points on the ground. Three most common ways to express the scale of a map are:

- Representative ratio (or fraction: RF): A simple ratio such as 1:10,000 or 1/10,000 where one unit on the map is equal to 10,000 of that same unit on the ground.
- Statement scale: Expression of the ratio between the map distance and the ground distance in words, e.g., 1:10,000 can be stated as one cm to a hundred meters.
- Bar scale: A linear graphical scale drawn on the map to facilitate the estimation of ground distances from measurements made on the map (Lo and Young 2002). Most of the maps prepared in this thesis show a bar scale.

Scale is one of the important considerations when designing, producing, using and calculating accuracy of maps.

Map projections

The transformation of the spherical Earth's surface to a plane surface is defined as 'map projection' (Lo and Young 2002). Angle, distance, direction and area are four spatial relationships between locations, and these play a role in creating projections that can be retained only in a globe or round surface. When global locations are transformed onto a flat map, one or more of these relationships is lost, which means whenever we create projections some type of distortion occurs. Three main ways for projecting locations are conical, cylindrical and azimuthal projections. The most widely used and general projection, Universal Transverse Mercator (UTM) (Burrough and McDonnell 1998), used for the purpose of this thesis. The UTM zones for Australia and conversion from geographic coordinate to AMG is shown in Appendix 7-1 and 7-2.

Coordinate Systems

Systems used to register and measure horizontal and vertical distances on a map are known as coordinate systems (Lo and Young 2002). Along with different projections, there are different but standardized ways of locating a point on maps. Coordinate systems are designed for detailed calculations and positioning (Chang 2002), and the maps on common coordinate systems are automatically aligned with each other (Clarke 2003). Longitude and latitude represent the most common coordinate system (Bettinger and Wing 2004) but the Geographic Datum of Australia 94 (GDA 94) is Australia's new standard coordinate system to maintain consistency (Geoscience Australia, 2004).

2.9 Global Positioning Systems (GPS)

The explosion in interest in GIS as a management tool has been accompanied by the development of a number of enabling technologies, one of the most important of which is the Global Positioning System (GPS) (Lange and Gilbert, 1999 p. 467). GPS was developed by the United States Department of Defense (DoD) to allow the military to accurately determine precise location anywhere in the world. GPS rapidly became an integral component of the emerging Global Information Infrastructure, with applications ranging from mapping and surveying to international air traffic management and global change research (USCG, 2003). The nature of forest resource management has also changed in fairly dramatic ways through the use by foresters of GPS integrated with other tools.

Many sectors of society now use GPS and related technologies to more efficiently make decisions and manage operation to meet their missions (Warnecke *et al.* 2002). GPS receivers are used in a wide range of activities (Timble 2003).

- Location. Determining the exact position on earth
- Navigation. Finding the way from one location to another
- Tracking. Monitoring the movement of people and other objects
- Mapping. Creating maps

- Timing. Bringing accurate timing to the world.

Forest resource managers use GPS for many purposes. Some uses are explored for the purpose this study and discussed in Section 6.3- 6.6.

Some examples of applications of GPS in forestry are: recording forest inventory and research plot centres; mapping forest boundaries and timber sales; characterization of forest stands; response to forest fire; maintenance of access roads (Apan 1999; McDonald *et al.* 2002). In the case of community-based forest management, GPS has been used to locate both bio-physical and socio-cultural information (Jordan 2002; Roper 2003).

What is GPS

The Navigation Satellite Timing and Ranging Global Positioning System (NAVSTAR GPS), simply known as GPS is a satellite-based radio-navigation system that is capable of providing extremely accurate 24-hour, 3-dimensional (latitude, longitude, and elevation) location data (Wells, 1987). GPS currently uses a collection of 24 satellites positioned in orbit to allow a person who has the equipment to automatically have their position triangulated to determine their location (CSU, 2003). GPS now comes in instruments that can be hand-held, and can be connected to a PC to allow automatic downloading of data.

GPS comprises three basic segments: (a) The space segment – a constellation of 24 satellites in orbit at an altitude of 20,000 kilometres above the Earth, (b) The ground-based control segment under the US Department of Defence which has monitoring and ground control stations and a master control station, and (c) The user segment – comprised of all of the users making observations with GPS receivers (Lange and Gilbert 1999).

An earth-centred ‘cartesian coordinate system’ is used in GPS surveying. The geocentric coordinates that are generally produced by GPS units are based on the centre of the earth and have *X, Y* and *Z* component. The *XY* plane passes through the equator, the *XZ* passes through the Greenwich meridian and the *Z* axis is from the centre of the earth through the north pole (see Geoscience Australia, 2004). The main reason of introducing the GDA 94 coordinate system in Australia was to enable ease of use of GPS technology (Geoscience Australia).

How GPS works

Global Positioning System satellites transmit signals to equipment on the ground. GPS receivers passively receive satellite signals; they do not transmit. The satellite and the GPS receiver have clocks that are synchronized. The GPS works by capturing the time of reception of the signal on earth and relating this to the time of transmission of the signal by the satellite (Jeffery 1998). The GPS measures how long it took the receiver to get the code that was emitted from the satellite, using the formula of:

$$Distance = Velocity * Time$$

The GPS estimates the distance between the user with the receiver and the satellite by measuring how long it takes the signal to get to the receiver. With measurements from three or more satellites, the GPS receiver can estimate a precise position of the user anywhere on the face of the earth, by using triangulation (Jeffery 1998).

GPS equipment and cost

At present a wide variety of GPS receivers are available that differ in their features, cost and accuracy. Although the terminologies relating to these categories vary widely Box 2-2 shows a common classification based on intended use. 'Recreation grade' GPS units are used mostly for outdoor recreational purpose that require only the ability to navigate to a location, 'mapping grade' instruments are used for land inventories and research projects where greater precision is important (e.g., locating single trees), and 'survey grade' GPS are used for very high accuracy, e.g., in bridge construction (DiPietro *et al.* 2002).

Box 2-2 GPS equipment and approximate costs

GPS Grade	Accuracy	Approx. cost (AUD)
Recreation	10m	$270.00
Mapping	1m	$6800.00
	sub-meter	$13,6000.00
Survey	0.1m	$27,300.00

Source (DiPietro *et al.* 2002)
(Approx. cost converted from USD to AUD on 8 July 2004)

For the purpose of this research project a 'recreation grade' Garmin GPS (i.e., GPS 76) was used that was easily available, inexpensive and user-friendly. The data generated in the field were easily downloadable to laptop and could be exported to a GIS program. Although it had relatively low accuracy (between 5 and 20 meter under favourable conditions) the instrument was adequate for the purpose of this thesis.

Merits and limitations of GPS use in forestry

GPS is generally less expensive, and more accurate and reliable than conventional methods for many forest navigation applications (MoF 2001: p. 39). For some forestry applications (e.g., inventory field sampling, resonance survey, and identification and positioning of forest recreation point features), the positioning accuracy, even with uncorrected GIS is usually considered sufficient (MoF 2001). The satellite service is free and anyone with a GPS receiver can receive the signals and locate position. The system supports unlimited users simultaneously.

The use of GPS has some limitations:

- GPS receivers give a location reading, which is subject to errors, some of which are under our control and others not.
- To obtain a GPS position reading, we need to occupy the point. If we cannot get to a point because of danger from wildlife or steep terrain we cannot obtain the GPS reading.
- GPS needs a clear view of the sky. Areas that are covered with a thick forest canopy cannot receive GPS signals.

- Elevation readings from receivers are not very accurate except from very expensive GPS units.

2.10 Remote Sensing

The United Nations in its Annex 'Principles Relating to Remote Sensing of the Earth from Space' (UN 1985) define remote sensing as "sensing of the Earth's surface from space by making use of the properties of electromagnetic waves emitted, reflected or diffracted by the sensed objects, for the purpose of improving natural resources management, land use and the protection of the environment". However, strictly speaking, remote sensing is not necessarily conducted from space, but includes all forms of photography and other 'remote' means of detecting information. Lillesand and Kiefer (1987 p.1) refer to:

"the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in direct contact with the object, area or phenomenon under investigation".

Remote sensing uses a wide variety of platforms, e.g., spacecraft, aeroplanes, balloons, remote controlled aeroplanes (Franklin 2001; Warnecke *et al.* 2002), capturing images with a camera (Bettinger and Wing 2004). However, remote sensing technology in forestry frequently refers to the use of platforms, such as satellites or cameras mounted on aeroplanes (Howard 1991). The range of applications of remote sensing in forestry include terrain analysis, updating of existing forest inventories, forest cover type discrimination, the delineation of burned areas, mapping of cleared areas and much more. Some examples are summarised in Section 4.4.

Photogrammetry, the collection of measurements from the image of an object or resource, is the primary method used for the creation of spatial data in forestry and natural resource management (Bettinger and Wing 2004). Aerial photography and images taken by digital cameras are used for some applications in this thesis. Readers interested in literature on remote sensing principles and satellite imagery in forestry are referred to valuable texts such as, Avery and Berlin (1992), Howard (1991), Lillesand and Kiefer (1987), and Sabins (1997).

2.11 Relationship between GIS, GPS and Remote Sensing

GIS and related technologies (e.g., remote sensing and the GPS) can be integrated with each other. The inter-organizational relationship and effectiveness concerning these three technologies have been greatly increased by utilizing modern computer systems and user-friendly software (Star *et al*. 1997). Many forestry and natural resource managers are using remotely sensed and GPS data widely to provide input to new GIS databases, to update existing databases and for monitoring land-use/land-cover changes of various types (Hoffer 1994). GIS data can often be valuable in the analysis of remotely sensed data, enabling significant improvements in the classification accuracies achieved. The relationship between the three technologies is shown in Figure 2-3.

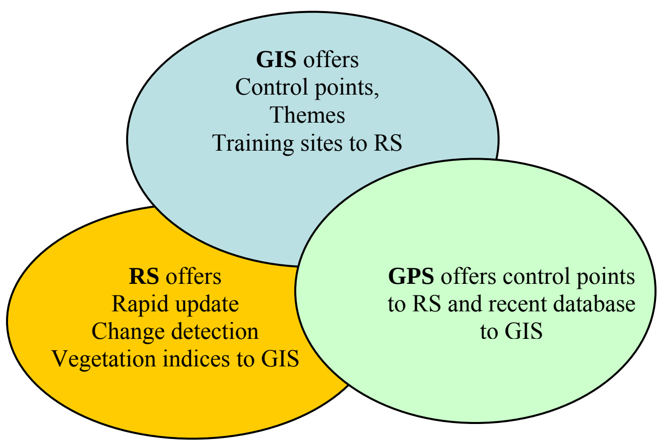


Figure 2-3 Relationship between GIS, GPS and RS

Some applications of GIS and related technologies in forest resource management are described in Chapter 4.

3 METHODS

3.1 Introduction

This chapter provides a summary review of the general approaches and methods relevant to the area of research covered in this thesis. In addition, the particular approach and framework and methods adopted in this research project are outlined.

Geographic information systems and participatory research methods have each become increasingly recognized over the past 20 years for their contributions to planning sustainable management of natural resources. Despite the popularity of both areas, it has only been within the last decade that researchers have considered integrating the two as a means of enhancing public participation and improving sustainable natural resource management (Eagle 2001; Obermeyer 1998). Meri and Bitter (2002) describe the two concepts as different schools, i.e., (i) the technocratic school, which argues that modern science is needed to identify problems and to find appropriate solutions, and (ii) the participatory school, which argues that local communities know the problems and can often find best solutions, and therefore that scientists, and resource managers should involve local people in planning and management.

Sharing local knowledge and combining this with modern technology can assist in developing appropriate solutions in resource management programs (Higgs *et al.* 2003; Jordan 1998; Weiner *et al.* 2002). Motivated by this spirit of methodological inquiry, this thesis involves the integration of GIS (and related technologies) with participatory research methods, in the context of community-based forest management.

This chapter is divided into seven sections. Section 3.2 provides an overview of the three broad research approaches combined in this study and each of these approaches is outlined in Section 3.3-3.5. The overall process framework used in this study is shown in Section 3.6 and ethical considerations are covered in Section 3.7.

3.2 The Research Approach

In this study, GIS and participatory approaches were combined in the conduct of research with the communities around the Wombat State Forest in Victoria. The research falls into three broad categories:

- Review of literature on GIS applications in forestry and community-based forestry worldwide
- Techniques from GIS and related technologies
- Participatory action research with community members in defining the needs for GIS in forest management.

Thus, although technical skills and methods from GIS and related technologies were essential in the research, the study also involved a major review of literature as well as action research with community members, i.e., participatory action research (PAR). Figure 3-1 shows the overall research approach adopted in this thesis.

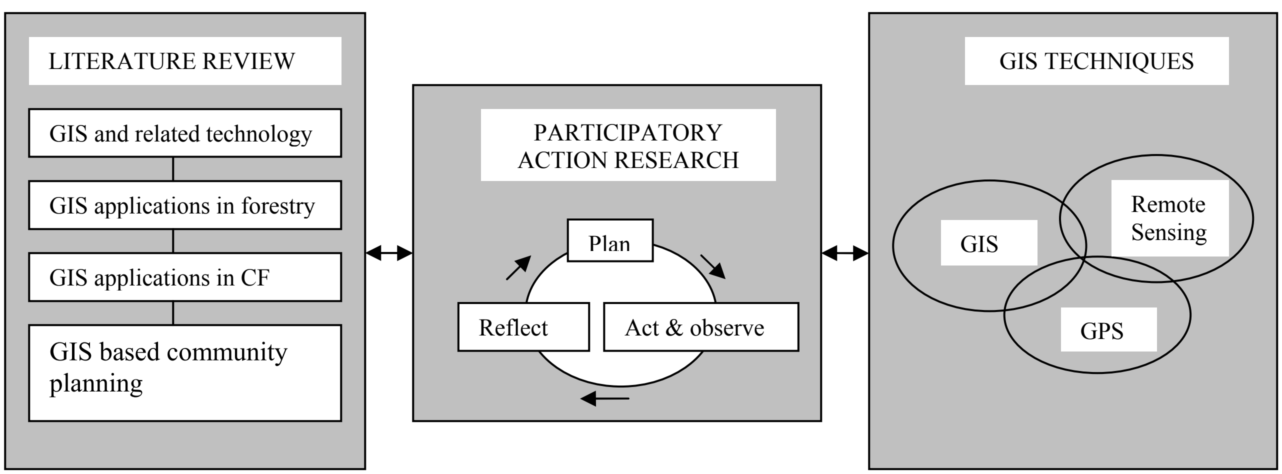


Figure 3-1 The three broad components of the research combined in this study

3.3 Review of Literature on Applications of GIS in Forestry and CBFM

The review of literature on applications of GIS in forestry and community forestry was a major component of the research. The main areas of GIS literature studied were applications of GIS in:

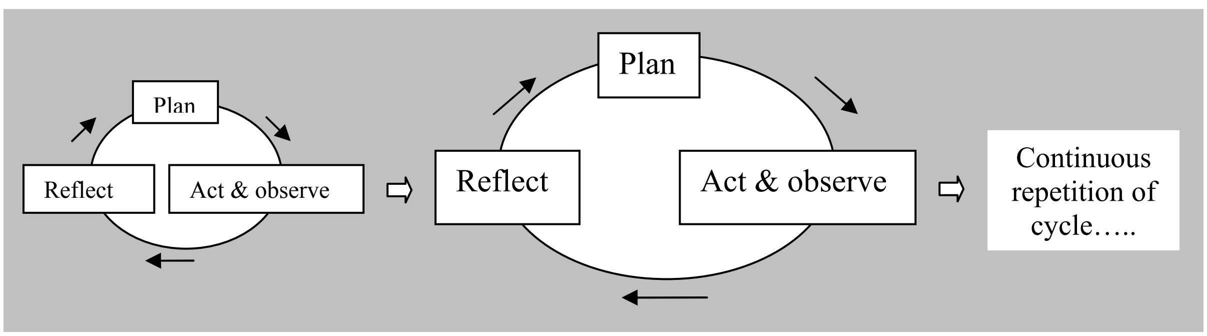
- conventional government managed forestry and natural resource management
- modern industrial forestry
- community-based forest management
- participatory land use planning.

Some especially influential texts used in the review were two large volumes on GIS applications in natural resource management edited by Heit *et al.* (1991, 1996), a text edited by Maguire *et al.* (1999), a book on GIS and community participation edited by Craig *et al.* (2002), and a recently published book on GIS applications in forestry and natural resources by Bettinger and Wing (2004). In addition to these main sources, examples of GIS applications were drawn from various scientific journals (e.g., Journal of Forestry, Cartography and Geographic Information Systems, Scandinavian Journal of Forestry Research), conference proceedings and resources from the internet.

From the extensive literature reviewed, a number of broad areas of application of GIS in forestry and community forestry were identified and these are presented with examples in Chapter 4 (Section 4.4). In addition, a selection of case studies is presented in Chapter 5 (Section 5.8) to represent the scope of GIS applications available in the literature. The cases were chosen from a variety of countries so as to provide a broad international view. Most of the case studies are related to use of GIS in forest and natural resource management for industrial (or conventional) forestry, while some involve applications from community-based forestry.

3.4 Participatory Action Research (PAR)

As depicted in Figure 3-1, the research approach combined GIS methods with PAR. In such ‘action research’, researchers work with a group of people to help define problem situations, plan a course of action, activate the plan, and then observe the results of the actions and reflect on those with the participants (Calhoun 1994; O'Brien 2004). Cycles of planning, action and reflection are repeated with a view to changing (improving) the situation in a direction decided by the participants. The role of the researcher is to assist the group to document and reflect on the results and the process, and to ensure that the stages of the cycle are completed in logical sequence. Corey (1953) cited in Miller (2004) defined action research as the process by which practitioners attempt to study problems in order to guide, correct, and evaluate their decisions and actions. Figure 3-2 shows the steps in a participatory action research procedure.



[Developed from work of various authors]

Figure 3-2 The participatory action research (PAR) cycle

In PAR, the planning phase is practical and constructive, and requires prior data gathering and involves much discussion among the participants (Kemmis and McTaggart 1988). Action happens when a plan is put into place and its effects observed in the context of the situation. Grundy (1986) states that the action is deliberate and strategic and that observation is the main research phase of PAR (Seymour-Rolls and Hugues 2000). Reflection is that moment where the participants examine the construct, then evaluate and reconstruct their concerns. The process continues in a sequence of repeated cycles (Figure

3-2) until desired outcomes are achieved. Modern authors on action research include Lincoln (2001) and Reason and Bradshaw (2001).

3.5 Methods for GIS and Related Technologies

GIS methods were a core requirement of this research and the basic concepts and methods of GIS and related technologies were summarized in Chapter 2. Foresters can use GIS to help their work in a number of areas, e.g., forest resource inventory, research, forest planning, management and policy (see Section 4.4). In the case of community forestry, this technology helps to integrate socio-eco-cultural and bio-physical information, and can be combined with participatory research methods to ensure that the interest and priorities of local stakeholders are included (see Section 4.3). Such integration can allow foresters to consider the potential effects of various policies or actions, and also to save time and money (Bettinger and Wing 2004).

The collection of data for GIS from various sources, the selection of GIS hardware and software for the purpose of this research, and data analysis are all part of the overall process, and these aspects are outlined in the following sections.

Data for GIS in this study

Gathering spatial data, preparing the data for GIS use and documenting those processes is usually the most expensive and time consuming (Wing and Bettinger 2003; Lo and Yeung 2002) component of any GIS project. Therefore in this short-term study, efforts were made to obtain and use GIS databases that already existed and are relevant for the purpose. A wide variety of information and GIS data layers were available from a number of sources, e.g., central and branch offices of the Victorian Department of Sustainability and Environment, The University of Melbourne Library, Australian Bureau of Statistics (ABS), Bureau of Meteorology (BOM). Primary data were also collected, using participatory resource mapping with support of local communities and using a GPS unit.

Computer hardware software and other equipment used

Selection and use of computer hardware and peripherals used for this study are outlined in Box 3-1.

Box 3-1 Computer hardware and peripherals used for this study

Computer Hardware. A Pentium based PC running Windows XP Professional operating system was primarily used for completing this research project and the related GIS applications. In addition, a Pentium based portable Toshiba Satellite Notebook running Windows XP Home Edition was used for fieldwork. CD-ROM and CD-RW and Flashjet USB drive were utilized to archive a variety of data related to this project.

Digitizer. A GTCO Super L II digitizer was used for capturing conventional analogue topographic maps and other relevant information (e. g. weed infestation, historical goldmines and water races) in a format suitable for storage and manipulation in a computer. Location of historical goldmines were digitised as point mode, water races are digitised in line mode and weed infestation area in polygon shape.

Plotter and printer. HP 750C A0 size Colour Inject Plotter was used to produce high quality, hardcopy computer output. The hard copy paper maps produced were made available to a variety of stakeholders and for their use. A Laser printer was used to produce A4 size hard copy paper maps which are included in this thesis.

Scanner LEXMARK X1100 Series flat bed scanner was used to convert pictures or maps, such as aerial photographs and some old pictures, to digital form. The resulting images are described by the raster data structure that includes pixels or grid cells.

Photo copier Konica Photo copier was used to copy some topographic maps and weed maps produced by the local communities. It was also used to enlarge A4 size paper maps to A3 or vice-versa for use by community groups involved in participatory mapping.

GIS software for this study

Accessibility of existing GIS database, ease of integrating information from existing sources were the main criteria used in the selection of software for this study. A brief description of various GIS programs available for forestry and natural resource management organizations are listed in Appendix 2-1. ArcView GIS 3.2 software with extensions, i.e., 3D Analyst 1.0 and Spatial Analyst 1.0 was selected for the project, for following reasons:

- available at The University of Melbourne, Creswick Campus
- as desktop software it can be set up easily on laptops to carry in the field

- it is simple to integrate with Garmin GPS and to download the GPS data
- an Arcview extension DNR Garmin was available free of cost (see Appendix 2-3)
- ease of operation (the software)
- ease of both standard and on-screen digitising
- the author was familiar with this software.

GPS equipment for this study

A recreation grade, low cost, handheld GPS (i.e., Garmin GPS 76) was used in this research project. Although it provides a relatively low level of accuracy (see Box 2-2 in Section 2.9) it was adequate for the purpose of this study (see Appendix 3-1 for brief description of Garmin GPS 76). In addition, these units can store the locations of points and data can be downloaded to a PC using a PC interface cable and free software (e.g., GPS Utility, Garmin.avx and DNR Garmin extension for ArcView). Data are compatible with ArcView GIS 3.2. More accurate GPS units cost over AUD 10,000.00 compared to a cost of AUD <400.00 for the Garmin handheld GPS.

Aerial photography

For some practical applications, colour aerial photography (scale 1:20,000) were utilized and these were scanned using automatic scanner and geo-referenced with use of known coordinates. The aerial photographs were integrated with other spatial data in the GIS, e.g., weed infestation and 'significant soak' maps were overlaid on aerial photography (see Section 6.3 and Section 6.6).

Digital camera

A Cannon Power-shot digital camera was used to take digital images of some study areas, e.g., weed infestations and management practices, significant soaks, and the resource maps prepared by community groups. The images were downloaded to a PC and some selected images are included in this thesis (see Plates 1-7 in Appendix 9-1).

3.6 The Methodological Framework for this Study

The research process started with review of literature on applications of GIS in forestry and community-based forestry, and the potentials and limitations. The author learned the principles of GIS and related technologies and gained practical experience about GIS software by attending various training courses, courses on the university campus and with other organizations, e.g., ESRI Inc., Australia, and online course offered by ESRI Inc., Redlands, California.

Early meetings with central and local level government authorities responsible for forest management in Victoria were necessary to gain understanding of government policy on collaborative forest management and sharing of spatial information sharing with community groups. Discussions were also held with various environmental organizations and forestry user groups (e.g., Environment Victoria, Wombat Forest Society, Blackwood/Barrys Reef Land Care) to identify user's spatial information needs and priorities. The field data collection for GIS was conducted with the various participating groups, according to their requirements (see Chapters 5 and 6).

The types of meeting varied from formal meetings with officials to seek cooperation or authority, to meetings in public halls covered by the local DSE staff, and then later, informal discussions and field visits to discuss problems and techniques with participatory groups. Steps in data collection are outlined in Chapter 6.

Both secondary and primary data were collected, as outlined in Section 3.5, in close collaboration with agencies and community groups. The action research process adopted, required that technical results of using GIS were constantly discussed with community members. This process framework is outlined in Figure 3-3.

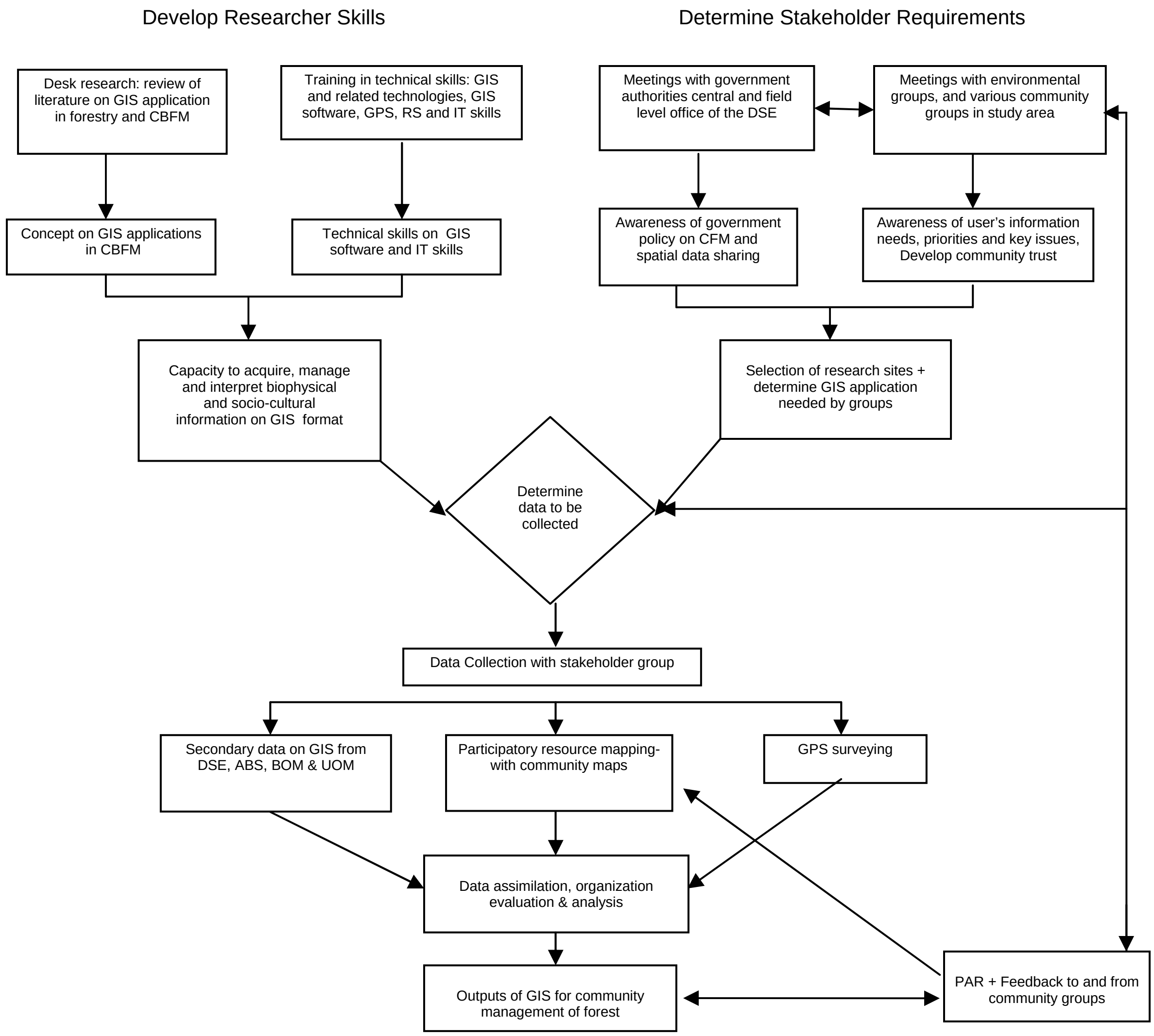


Figure 3-3 The process framework for this study

(For acronyms see List of Acronyms p. XII)

The framework outlined in Figure 3-3 shows how the research originated, and how the researcher's capacity was developed. The top row of boxes shows the background of the study, in which the researcher was mainly involved in gathering background knowledge and skills, and contacts in agencies and the community. Later in the process, data collection commenced from various sources for developing the GIS needs of the various stakeholder groups. Figure 3-3 does not show the reflection process required in PAR, as this varied with each participatory group.

3.7 Ethical Considerations in this Research

Although this study started as primarily a technical project in GIS, the work became increasingly people-oriented as research proceeded. Initial contacts with the government agencies (e.g., DSE and BOM) led on to meetings with community groups and eventually to adopting a participatory action research approach for part of the study.

In working with people (in agencies and community groups) it was important to establish and follow ethical principles for the conduct of the work, even though much of the work was in meetings and discussions arranged through or by DSE (which has its own human ethics procedures). The principles in Box 3-2 were drawn from Robson (1993 p. 33), Kemmis and McTaggart (1981 p. 43-44), Bryman (2001 p. 479-481) and Jesani and Barai (2003) as a guide to ethical considerations in dealing with collaborators in this study.

Box 3-2 Guidelines on ethical aspects of working with collaborators in this study

- **Protocols observed**. Take care to ensure that relevant persons and authorities are contacted and informed, and that approvals are obtained.
- **Stakeholders involved**. Involve people with a stake in the research, to help design the work so as to best serve their interests.
- **Anonymity of participants (and confidentiality) ensured**. Do not mention individuals names in the thesis or other publication. Keep personal information confidential and protect all original data by password on computers or lock away.
- **Transparency and feedback for participants**. At all times keep collaborating organisations and their staff, and participating community members informed of progress, and ask for ideas and feedback.
- **Participants' receive output**. Make outputs of the research available to participants, in forms useful to them.
- **Non-exploitation**. Do not consume collaborators time except on essential matters in which they wish to be involved.
- **Safety measures and risk minimization**. Take appropriate precautions to minimize risk during field work.

The ethical appropriateness of the activities were largely verified through the action research process, which involved constant discussion with, and feedback from, community members on the GIS products derived from the project. Work was not completed until members expressed satisfaction with the task. The researcher was careful not to raise community expectations of outcomes from the project over and above those achievable within the time and resources available. At the end of the project, community members (and DSE) expressed sincere satisfaction, and requested a continuation of the community-university partnership with other student projects, if at all possible in the future (P. Liffman [Blackwood/Barrys Reef Land Care, Victoria] pers. comm. March 2004).

4 MAJOR APPLICATIONS OF GIS IN FORESTRY AND COMMUNITY FORESTRY

4.1 Introduction

This chapter deals mainly with the first objective of this thesis, i.e., to review the applications of GIS in forestry and community forestry worldwide (see Section 1.5). It also discusses current situation of GIS applications and factors hindering use of GIS in Nepal to use this information to relate the findings of this study in Nepalese context. Availability and potential of free GIS/GPS software for use of community based GIS also discussed.

GIS nowadays makes a major contribution to various aspects of forest management and Tomlinson (1987) reports that forestry has been responsible for a significant growth in the use of GIS. He claims that the earliest inspiration for using GIS in forestry was the capability to update forest inventory on a regular basis and reduced cost. As management goals for forestry are becoming more diverse, so the importance of GIS technology increases. For the relatively new, multi-disciplinary concept of community forestry, GIS offers great potential as a means of integrating socio-cultural information with bio-physical data (Jordan 1998; Jordan and Shrestha 1999; Kyem 2002). This chapter explores some GIS applications in both industrial forestry and community forestry that have been used around the world.

Section 4.2 discusses the typical requirements for spatial information for traditional forest management. The additional information required for CBFM are outlined in Section 4.3. Major GIS application areas in forestry are discussed in Section 4.4 and some examples available globally are summarised in Section 4.4.1 to 4.4.12. Section 4.5 reviews the application of GIS in the Nepalese context and Section 4.6 outlines the potentials to use free GIS/GPS softwares available in the internet.

4.2 Spatial Information Required for Forest Management in General

All forest managers need accurate and timely information to make wise decisions on resource management. There is often a direct relationship between the quality of information and cost of collection, handling and storage (Bettinger 1999; Bettinger and Wing 2004). GIS and related technologies offers substantial advantages by allowing high quality and timely output of information at low cost, compared to other methods (Burrough and McDonnell 1998; Green 1992; Chrisman 1997; Huxhold and Levinsohn 1995). Warnecke *et al.* (2002) state that forestry organisations can become more efficient and productive by using the analytical capabilities of GIS, which were previously not available.

Forest managers use various types of spatial information for planning and policy making, research and decision making. Information required for forest management can be collected in various ways. Table 4-1 shows a typical set of spatial information required for traditional forest management.

Table 4-1 Spatial information traditionally required for forest resource management

Information category	Purpose
Administrative boundaries • cadastral boundaries, forest administration boundaries, timber concession boundaries • compartments and sub-compartments	General administration, management and planning
Terrain features • elevation, slope, aspect • digital terrain model (DTM), • triangulated irregular network (TIN) • hill shade, drainage	Planning of timber harvesting (e.g., road construction), site assessment (e.g., susceptibility to wind throw)
Infrastructure • roads, tracks, etc • power lines, pipelines etc • building and other structures	Planning and management of forest operations, monitoring and evaluation Maintenance of forest roads and culverts
Soil and understorey vegetation	Site assessment and silvicultural treatment
Forest stand characteristics • species composition, age • yield class, stand density	Planning and management of forest operations (e.g., thinning, harvesting)
Management activities • planned and actual silvicultural treatment (thinning harvesting, etc) • damage control (e.g., insect, disease, fire, wind and encroachment)	Monitoring

(Apan 1999 p. 22; Sushilawati and Weir 1994 p. 167)

The information listed in Table 4-1 concerns not only forest vegetation but also a wide range of other natural and artificial features. Apan (1999) states that in community forest management, information on socio-economic and cultural issues would be required in the data set, in addition to the standard data types.

4.3 Spatial Information Required for CBFM

In addition to conventional data such as that shown in Table 4-1, community forestry requires data on socio-economic and cultural variables that affect local people, their needs, priorities and willingness to participate in forest management ((Jordan 2002; Kyem 2002; Meredith *et al*. 2002). Table 4-2 shows additional types of spatial information required for community-based forest management.

Table 4-2 Examples of information required for CBFM (in additional to data types listed in Table 4-1)

Information category	Purpose
Socio-economic information • demographics • employment • infrastructure, livelihood needs	Determine local community (and stakeholder) interest in forest management
Cultural beliefs, tenure and other rights • cultural heritage • historical sites	Traditional rights, eco-tourism potential, conservation of heritage sites

(Eagle 2001; Grove and Hohmann 1992; Higgs *et al.* 2003; Jordan 2002)

Grove and Hohmann (1992) argue that GIS and related technologies have the capability to integrate disparate information types, such as those shown in Table 4-1 (mostly biophysical information) and Table 4-2 (socio-economic and cultural information), for use in decision making. Harris and Weiner (2002) state that GIS can empower forest user communities by providing them with greater access to data about their own areas and resources, and simultaneously increasing the capability for surveillance over neighbours.

4.4 Major Applications of GIS in Forestry Globally

Some major areas of application of GIS taken from the literature on GIS and forest management generally are listed in Box 4-1. All of the application areas listed are also applicable in community-based forestry.

Box 4-1 Major application areas for GIS in forest management

- Forest health monitoring: includes insect pest monitoring
- Resource inventory: includes resource assessment and inventory
- Forest fire and emergencies: includes pre-planning and post fire assessment
- Forest conservation and biodiversity: focused on conservation
- Forest road access and harvest scheduling: road network and harvesting
- Forest ecosystem management and rehabilitation: ecology and ecosystem applications
- Wildlife habitat: wildlife habitat conservation and planning
- Water wetlands and watersheds: conservation of soil and watersheds, and wetlands
- Recreation and community-based eco-tourism
- Strategic planning: strategic planning purpose
- Participatory planning: planning with involvement of local communities.

Source: Numerous papers on literature on forestry and GIS.

Green (1994) stresses the requirement in all forest management for up-to-date information to (i) describe the resources of interest, (ii) predict what will happen to those resources if certain actions are undertaken, and (iii) prescribe the best course of action given specified goals. The items listed in Box 4-1 are major real-world applications of GIS associated with forest and forested land management, and each one is outlined (with examples) in following sections.

4.4.1 Application I: Forest health monitoring

The use of GIS in forest health applications is expanding (Warnecke *et al* 2002). Forest health monitoring involves recording the attacks by insects, diseases and other pests in plantations or natural forest. Spatial data sets and GIS technology are vital in risk assessment and in planning prevention and response strategies (Apan 1999). GIS enables foresters to visually display insect and disease patterns geographically, and to estimate severity and direction of spread, based on tree species occurrence and other parameters.

Collaboration of local community groups with state and federal agencies can be invaluable for forest planning and management. As insects and diseases often spread across political boundaries, GIS information can allow ease of sharing of information between states and countries. Some applications of GIS and related technologies within the general area of forest health monitoring are summarized in Table 4-3 from literature.

Table 4-3 Examples of GIS applications in forest health monitoring

Application	Citation	Location/Country
Use of GIS to monitor sudden death of Oak forest and Monterey Pine Pitch Canker monitoring	(CDOF 2003)	California, USA
Pacific Forestry Centre(PFC) has used a GIS to store data from annual ground and aerial surveys and added data from historical maps	(McKendry and Eastman 2002)	Canada
Use of GPS for the spray application of aerial pesticides, use of GIS for aerial survey to annually delineate gypsy moth defoliation	(VDOF 2003)	Virginia, USA
Regional survey map of mountain pine beetle	(Sickle 1996)	British Columbia, Canada
Gypsy moth survey using Magellan 315 GPS and other insect outbreaks	(Warnecke *et al* 2002)	Indiana, USA

Early identification of insect and disease occurrence is vital for community groups to manage their forests against insect and disease.

4.4.2 Application II: Forest resource inventory

Forest resource inventory is the recording and assessment of the distribution, quantity and quality of forest resources available for management. According to Higman *et al.* (1999) resource inventory data should include:

- Timber resources, e.g., species types, sizes, volume, number of trees, class/stand structure, crown closure
- NTFPs, such as lianas, fruits, nuts, bamboo, honey
- Other aspects such as soils, water sources and wildlife.

The acquisition of basic inventory data is fundamental to sustainable community forest management. Inventory data are used in the planning and management of forest resources. GIS can be used to store inventory and analyse inventory data and estimate how fast the resources grow and what changes occur in response to management. Once data are entered in a GIS, maps can be displayed showing general species distribution and the area of stands (or other features – such as swamps or glades) and the areas can be calculated (Green and Congalton 1990). Some examples of GIS applications in resource inventory (for both industrial and community forest) are summarised in Table 4-4.

Table 4-4 Examples of GIS applications for forest resource inventory

Applications	Citation	Country/Location
Assessment of rate and location of deforestation	(Hutachroen 1987)	Thailand
Forest land cover assessment	(Warnecke *et al.* 2002)	Mississippi, USA
Determination of rates of deforestation	(Liu *et al.* 1993)	Philippines
Analysis of ecological, socioeconomic and vulnerability assessment to improve resource management activities	(Warnecke *et al.* 2002)	Maryland, USA
Mapping and monitoring of tropical forest	(Legg 1993)	Sri Lanka

The use of GIS in forest inventory is usually the first application of GIS in any forest management program. Once management staffs learn the basics of GIS, many other potential uses can emerge, especially in CBFM.

4.4.3 Application III: Forest fire and emergencies

The danger of fire to humans and forest resources is an important concern for most forest managers and the modelling capabilities of GIS have been effective in this context. Fire management activities include fire prevention, controlled burning and post-fire recovery action (McKendry and Eastman 2002). Holder *et al.* (1990) report that forest fire managers have used GIS for fuel mapping, weather condition mapping, and fire danger rating.

Bush fire is a major environmental problem in Australia (Coleman and Sullivan 1996). In recent years, fire and emergency applications have proven to be one of strongest uses of GIS. Warnecke *et al.* (2002) state that GIS is proving to be a very beneficial resource and tool for a wide range of uses - from simple fire mapping to prediction of the complexities of fire behaviour. GIS is an integrating tool for fire related factors. Some examples of GIS use in relation to forest fire are summarised in Table 4-5.

Table 4-5 Examples of applications of GIS in managing forest fire and emergencies

Applications	Citation	Country/Location
Use of GIS-based model in the prevention and control of forest fire	(Pons *et al.* 1997)	Catalan, Spain
PC-based fire spread prediction application is developed by CSIRO	(Coleman and Sullivan 1996)	Australia
MapInfo Professional ™ used to plot controlled burns and wildfires, locate fires suppression resources, and monitor wildfire activity	(SCFC 2003)	South Carolina, USA
A fire growth model was linked to a GIS to evaluate its potential to minimize the cost of controlling and managing forest fires	(Holder *et al.* 1990)	Ontario, Canada
GIS used for fire suppression, but increasingly for fuel treatment and preparedness	(Warnecke *et al.* 2002)	New Mexico, USA

While a central GIS can be valuable in planning fire management and control, the linking of GIS facilities to portable technologies like GPS, radio and other communication equipment becomes important for effective use of GIS in actual fire fighting and other forest emergencies.

4.4.4 Application IV: Forest conservation and bio-diversity management

GIS can provide a valuable environment from which to describe, analyse, and model ecosystem processes and functions. Design consideration for conservation areas such as size and number, shape, fragmentation, buffers, zoning, corridors and connections could be easily produced and analysed in a GIS, if appropriate data sets are available (ICIMOD 1999).

Relationships among ecosystem components can be explored and visualized using the powerful analytical and visualization tools. Some examples of GIS use in forest conservation and biodiversity are summarised in Table 4-6.

Table 4-6 Examples of GIS applications in forest conservation and biodiversity

Applications	Citation	Country/Location
Use of GIS to develop a comprehensive biodiversity information system relevant to the sustained preservation of biodiversity	(Scott *et al.* 1991)	Idaho, USA
GIS-based modelling of land-use change scenarios in planning for the conservation of native biodiversity within the Goulburn Broken Catchment	(Wilson and Lowe 2003)	Victoria, Australia
Use of remote sensing and GIS to characterize and analyse the fragmentation of landscape	(Jorge and Gracia 1997)	Brazil
Land cover maps were derived using multi-temporal remote sensing data with GIS models	(Wang and Moskovits 2001)	Chicago, USA
Use of GIS and systematic sampling to investigate patterns of forest composition and biodiversity within a lowland tropical-wet forest	(Lachowski *et al.* 1992)	Costa Rica

The use of GIS for biodiversity conservation usually progresses from simple databases and maps showing species occurrences, towards various forms of modelling of ecological diversity.

4.4.5 Application V: Forest road and harvest scheduling

Planning forest roading is an important aspect in scheduling stands for timber harvest. Spatial forest modelling using GIS technology is nowadays considered essential to planning harvesting strategies in industrial forestry (Warnecke *et al.* 2002). Spatial models use both the absolute and relative geographic positions of forest stands in developing and testing harvesting strategies.

Forest managers often need to delineate buffers around water features, such as rivers, lakes streams, and ponds. These buffers define a riparian forest where harvesting activities are excluded or limited to partial cuts (Bettinger and Wing 2004). Such forest buffers protect aquatic organisms, maintain water quality, and protect birds and animals by providing a water source and preserving travel corridors. Table 4-7 summarizes some examples of GIS applications in forest road and harvest scheduling.

Table 4-7 Examples of GIS applications in forest road and harvest scheduling

Applications	Citation	Country/Location
Use of GIS reduced the database update process, by allowing easy and consistent calculation of areas and develop estimation of logging potential	(Stumpf 1994)	California, USA
GIS used to prepare a spatial decision support system for long-term forest management planning with linear programming	(Naesset 1997)	Norway
GIS used in forest harvesting and management in the design of logging roads, forest monitoring and forest land allocation	(Susilawati and Weir 1994)	Indonesia
Use of GIS on state lands for calculating sustainable harvest level	(DNR 2003)	Washington, USA

The value of GIS is not only in planning road and other corridors for forest management but allows easy estimation of areas of non-harvestable forest and hence the assessment of harvest viability.

4.4.6 Application VI: Forest ecosystem management and rehabilitation

The growing public concern on loss of sensitive plant and animal ecosystem is a great challenge to ecologists and forest managers. Salwasser *et al*. (1992) stress natural resource management practices must be ecologically sound, economically feasible and socially acceptable. Ecosystem management is a process for implementing principles of sustainability (Gregg 1994). GIS and related technologies have helped forest ecologists and resource managers to recognize landscape-level ecological issues (Sample 1994) and to plan forest regeneration progress. Table 4-8 summarizes some examples of GIS applications in forest ecosystem management and rehabilitation.

Table 4-8 Examples of GIS applications in forest ecosystem management and rehabilitation

Applications	Citation	Country/Location
GIS used in development and analysis of a chronosequence of late-successional forest ecosystem	(Morrison 1994)	British Columbia, Canada
GIS and remote sensing used for defining, mapping and managing forest ecosystems	(Cleland *et al.* 1994)	USA
Study of stability and productivity of Scotch pine ecosystem under drastically changing emission and deposition situation for sulphur dioxide, alkaline dusts and nitrogen using GIS	(Flechsig *et al.* 1996)	Eastern Germany
A PC-based system was developed to allow resource planners and managers to determine the consequences of different management alternatives	(Oliver and McCarter 1996)	Washington, USA
GIS used to address the cumulative effects of forestry practices on air, soil, water and wildlife	(Schriever and Birch 1996)	Oregon, USA
A GIS- based forest rehabilitation need index was developed by addressing the need for area prioritization and resource allocation in forest rehabilitation	(Apan 1996)	Philippine

The use of GIS and related technologies in forest ecosystem management and rehabilitation has grown in recent years due to changing scenarios in forest management, but the forester and resource manager should understand its capabilities, capture potential and its constraints.

4.4.7 Application VII: Wildlife habitat management

GIS and related technologies offer significant advantages over the use of analog maps in the assessment and planning of wildlife habitat. Site-specific habitat management can help alleviate some resource management conflicts (Nyberg *et al.* 1989). The modelling capability of GIS can be used to assess daily and seasonal habitat interspersion (Eng 1991). Table 4-9 summarizes some examples of GIS applications in wildlife habitat conservation and planning.

Table 4-9 Examples of GIS applications in wildlife habitat management

Applications	Citation	Country/Location
Use of GIS and satellite imagery in identifying potential habitat sites for wildlife species in Phustain Wildlife Sanctuary	(Mongkolsawat and Thirangoon 1998)	Northeast , Thailand
Test the accuracy of GIS-based wildlife habitat model BIRDHAB to predict the relative habitat quality for birds at a stand level	(Kilgo *et al.* 2002)	South Carolina, USA
Use of GIS and satellite-based vegetation maps to determine the feasibility of GIS as a practical tool in wildlife habitat assessment and prediction in the Arctic and related land management	(Danks and Klein 2001)	Alaska, USA
GIS-based salmon habitat mapping using a number of approaches including participatory land use planning programs, introducing stream stewardship guidelines, and studying the life cycles of salmon and the relationship with surrounding habitat	(Nimmao 1996)	British Columbia, Canada
Study of economic potential of community-based wildlife management using GIS	(Cencini and Menegatti 2000)	Zimbabwe

GIS-based technologies provide efficient means to model the spatial distribution of wildlife populations and habitat suitability. However, the effectiveness and accuracy of such models depends on knowledge of wildlife habitat and ecological relationships (Mongkolsawat and Thirangoon 1998)

4.4.8 Application VIII: Water, wetlands and watershed management

Increasing public concern regarding soil conservation, watershed planning and water quality monitoring has led to a rise in the use of GIS and related technologies in this field. Warnecke *et al.* (2002) claim that water is the most fragmented, overlapping and confusing natural resource – but the analytical capability of GIS technologies can help to manage land and water related conflicts (Berry 1994). Some examples of applications of GIS and related technologies within water wetlands and watershed conservation and management are summarised in Table 4-10.

Table 4-10 Examples of GIS applications in water, wetlands and watershed management

Applications	Citation	Country/Location
GIS-based watershed management system by identifying wetland areas in the Welland River Channel	(NPCA 2003)	Ontario, Canada
Preparation of 3-dimentional GIS-based model to delineate sediment deposition zones in the Clinch River	(Levine *et al.* 1996)	Tennessee, USA
GIS-based decision support to investigate the interaction of water quality management and climate variability and change	(Knight *et al.* 2000)	Bulgaria
A state-wide GIS database that included soil, topography, vegetation, hydrography and land ownership to address wetland prioritization projects	(AFC 2003)	Arkansas, USA

Forested ecosystems help to reduce water pollution and to provide high-quality water. Community forestry groups such as those around the Wombat Forest in Victoria, are interested in mapping wetlands and soaks using GPS and GIS, so that they can prepare water conservation plans (M. Faulks [Water and Hydrology Working Group, Wombat CFM] pers. comm. February 2004) (see Section 6.4).

4.4.9 Application IX: Recreation and eco-tourism planning

Use of GIS in recreation planning and research is a relatively new application in forest resource management (Meighen and Volger 1997). Ecotourism planning requires exploration of diverse types of natural and cultural attractions along with demographic characteristics of tourist populations (Banerjee *et al.* 2003). The use of GIS and related technology is becoming increasingly popular to provide base-line information for existing and potential tourism. This and other examples of GIS use in this field are shown in Table 4-11.

Table 4-11 Examples of GIS applications in recreation and ecotourism

Applications	Citation	Country/Location
Recording and analysis of tourism resource inventory information	(Willims *et al.* 1996)	British Columbia, Canada
Identifying and mapping effects of visitor use on trails was conducted in popular trekking destination in the Himalaya	(Nepal 1999)	Himalaya region, Nepal
Examination of recreational use levels in McDonald-Dunn research forest	(Wing and Shelby 1999)	Oregon, USA
Identifying potential ecotourism sites using GIS and remote sensing techniques in forest dominated areas	(Banerjee *et al.* 2003)	West Bengal, India
Conservation of tropical reef ecosystems and biodiversity of the marine environment to encourage international tourism	(Domroes 2000)	Maldives

The use of GIS in identifying important tourist locations and to provide visualization of tourism activities in and around forest areas is rapidly increasing in countries like Nepal.

4.4.10 Application X: Strategic planning

Strategic planing has become increasingly important for most forestry and natural resource organisations, and the use of GIS has become intimately tied to the entire strategic planning process (ESRI 2004; Obermeyer and Pinto 1994). The abilities of GIS in storage, analysis and management of vast quantities of diverse information have been invaluable in assisting forest managers and planners to manage their day to day work both tactically and strategically (Bocco *et al.* 2001; Obermeyer and Pinto 1994).

A high-quality GIS database describing the state of the forest can be combined with spatial and temporal decision models to explore alternatives in forest planning (Sessions *et al.* 1994). Efficient data storage and display facilities are necessary for solving modern forest planning problems. Some examples of GIS (and related) applications in strategic planning are summarised in Table 4-12.

Table 4-12 Examples of GIS applications in strategic planning

Applications	Citation	Country/Location
Development of an approach for facilitating identification and prioritisation of visually sensitive areas using 'weighted viewshed analysis'	(Bruce 2000)	Tasmania, Australia
Generalization of spatial data for strategic planning model for large estate forests	(Nelson 2003)	British Columbia, Canada
Combination of different kinds of data and criteria affecting the total utility of the forest area in landscape ecological planning	(Store 2003)	Finland
Comparison of different spatial planning issues and their impacts on forest management objectives	(Walters and Cogswell 2002)	Canada
GIS-based study of analytical tools for strategic and tactical forest resource management planning	(Remsoft Inc, 1994)	New Brunswick, Canada

Lang and ESRI (1998) claims that GIS is ideal for analysing the impact of development, the consumption of natural resources, and for strategic planning.

4.4.11 Application XI: GIS for participatory planning

GIS-based participatory planning is becoming popular in resource assessment, planning and implementing community-based forestry projects. There are an increasing number of projects that provide local community access to information technology and the Internet. Integrating local and traditional knowledge with modern technologies can help to address community priorities and enhance planners ability to make wise decisions. Some examples of GIS applications in participatory planning are summarised in Table 4-13.

Table 4-13 Examples of GIS applications in participatory planning

Applications	Citation	Country/Location
GIS and PRA used in local level land use planning	Meri and Bitter (2002)	Sri Lanka
Use of GIS to produce community-based maps and promote collaborative natural resource management	(McConchie and Mckinnon. 2002)	Southeast China
GIS used to analyse forestry changes and support management decisions for sustainable community forest management	(ESRI 2003b)	Mamiraua Reserve, Brazil
Assessment of land use and land resource pattern in the limestone mining area and environment	(Raghavswamy *et al.*, 2002)	India
Use of GIS in participatory resource planning	(Gonzalez 2000)	Ifuago, Philippines

GIS and related technologies have made it possible for community groups to compile information on their lands with the level of precision and sophistication demanded by governments and international organisations (Rocheleau and Edmunds 1997).

4.5 GIS Applications in Community Forestry in Nepal

General outline

The preceding sections have shown the potential for GIS applications in almost every aspect of forest management. This section reviews the current status, potential opportunities and some challenges of GIS in community forestry in Nepal, so that some of the findings of this research with the WSF can be related to the Nepalese context in Section 7.2.5.

Current GIS applications in CF

Various international non-governmental organizations (INGOs) and certain government agencies are developing GIS databases for use in the forestry sector of Nepal. Community forestry is a major feature of government forest policy in Nepal and the employment of GIS in community forestry is increasing recently.

However, GIS is currently used in community forestry in Nepal only for research purposes and in some pilot descriptive studies of community forests. Some international donor-supported forestry projects (see Appendix 5-1) have started to use GIS and related technologies in various community forestry activities. The uses of GIS, GPS and aerial photographs for various purposes in community forestry are reported by Marther *et al.* (1998), Jordan and Shrestha (1999), Jordan (2002), Shrestha and Tuladhar (2003), Acharya (2003), Kunwar (2004). Some current applications of GIS in CF in Nepal are summarized in Box 4-2.

Box 4-2 Current use of GIS and related technologies in CF, Nepal

Use of aerial photographs in conjunction with GIS were tested as a possible alternative of current chain and compass practices for surveying community forests.

Use of large scale aerial photographs with GIS for species identification and participatory forest resource inventory.

Combined use of GPS and large scale aerial photography to delineate exact community forest boundaries, internal community-designated boundaries, and to calculate forest area and produce maps.

Use of GPS and photo-maps in combination with participatory tools for gathering information for community forest operational plans.

(Jordan 1998; Mather *et al*. 1998; Acharya 2001; Acharya and de-Boer 2000)

In the authors' experience with the Nepalese Ministry of Forest and Soil Conservation, most of the applications listed in Box 4-2 were started as pilot projects and are not common in many forest-user communities.

Factors hindering use of GIS in CF in Nepal

A wide range of economic, social and cultural problems are reported to have hindered the uptake of GIS applications in Nepalese community forestry. Those that are mentioned in the literature are summarised in Box 4-3.

Box 4-3 Factors hindering GIS use in CF, Nepal

Poor economic conditions: GIS facilities are not affordable for resource-poor community forest user groups (without outside assistance) even though the cost of computer hardware and GIS software has dropped markedly in recent years.

Lack of trained personnel: Trained man power to operate GIS is usually lacking in most community forestry organizations and developing countries.

Lack of existing databases: Digital databases and other information required to feed GIS is usually lacking.

Poor information flow: Lack of cooperation and poor information flow between various users of spatial information.

Restricted access to information: Bureaucratic agencies and officials restrict the dissemination of and access to spatial information to local communities.

Marther *et al.* (1998), Jordan and Shrestha (1999), Jordan (2002), Shrestha and Tuladhar (2003), Acharya (2003)

In the author's experience in Nepal, most of the factors hindering GIS listed in Box 4-3 could be overcome gradually with time and appropriate policy support and funding. Some of the experience gained in research undertaken in this project in Australia may have implications in overcoming the factors that hinder GIS use by resource-poor community groups in Nepal and other developing regions (see Section 7.2.5).

4.6 Free GIS/GPS Software and Potential Uses to Community-based GIS

Even though the cost of GIS software has dropped considerably, GIS is often unaffordable to non-profit community organizations and forest user communities. Also, full utilization of the wide variety of applications and functions of commercial GIS software requires a level of expertise and resources that is lacking in many community-based organizations. On the other hand, a wide variety of freeware is available in the internet that can be used by community organizations for basic GIS set-ups, particularly at the initial phase. Some useful freeware for forest user communities and non-profit community organizations is listed in Appendix 2-2 and 2-3.

A wide variety of free software for downloading GPS data to a PC for use with GIS are available from the internet and can be useful to community groups and non-profit, resource poor organizations. Most are compatible to common GIS desktop GIS software. Software listed in Appendix 2-2 and 2-3 could be useful to forest user communities for a wide variety of purposes in GIS, including data viewing and querying and analysis. The Map Explorer software developed by ESRI (UK) was selected for inclusion with the GIS database made available by DSE for WSF groups. Some main features of that software are listed below, and are further described in Section 5.5.

- Support wide variety of raster and vector datasets
- More user friendly comparing to other freeware
- More applicable for forestry data viewing and querying and analysing
- Supports image viewing (e.g., aerial photographs – commonly used in forestry).

Although most freeware programs do not have the capability for complex spatial analysis and modelling, forest community groups usually have only basic requirements for software at the initial stages of setting up a GIS. It is good idea to use freeware in the project development phase, and once the community groups are armed with a basic GIS database and some GIS skills, they can purchase commercial GIS software as needed.

4.7 Conclusions about Applications of GIS in Forestry

Review of global literature on GIS applications shows there is high potential for use of GIS in a wide variety of applications, from conventional management focused issues, (e.g., timber stocks, conservation and resource inventory) to modern concerns, such as community-based ecotourism and participatory planning. Some observations from the literature are that:

- GIS is frequently used in various aspects of forest management in industrialised nations (particularly in Northern America and Canada followed by Europe) but use of GIS in developing countries has increased in recent years. The declining cost of computer hardware and GIS software, user friendliness of GIS software and increasing awareness, are factors in this trend.
- The spatial information required for community-based forest management is much broader than in 'conventional' government-based management.
- The integration of GIS with participatory research methods is increasing, especially in developing countries like Philippines, Thailand and Nepal. Such integration is important in the case of community-based forest management where local knowledge regarding resource management is essential if management aims are to be achieved.
- To establish a community-based GIS requires a well-organised plan that includes tasks such as identifying priorities of different stakeholders, management of institutional as well as technological issues, and providing relevant training to community facilitators and GIS operators.
- A standard PC (even a laptop computer) can be used with Desktop GIS software for a community-forestry GIS project. There is scope for use of freeware available on the Internet by resource-poor community organisations.
- Various constraints have been found in using GIS in forestry, e.g., lack of access to services and advice for information technology, requirement for technical skills in collecting data and maintenance of databases, lack of availability of suitable data (format and structure) for particular projects. Most of these are more

pronounced in developing countries like Nepal and among resource poor community organisations.

The increasing trend towards use of GIS and related technologies in forestry and community forestry indicates that greater diversity in application of GIS can be expected in future. Chapter 5 identifies stakeholder's requirements for the use of GIS in a community-based forest management initiative in the WSF in the first two years of its development.

5 COMMUNITY-BASED GIS IN THE WOMBAT STATE FOREST

5.1 Introduction

This chapter deals mainly with Objective 2 of this research, i.e., to determine stakeholders' views on their requirements for the use of GIS in community management of the Wombat State Forest (see Section 1.5). However, it is also concerned with setting the scene for Objective 3, i.e., to prepare, demonstrate and test various applications of GIS requested by community groups in the WSF. In Section 5.8 some examples of community-based GIS applications in resource management in other regions of the world are outlined, with a view to providing a wider range of examples.

In 2003 when this study commenced, the WSF had only recently been declared as a pilot area for community forest management by the Minister of Sustainability and Environment in the State of Victoria (Anderson 2003a). This was the first instance of community forestry in Australia (Petheram *et al*. 2002). As part of the community forestry process, various 'issues based' working groups were formed, to deal with particular aspects of forest management. Members of some of these working groups (see Section 5.2) around the WSF showed enthusiasm for access to and use of a variety of geographic information for their particular purposes in forest management. The nature of data requirements was diverse and based on the particular objectives of the groups, e.g., Water and Hydrology Working Group members were interested in water bodies, waterways, and the mapping of soaks at the head of catchments, while the Weed and Pest Animals Working Group was concerned with recording and mapping the distribution of various weed species around the forest and its settlements.

Section 5.2 shows the various issue based working groups and the spatial data requirements that were expressed at meetings at the early stages of community forest management. Various models for making GIS data available to community groups are listed in Section 5.3 and two approaches adopted around the WSF are discussed in Section 5.4. In Section 5.5, a government initiative for community-based GIS, the development of the Forest Explorer CD of the Wombat State Forest, is outlined. Section 5.6 describes the 'university-community partnership' for community-based GIS initiated by the author of this thesis. In Section 5.7 the creation of community-GIS database in the WSF is discussed in brief. In Section 5.8, some international cases of community-based GIS for community forest management are reviewed, and lessons are drawn for the future use of GIS in the Wombat State Forest.

5.2 Issue Based Working Groups and Spatial Data Requirements for CBFM in the WSF

The various issue-based working groups formed before or during the first year of the development of the Wombat CFM initiative are shown in Figure 5-1.

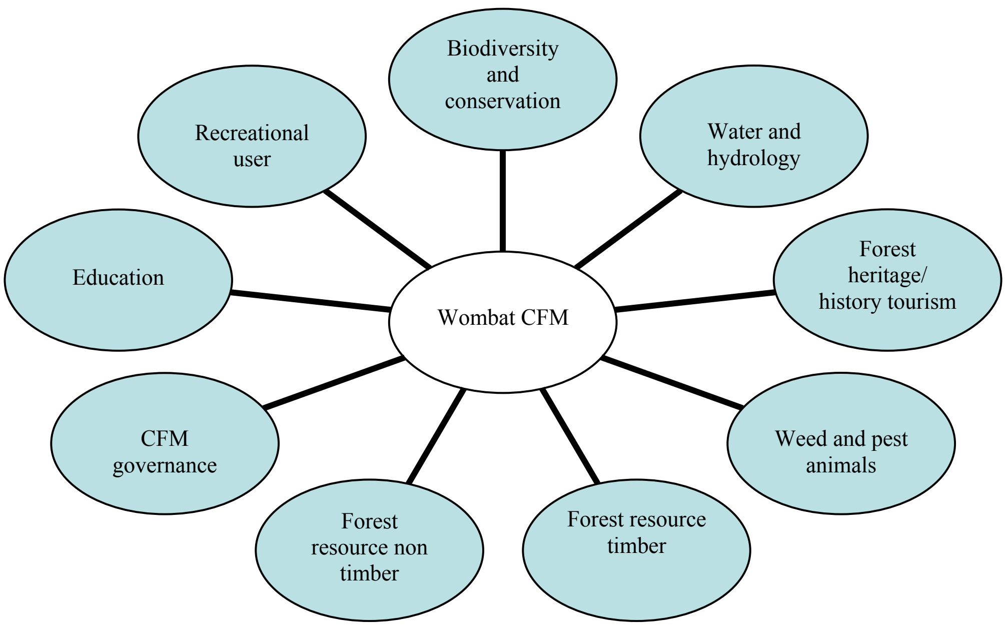


Figure 5-1 The nine working groups (in blue) of the Wombat CFM initiative
(Modified from text: WNL 2004a, 2004b, and 2004c)

All the working groups shown in Figure 5-1 have shown interest in the use of GIS in their early activities (Baral 2004; Liffman 2004). Following a series of meetings around the WSF in 2003, it is claimed that that communities demonstrated 'an appetite for up-to-date information and tools' (Anderson 2003b), so that decision-making can be based on the best available information. A list of data themes was developed from ideas provided by community members at meetings during the establishment of community forest management and this is shown in Box 5-1.

Box 5-1 List of GIS themes considered useful by community groups for Wombat CFM in 2003

Topography	Rivers	Recreation sites
Geology	Waterways	Highways
Soils	Rainfall	Roads
Soil depth	Management zones	Tracks
SFRI layers	Forest boundaries	Streets
Standing volume	Catchments boundaries	Other public land uses
Ecological vegetation class (EVC)	Coupes	Water bodies
	Blocks	Mineral springs
Flora sites	Historical sites	Mineral and fresh water
Fauna sites	Cultural sites	Recharge zones
Major towns	Walking tracks	Fire history
Places of interest		

Source: (Anderson 2003b)

Most of the data themes listed in Box 5-1 could be useful to more than one working group (e.g., topographic information), while others are useful for specific issue-based groups. The 34 information types shown in Box 5-1 and 51 additional information types subsequently requested by various working groups have been classified for this thesis into three categories, i.e., (i) environmental, (ii) social and (iii) economic, as shown in Table 5-1. The importance ranks (A and B) shown in table were based on the views of the coordinator of CBFM in the WSF in 2003 (T. Anderson [DSE, Daylesford] pers. comm. April 2003).

Table 5-1 List of GIS themes according to information category and importance

Layer description	Category			Rank	Layer description	Category			Rank
	Env	Soc	Eco			Env	Soc	Eco	
Forest type	*			A	Mineral springs	*	*	*	A
Land use	*			A	Fire fuel breaks		*		A
Tree cover	*			A	Fire hist. most recent fires		*		A
Land cover	*			A	Fire origin/history		*		A
Res. availability	*			A	Logging history		*	*	A
Land availability		*	*	A	Harvested logging coupes			*	A
Major towns		*		A	Utility power/telecommunication		*		A
Town boundaries		*		A	Satellite image	*			A
Catchments boundaries	*			A	Forest management zones		*		A
Adm. boundary features		*		A	Sites of biodiversity significance				A
Place names		*		A	Rainfall isohyets		*		A
Major river basins	*			B	Admin boundaries		*		A
Water bodies	*			A	Topography	*			A
Population		*	*	A	Flooding extent	*			B
Skills/employment			*	A	Flood features heights	*			B
Major roads		*		A	Forest cover change	*	*		A
Forest service roads		*		A	Forest plantation			*	A
Railways, rail stations		*		B	Forest management boundaries		*		A
Elevation- contours	*			A	Forest management blocks		*		A
Elevation- DEM	*			A	Land for wildlife properties		*		A
Elevation - TIN	*			A	Locality boundaries		*		A
Slope	*			A	Flora fauna survey sites		*		A
Aspect	*			A	Water supply catchments		*	*	B
Shaded relief	*			B	Wind break lines	*			B
Soil type	*			B	Vicmap hydrology	*			B
Soil texture	*			B	Vicmap satellite imagery	*			B
Soil drainage	*			B	GPS base map stations			*	B
Precipitation annually	*			A	LGA boundaries		*		B
Precipitation monthly	*			A	Aboriginal comm. boundaries		*		B
Precipitation max/min	*			A	Mean annual monthly evaporation	*			B
Temperature annually	*			B	Mean monthly evaporation	*			B
Temperature monthly	*			B	Geological rock types	*			B
Temp. max/min	*			A	Relative forest growth stage	*			B
Flora endangered	*			A	Historic sites line		*		A
Fauna Endangered	*			A	Historic sites point		*		A
NWFP availability			*	A	DSE and Parks Victoria offices		*		B
Wetlands	*			A	Ramsar wetlands in Victoria	*			B
Bee keeping sites			*	A	Rock site location	*			A
Mining area			*	A	Common place name		*		B
Past mining sites			*	A	Biological habitats	*			A
School/college location		*		B	Emergency service facility loc.		*		B
Churches		*		B	Parks Victoria regions		*		A

[Env. = Environmental, Soc. = Social, Eco. = Economic]
[Importance ranks: A = essential, B = useful if available but not essential]

5.3 Models for Making GIS Available to Community Organizations

Craig and Elwood (1998) note that GIS can play an important role in the success of community organizations. Community groups (including forest communities) have used GIS and GIS-based maps in different ways and for a wide variety of purposes. Ways of making GIS available to community organizations differ widely, and Leitner *et al.* (2002) identify six such models (see Box 5-2).

Box 5-2 Six models for making GIS available to community organizations

Community-based (in-house) GIS: A GIS facility is located within the community organization office. Direct and immediate accesses of GIS facilities are available to the community and provide the possibility to create their own database and maps.

University/community partnerships: Universities and community groups find a project of common interest and work together. University staff and students support community organization's mapping needs in various ways.

GIS facilities in universities and public libraries: Access to GIS and spatial data is provided through publicly accessible GIS facilities at universities and public libraries.

Map rooms: Various city and state offices (such as natural resource department) provide communities with land use/land cover data or maps relevant to their planning purposes.

Internet map servers: Pre-defined maps are made available to community organizations via the internet.

Neighborhood GIS centres: Neighbourhoods pool their resources and expertise, to provide a central facility that all affiliated community organizations could use.

(Leitner *et al*. 2002)

Each model outlined in Box 5-2 has advantages and disadvantages, and different models and modifications are appropriate for different situations (Leitner *et al.* 2002). Two models that were considered appropriate for the circumstances of the Wombat CFM are discussed in the following sections.

5.4 Community-based GIS Approaches in the Wombat State Forest

Two approaches from Box 5-2 that have been adopted for establishing GIS for community forest management in the case of the WSF are:

(i) a government initiative for community-based (in-house) GIS, and
(ii) a university-community partnership involving research students.

The first approach was by the Department of Sustainability and Environment (Forest Resource Inventory Section) and the second involved the author of this thesis in this research project through the University of Melbourne.

The two initiatives, although started independently, were developed in close association and efforts were combined at various stages and in the products provided to the community. For example, the university student/researcher worked directly with DSE to collate data on socio-economic aspects, but directly with community groups to produce weed maps. However, all the GIS data and maps were incorporated in the major product provided to the community by the DSE project, i.e., the Forest Explorer CD for the Wombat State Forest. Other efforts made by the student researcher included rainfall mapping (in association with the Bureau of Meteorology). These two linked approaches to producing community GIS databases for the forest communities of the WSF are depicted in Figure 5-2.

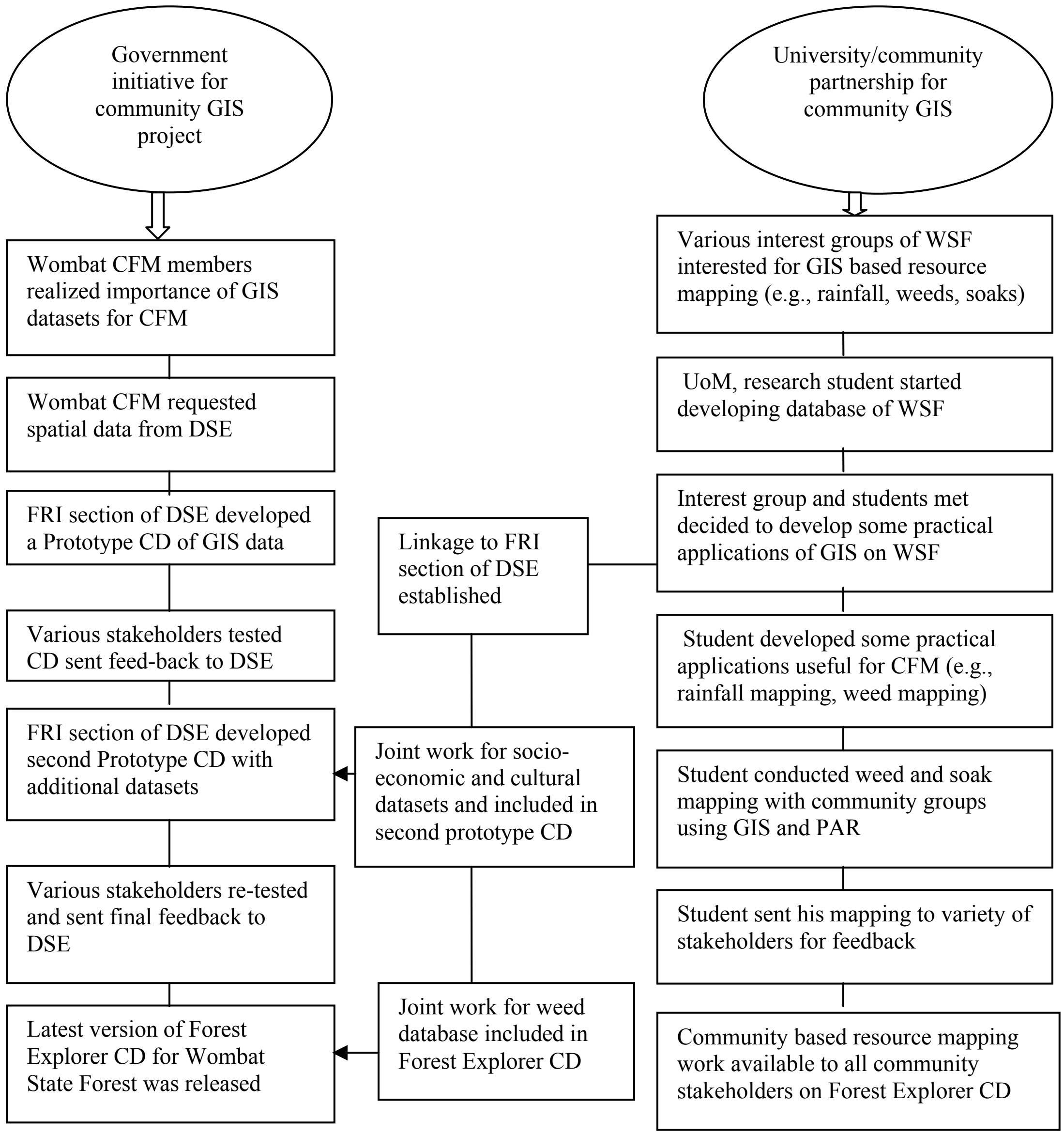


Figure 5-2 Flowchart showing two approaches and steps to providing support for community-based GIS in the Wombat State Forest

(For acronyms see List of Acronyms, p. XII)

The boxes in the central column of Figure 5-2 show linkages between the two initiatives and joint efforts to produce a community GIS database. These two initiatives are further explained in the following two sections.

5.5 A Government Initiative for Community-based GIS: the Forest Explorer CD for the Wombat State Forest

General outline

The government initiative to make GIS data available to the WSF community was initiated by the Forest Resource Inventory (FRI) section of the DSE from early 2003, after community groups requested a wide variety of GIS data sets (see Box 5-1). Instead of providing crude GIS datasets for community use, the DSE team produced a compact disk that included both simple (free) GIS software and a range of data sets – in a 'toolkit' entitled the 'Forest Explorer CD for Wombat State Forest'. This meant that users did not have to obtain their own GIS software to use the resource on their computers.

The Forest Explorer CD for Wombat State Forest (WSFCD) included a variety of spatial data that had previously been collected, formatted and maintained by various divisions of the Department of Sustainability and Environment (DSE 2004). WSFCD is intended to provide the community with access up-to-date spatial datasets on the Wombat State Forest. The main features of the WSFCD are:

(i) free Map Explorer software that enables users to view forest data, explore data and produce maps

(ii) a wide variety of environmental, economic and socio-cultural datasets and

(iii) a user guide that includes a data catalogue and extensive tutorials on using the resource.

The forest explorer CD development process portrayed in Figure 5-3 illustrates the overall course of action taken by the FRI section of DSE to make GIS data available to the Wombat CFM.

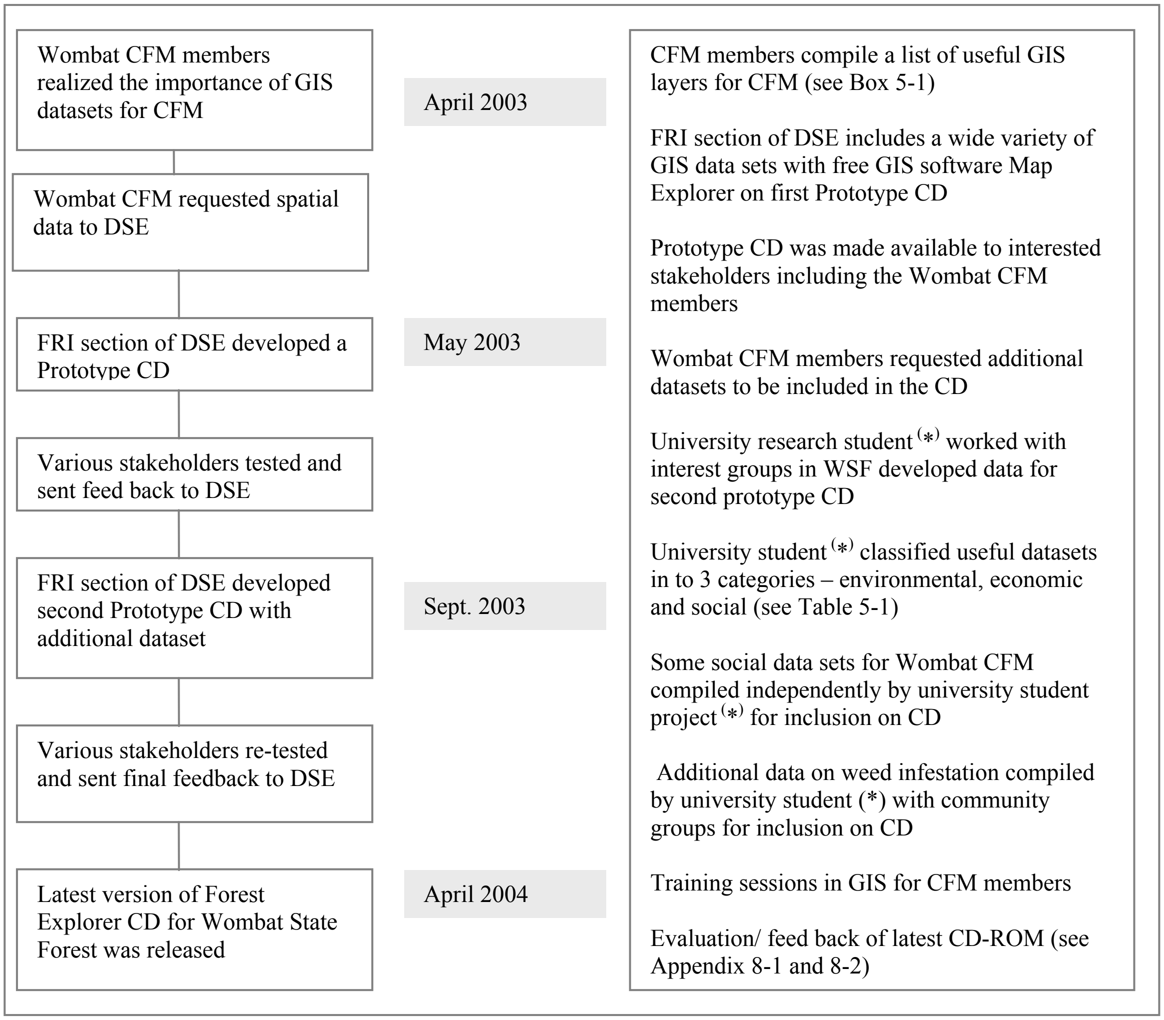


Figure 5-3 Development of the Forest Explorer CD for WSF, showing timelines

(For acronyms see List of Acronyms, p. XII)

The left side of Figure 5-3 shows the steps in the process and the right side shows some parallel activities conducted during the process. The asterisks (*) show where the author of this thesis was involved directly in parts of the process, in meetings with community members in the WSF and in developing data sets in the Melbourne office of FRI section of DSE.

Map Explorer software

'Map Explorer' is GIS software (available free of cost by ESRI UK) that enables people to view, query and map spatial data. Because of its ease of use (and free availability), this software can be a valuable tool for resource-poor community organizations and individuals who have access to a computer. The main features and technical specifications of this software are summarised and other freeware available in the internet and may be useful for the Wombat CFM (and other community organisations) is listed in Appendix 2-2.

Useful GIS databases

The most important feature of the Forest Explorer CD is its provision of a wide variety of environmental, socio-cultural and economic databases. These data are easy to understand and analyse for a computer-literate person with no prior GIS experience. Some major information types included are:

- **Environmental:** Information related to forest characteristics, biodiversity, bio-physical features, water catchments, fire and weeds
- **Socio-cultural:** Population characteristics, education levels, historic sites, aboriginal communities, occupation projects
- **Economic:** Information regarding industry, timber produce, non-wood produce, occupation.

Certain data sets on the WSFCD (i.e., the rainfall isohyet, historical tramways, weeds and aspect layers) were created mainly in the research for this thesis, as a part of the separate but linked project in community-GIS (see Section 6.2 – 6.7).

Tutorial for users of the Forest Explorer tool kit

An extensive tutorial on the Forest Explorer CD assists users to view and analyse information. These tutorials are designed for use by a range of GIS users – from beginners to experienced people. Topics are arranged under two main components:

(i) theory (concepts and GIS use and the Map explorer software)

(ii) tutorial (allows practice with the tools and functions).

5.6 The University/community Partnership for Community-based GIS in the Wombat CFM

In recent years universities and research organizations world-wide have become involved with assisting community organizations with their mapping needs through a variety of mechanisms (Leitner *et al.* 2002). In such programs research students are sometimes involved in providing a service to community groups. Such an initiative was taken by the author of this thesis and his academic supervisors, with local communities, to develop a GIS database and certain applications in CBFM. Examples of particular GIS applications that were developed in this study by the university-community partnership are summarized in Box 5-3.

Box 5-3 Issue based interest/working group of WSF and their interests in GIS database and/or mapping (some examples 2003)

Weed and Pest Animals Working Group was interested to map weed and pest animal distribution around Blackwood/Barrys in the WSF, as the basis for an integrated weed management plan.

Water/Hydrology Working Group was interested in mapping significant 'soaks' at the head of the Coliban River watershed, so they can make a conservation plan in future.

Wombat Forest Society, Daylesford was interested in having rainfall isohyets map of WSF and its surrounds to use for various natural resources planning purposes.

Heritage Working Group wanted to digitize old paper maps of historic tramways, goldmines and water races, to prepare future management plan, construct heritage trail.

[These applications are described in Chapter 6]

Besides the interest groups listed in Box 5-3, the Biodiversity and Conservation Working Group and the Recreational User Working Groups have shown interest in developing a GIS database for their purposes, but limited time and resources prevented the work on those topics within this project.

The flowchart in Figure 5-4 illustrates the process undertaken in this research to generate GIS databases with interested working groups of the WSF.

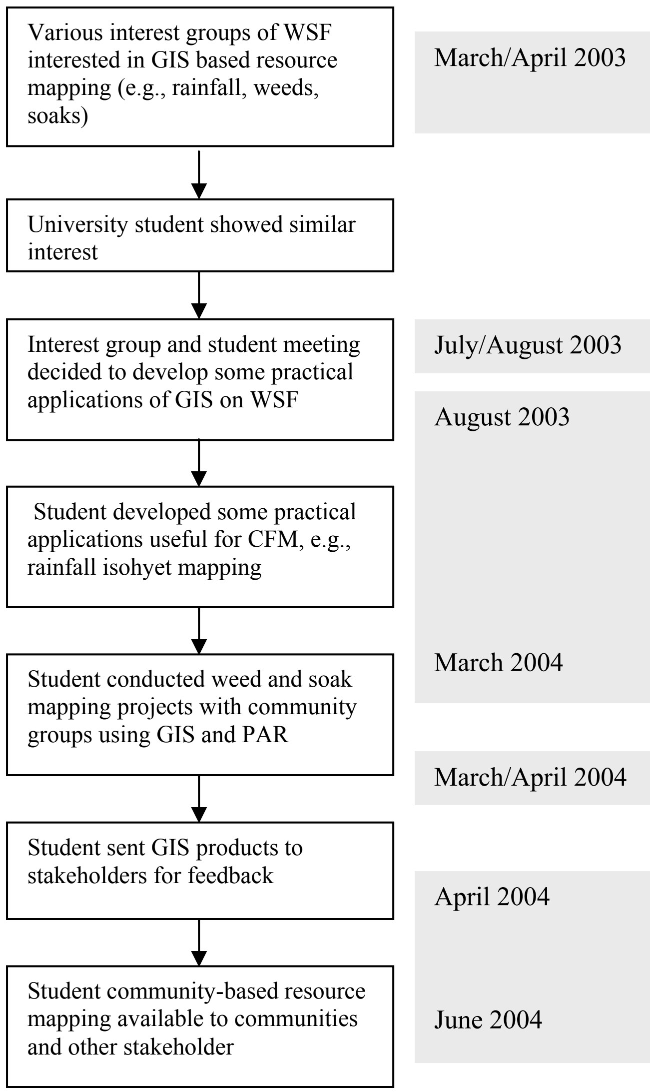


Figure 5-4 Process and timelines for community-GIS database generation by the University of Melbourne-Community partnership

(For acronyms see List of Acronyms, p. XII)

Although most working groups associated with CBFM in the WSF showed interest in developing GIS databases, identifying interested volunteer community members to work with the university project took considerable time. Locating suitable data was also time consuming in many cases. The following section covers acquiring and creating a community-GIS database for the purpose of preparing and demonstrating some practical applications of GIS in the WSF.

5.7 Acquiring and Creating Community-GIS Databases for the Wombat CFM

Accurate, consistent and appropriate database creation is fundamental for any GIS project. For successful implementation of a community-GIS project the database must be useful for community use, and needs to be converted to a common and compatible digital format (Lomis 2000). The main purpose of acquiring, creating and organising a community-GIS database was for use in preparing and demonstrating practical applications of GIS (discussed in Chapter 6).

Availability of existing GIS data

Availability of relevant, existing databases can reduce both time and money for a new GIS project. Bettinger and Wing (2004) mention four general cases common in forestry and natural resource organisations regarding the availability of GIS databases in Box 5-4.

Box 5-4 Common situations regarding GIS database availability in forestry

Data not available: Required GIS database for the specific project do not exist or not available.

Data available but not appropriate: Some sorts of GIS data are available but were created for other purposes and are not appropriate for a specific propose.

Data available and partly appropriate: GIS databases prepared for other purpose but not completely useful for a particular project.

Data available and appropriate: Adequate amount of appropriate GIS data available for particular project.

According to Bettinger and Wing (2004) the first three cases are most common and the last case is very rare in most of the real world situations hence takes considerable time for acquiring and developing a GIS database.

In this study in the Wombat State Forest the author most commonly encountered the first three cases outlined in Box 5-4, which are common to other forestry situations. Some spatial data layers available from other sources were collected and converted for use by community groups (e.g., topographical data available from Education Resource Centre, The University of Melbourne were used to prepare a hardcopy paper map to trace weed infestation by community groups). New GIS databases were created using various techniques from primary sources in other cases.

Data sources and collection

Collection of existing GIS data in this research project was from various sources, such as:

- Topographic data from Education Resource Centre library of The University of Melbourne
- 1:20,000 scale colour aerial photography taken in 1997 (available from commercial suppliers)
- Old paper maps of historic goldmines, water races and watercourses from community groups members around Simmons Reef
- Old paper maps and information on historic tramways from BNR section of the DSE
- Average annual rainfall data of some rainfall stations around the WSF from Bureau of Meteorology (BOM).

Use of these data and development of some practical applications useful for community groups around the WSF is discussed in Chapter 6. Collection of primary data is outlined in the following section.

Creating new GIS data

Chang (2002) states that GPS data are becoming an important source for vector data input, but that paper maps are still predominant sources for creating new GIS data. For the purpose of this research, field data were collected in two main ways; (i) using hand-held GPS, and (ii) from paper maps drawn by community members on base maps produced by the researcher (e.g., weed maps; Section 6.3). Some existing historic paper maps were digitised using ‘on-screen” (or *heads-up*) digitising, and standard digitising. These techniques are discussed under practical examples of GIS in the WSF in Chapter 6.

Some examples of community-based GIS in other parts of the world, that are considered relevant to CBFM in the WSF, are outlined in the following section.

5.8 Some Cases of Community-based GIS and Lessons for the WSF

Six examples of community-based GIS from other parts of the world are outlined in Boxes 5-5 to 5-10. These case studies are drawn from literature on attempts by supporting agencies to involve local communities in decision-making, enhance communication and understanding, and to incorporate people's ideas in the planning process.

Box 5-5 Case study 1: Community integrated-GIS for local capacity building
(from Maine, USA)

The Island Institute is supporting the development of a community integrated GIS approach to increase local information and management capacity, and to make quality information available to the entire community. This includes information that can support planning, conservation education and governance.

Vinalhaven community is working to create an 'Information Commons' – a place where community members can access a collection of GIS data and other information in support of educational projects, town government needs, and environmental conservation with the help of the Island Institute. Interest in GIS emerged from a comprehensive planning process, where community members recognized the need for accurate geographic information and tools.

The Institute supports GIS works through institute fellows who are recent graduates placed on the island at the request of the community. Fellows work for one to two years on a community project and the Institute hosts regular workshops for community members involved in GIS work to provide software training and acquiring GIS data.

Lessons: An integrated community approach to GIS must involve local capacity building in GIS, and can use existing contacts and community resources.

(Island Institute 2003)

Box 5-6 Case study 2: Community participation in fire management planning using GIS (from Trinity County, Northern California, USA)

In the USA local communities are not normally involved in the fire suppression planning or pre-fire decision-making processes. The increased impact of wildfire in Trinity County, Northern California during last two decades has led to a search for more effective means of fire control.

Trinity County Fires Safe Council (FSC) initiated a project to involve local communities in forest fire management activities in 1999. The main object was to capture local and regional knowledge and expertise in fire management as efficiently and effectively as possible. To achieve these objectives, local NGOs were involved with participatory research and community mapping methods. Data layers pertinent to fire management, including topography, roads, hydrography, vegetation and post fire starts, were collated from USFS, the Bureau of Land Management, and the California Department of Forestry and Fire Protection. Once the data were compiled, base maps useful for information gathering with community members and future fire management modelling were generated.

Trinity County set out to identify community safety zones and escape routes in case of catastrophic fire and keep water tenders and other equipment locally available. It is currently involved in developing an overall strategic plan for fire management in which community recommendations will play a significant role.

A FSC team works jointly with community groups, (i) to gather and develop GIS with available spatial data for the county that were pertinent to fire, and (ii) to identify local knowledge and relevant spatial data.

Lessons: Local communities possess valuable knowledge of place fire history and fuel loading. Local site specific knowledge and experience with the terrain, past fire behaviour and locations for emergency fire lines could save lives, time and money during emergencies.

(Everett 2003)

Box 5-7 Case study 3: Community-based GIS to assess forest resources and develop resource plan
(from Dolakha District, Nepal)

Participatory photo-mapping, participatory inventory and global positioning system (GPS) surveys were combined to assess forest resources and develop resource use plans of community forestry user groups. GIS outputs included images and management information that were used to form the basis of a visual report/ management plan.

The local community contributed by providing resource information and participating in feedback meetings. Jordan (2002) concluded that community-GIS is an appropriate and valuable tool for community forestry in Nepal and should have much wider applications in participatory development work.

Lessons: Participatory GIS can empower forest communities by involving them in the decision making process. It can also raise people's expectations for information availability.

(Jordan 2002)

Box 5-8 Case study 4: Community GIS for forest resource management
(from British Columbia, Canada)

Initially, Long Beach Model Forest (LBMF) provided support for the establishment of mapping GIS and database management potential in local communities, involving a GIS project coordinator. To begin with, baseline data sets of planemetric, topographic, land use and forest inventory were assembled and distributed to the communities. Training in GIS was provided and mapping and data management issues were discussed with communities.

The main assumption was that if genuine users (whose daily lives are affected by the operation of the forest management systems) participate in GIS applications the achievement of sustainable forest management would be more likely. Some communities have completed provincial forest, wildlife and environmental data capture and mapping. Community GIS programs are now part of forest resource management activities.

Lessons: If community level organisations increase their capability to be involved in mapping and data management this can result in greater local understanding of, and participation in, resource planning and management processes.

(LBMF 2003)

Box 5-9 Case Study 5: GIS to produce community-based maps to promote collaborative natural resource management
(from Yunnan, China)

This paper explores the use of MIGIS (an acronym for community based planning which integrates the techniques of Participatory Learning Action or PLA and Mobile Interactive GIS) to facilitate a negotiated, bottom up approach to deforestation with the Hani farmer of Luchun County, Yunnan in southwest China. During the MIGIS exercise, GIS was used at four levels, to:

- Construct a database to store information relating to each household. Both visual and statistical records of the villages were created
- Identify and quantify the constraints on development options imposed by the physical environment e.g., slope, aspect and land use
- Compile baseline information as to the conditions present at the start of the project. The results of any development initiative or intervention can be assessed against this situation, and
- Test various scenarios, such as the impact of setting up riparian forest buffers, and to model what would happen to the remaining forest if no action were taken. These scenarios provided valuable information that stimulated discussion and helped farmers to focus attention on issues, problems, and possible solutions.

Lessons: Combination of GIS and PLA tools can be useful in community based planning and decision making.

(McConchie and McKinnon 2002)

Box 5-10 Case study 6: P-GIS for local level participatory planing
(from South Africa)

Research was conducted to identify means of integrating community resource management options into district level policy and planning. In Northern Cape Province in South Africa the following data sets were compiled for the development of participatory GIS database and local level participatory planning:

- Water points: point location of water points which including information on the type and state of repair of the water points (community assessment)
- Grazing quality: quantitative assessment of grazing (community assessment)
- Village boundaries (community assessment)
- Firewood locations (community assessment)
- Precipitation (1’X1’ grid): mean monthly rainfall (Climate Centre for Water research, South Africa)
- Vegetation types (25m.X25m. grid) maximum likelihood classification of Landsat Thematic Mapper ™ satellite imagery
- Normalised difference vegetation index- 25mX25m. grid
- Biomass levels assessed from Landsat TM satellite imagery.

Once the participatory maps were incorporated into a GIS at local level, it was possible to utilise the qualitative and quantitative data.

Lessons: The availability of spatially referenced environmental data can make a critical difference in building the capacity for environmental planning at local level. This has been achieved through the development of a participatory GIS in local level which integrates bio-physical assessment of the local resource base as well as participatory assessments of stakeholder needs, interests and capabilities.

(Weiner and Harris, 2002)

The ‘lessons’ learned from applications of GIS in community-based forest management globally can be valuable in adopting GIS for use in the WSF. The examples provided show particularly the potential value of incorporating local knowledge and experience, the value of GIS in local capacity building and the ability of GIS to integrate different types of data in forest management.

5.9 Some Observations on Community-based GIS for the WSF

The joint provision of two projects to support the use of GIS by the community in the WSF could be seen as wasteful duplication of effort. However, the process described in this chapter, of the development of GIS for community use in the WSF, shows that close communication and cooperation between the two GIS initiatives can be complementary. The student project was assisted by experts and resources for GIS in the FRI section of the government department (DSE), while the student was able to add to the overall effectiveness and output by working directly with community groups in gathering important raw data in the field, to feed into the DSE's Forest Explorer CD project for the community. The involvement of a university research student in close coordination with a government agency and community groups shows the potential for use of university resources for community development activities, and for providing valuable experience for students.

The brief review of some international examples of community-based GIS shows that the scope for community-based GIS in forest resource management and decision-making is much greater than that used in the Wombat CBFM initiative. In Chapter 6 some practical applications of GIS developed for and with various community groups around the Wombat CFM are discussed and some strengths and limitations of community-based GIS are outlined.

6 APPLICATIONS OF GIS IN THE WOMBAT STATE FOREST – SOME PRACTICAL EXAMPLES

6.1 Introduction

This chapter deals mainly with Objective 3 of this research, i.e., to develop and, demonstrate some practical applications of GIS requested by community groups of the Wombat State Forest (see Section 1.5). It also concerns Objective 4, i.e., to identify the strength and limitations of GIS applications in community forestry.

In early 2003 visits were made to the Wombat State Forest for informal meetings with a variety of stakeholders in management of the forest. It became apparent that there was potential to develop applications of GIS useful for community groups (see Box 5-1 in Section 5.2), and so a university-community partnership was developed for GIS in the Wombat State Forest, as discussed in Chapter 5. This chapter presents some applications of GIS that were developed in the WSF in 2003 and 2004, some outcomes of such applications, and strengths and limitations of use of GIS in community forestry.

Each of the GIS applications in the WSF is covered in a standard format in the following six sections. Section 6.2 deals with the preparation of a rainfall isohyet map for the WSF area, and Section 6.3 outlines a community weed mapping project in part of the WSF. A simple initiative involving the mapping of 'significant soaks' in an important watershed in the WSF is described in Section 6.4. Section 6.5 covers the conversion of old historic paper maps to digital format, using two digitising processes. Section 6.6 deals with application related to forest health monitoring and Section 6.7 covers preparation of a slope (and aspect) map of the WSF. Lessons drawn from the practical applications of GIS in the WSF are discussed in Section 6.8 and some outcomes are outlined in Section 6.9. In Section 6.10 some strengths and limitations of using GIS in community forestry are summarised from the international literature. The chapter concludes with some implications of the research for use of GIS in community forestry and other community-based resource management projects.

6.2 GIS Application I: Rainfall Isohyet Mapping

Location: Wombat State Forest and its surrounds.

Origin and purpose: From an early date, members of the Wombat Forest Society, other community members and forestry professionals expressed interest in having access to maps showing annual rainfall distribution for the Wombat State Forest and surrounding areas. The intended purposes for the mapping were stated as:

- Improved community awareness and understanding of major environmental variables in the WSF
- Use with other environmental data to study flora and fauna species distribution
- Prediction and mapping of site suitability (e.g., for re-introduction of endangered species), productivity, sensitivity and other ecological features.

Form of final product: Digital and paper maps showing 100 mm annual rainfall isohyets of the WSF and surrounds (Figure 6-1).

Commenced: July 2003 **Completed:** August 2003

Distribution: The final product was distributed to the WSF community through inclusion in the Forest Explorer CD of the WSF, and to the Bureau of Meteorology, Melbourne, which provided the data for this application.

Data software, hardware and other equipment used:

Data:

- Annual average rainfall data from 52 rainfall stations around WSF. Climate data can be purchased from the Bureau of Meteorology (BOM) in Melbourne. For this study, data were kindly made available free, on the basis that BOM be provided with a copy of the isohyet mapping
- Various resource data (i.e., resource availability map of WSF, ecological vegetation classes) used as a base map for the isohyets were obtained from the FRI section of the DSE, again on the basis that the researcher provide the output to DSE.

Software:

ArcView GIS 3.2, MacGIDZO, Surfer 7.0 and MS-XL software.

Hardware and peripherals

Pentium based PC running with XP Professional, CD-ROM, CD-RW and Flashjet USB drive, GTCO super L II digitizer, a laser printer.

Method: The major steps involved in preparing the rainfall isohyet map of WSF are summarised in Box 6-1.

Box 6-1 Steps in rainfall isohyet mapping of WSF

Step 1: Collect crude rainfall data from BOM and rearrange according station name, *X, Y* coordinate and *Z* as mean annual rainfall using MS Excel.

Step 2: Convert geographic coordinates in BOM data to Australian Map Grid (AMG) (see Appendix 7-2) so that final output can be overlaid with other resource maps.

Step 3: Save spreadsheet data as a text (tab delimited) or dbase file so that data can be imported to ArcView GIS as a new table.

Step 5: Open ArcView GIS project and view window and highlight the Table.

Step 6: Specify the file name with rainfall data then click OK. The table is added to ArcView window. Then highlight the view window and select Add Event theme from theme menu.

Step 7: Specify table name and *X, Y* field and click OK. The rainfall data are imported to ArcView as a point theme.

Step 8: From Surface menu, interpolate grid to specify output grid extent, and specify output grid cell size; Leave number or rows and columns as defaults.

Step 9: In Interpolate Surface dialogue box specify *Z* value as mean annual precipitation and check Nearest Neighbour and OK.

Step 10: From Surface Create Contour, and specify contour interval i.e., 50 or 100m.

Step 11: Add Contour.shp as a new theme and overlay with other resource maps, i.e., resource availability map of WSF.

The list of steps in Box 6-1 describes the final steps adopted in preparing the rainfall isohyet map using ArcView GIS software. However other technology was also tried before the final process was developed. The software MacGRIDZO (a gridding and contouring software) and Surfer 7.0 (a contouring and 3D surface mapping program) were used initially. The rainfall isohyets prepared with MacGRIDZO could not be saved as an ESRI shape file and it was not possible to overlay with other resource maps. Although rainfall contours can be created by using Surfer and it is possible to export as an ESRI shape file, the map prepared using ArcView was used in the final product for consistency with other products for this GIS application.

Accuracy and limitations of the rainfall isohyet mapping: The rainfall isohyet map produced is based on 52 rainfall stations located at certain human settlements around the WSF and may not represent the whole area evenly or precisely. The 100 mm isohyet intervals are rather coarse, but more precise mapping could not be achieved with the spread of stations available. Some of these rainfall stations had existed for much shorter periods than others (5 – 100 years). During data analysis only the data from Universal Transverse Mercator (UTM) zone 55 were included (see Appendix 7-1 for UTM Zone for Australia), as two UTM zones cannot be joined accurately in one map. This means that the rainfall contours are not available outside the zone 55 shown in the map, although these could easily be produced by the same method if the data could be obtained for adjoining zones.

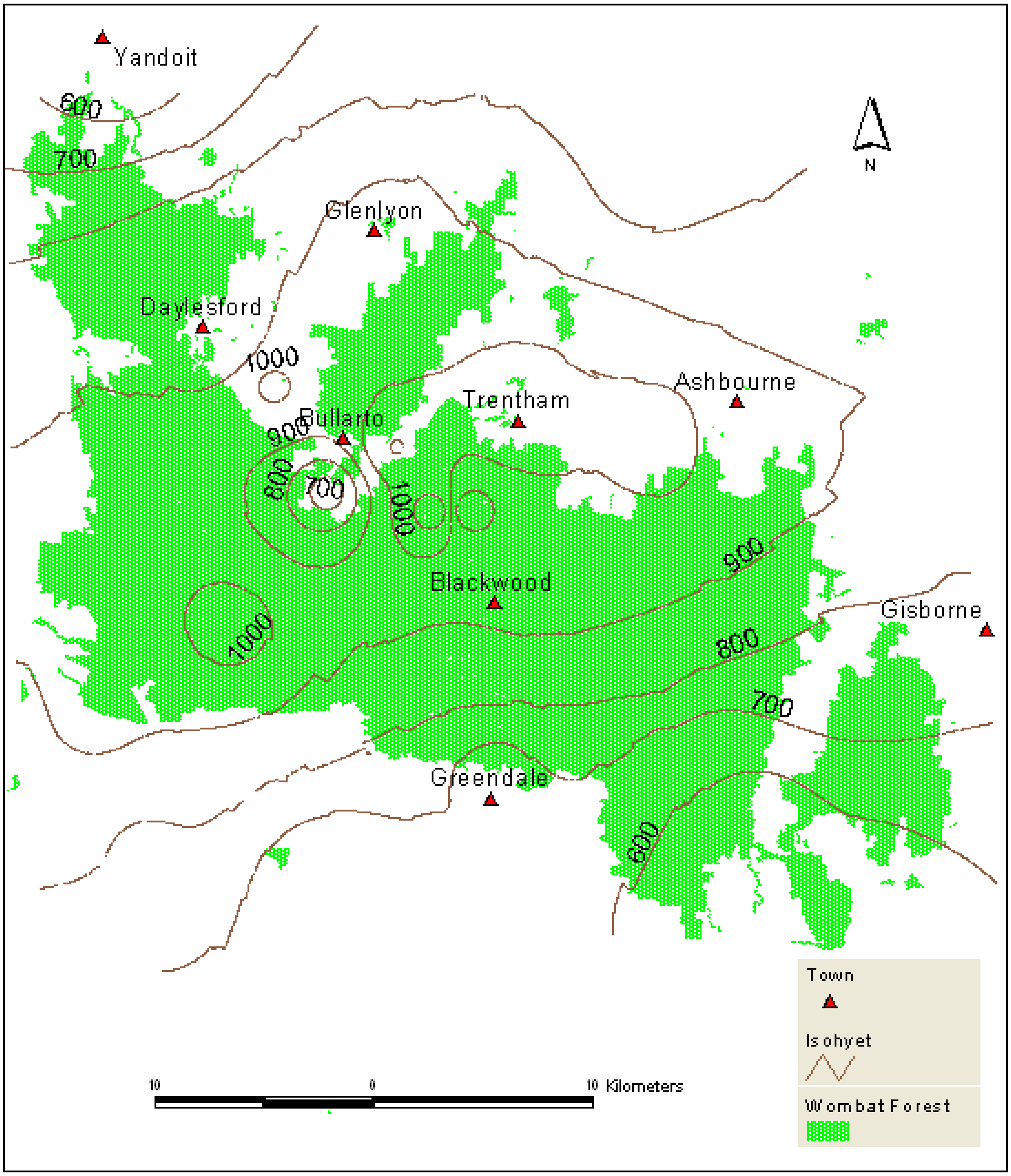


Figure 6-1 Map of the WSF showing rainfall isohyets in mm/yr and some towns

6.3 GIS Application II: Weed Mapping

Location: Blackwood and Barrys Reef area of the Wombat State Forest
Origin and purpose: Parts of the Blackwood and Barry's Reef areas in the Wombat State Forest are heavily infested with various weed species (e.g., gorse, broom, blackberry and thistles) and local community members are concerned to develop plans for weed eradication. The infestations are spreading and represent serious environmental and fire hazards. This issue has been raised in various workshops and forums by community representatives from Blackwood and surrounds for many years and also as part of the CFM process (Liffman 2004). But little support has been forthcoming from government, because the extent of the problem has not been properly documented (D. Glover [DSE, Ballarat] pers. comm. June 2003).

The weed mapping was requested first by members of the 'Blackwood/Barrys Reef Land Care '. Subsequently the request was made by the 'Weed and Pest Animal Working Group' of the Wombat CFM initiative, and the DSE Manager, Forest Management, Midlands Forest, Victoria also expressed interest in the work and provided data on existing weed mapping in the WSF.

Good decision-making and development of a weed control strategy depends on the availability of sound information on weed type, distribution, pattern, and density. The community's purpose for weed surveying and mapping was to identify and delineate land with various weeds in Blackwood/Barrys Reef and prepare maps that can be used in a submission for funding a weed control strategy for the area. The DSE wanted the data to add to their GIS database for integrated pest management systems (IPMS).

Form of final product: Digital and hard copy paper maps of weed distribution around Balckwood and Barrys Reef in the WSF (see Figure 6.2 and 6.3).
Commenced: December 2003 **Completed**: March 2004
Distribution: The final product was distributed to many stakeholders – primarily to the community groups of Blackwood and Barrys Reef, the Weed and Pest Plants and

Animals Working Group of the WSF community management initiative and to DSE Offices at Daylesford, Ballarat and Melbourne (FRI section).

Data, software, hardware and field equipment:

Data:

- GIS data layers, i.e., roads, watercourses, contours and property
- Aerial photographs
- Primary data on weed collected with various community groups around Blackwood/Barrys Reef namely Simons Reef, Blue Mount, Newbury, Golden point
- Hard copy paper maps of the study area with roads, watercourses, property parcel, and contours prepared by researcher using existing GIS data.

Software:

- ArcView GIS 3.2 software, DNR Garmin and GPS Utility.

Hardware:

- Pentium IV Desktop computer, Digitising Tablet, Photo copier, Printer and Plotter.

Field Equipment:

- Hand held Garmin GPS (GPS 76) with PC interface cable
- Portable TOSHIBA notebook computer
- Canon Power-shot digital camera.

Method: A process for collecting field information was developed at a community meeting at Blackwood (Baral *et al*. p. 9). The participatory 'action research' cycle shown in Section 3.4 (Figure 3-2) guided the approach adopted in this application. The major steps involved in weed mapping are outlined in Box 6-2.

Box 6-2 List of steps on community-based weed mapping

Step 1: Meetings and walks with community members (includes discussion and observation of weed infested areas with community groups).

Step 2: Preparation of paper maps of each part of Blackwood /Barry's Reef area (using 1:8000 topographic maps showing property boundaries to guide users in locating points).

Step 3: Paper maps distributed to members in each area and symbols explained.

Step 4: Community members standardise on species identifications and on mapping symbols (and community delegates different areas to different individuals).

Step 5: Community members map weeds in their areas and submit hand-drawn drafts to the researcher (assistance given with use of GPS to locate weeds in certain difficult areas).

Step 6: Weed information on hand-drawn maps digitised using ArcView GIS to produce digital maps (see Appendix 6-1 digitising process).

Step 7: GPS data were downloaded to PC, converted to ArcView shape file and imported to ArcView GIS 3.2 (see Appendix 3-2).

Step 8: Digital maps printed in different size and scale and returned to community to check.

Step 9: Maps of different areas were merged to produce combined database using Geo-processing tool available in ArcView GIS.

Step 9: Final maps incorporating edits from community feedback were prepared and distributed to concerned stakeholders.

Step 10: Reflection and feedback was continuously encouraged on the action research process to ensure future effort could be improved.

The steps summarised in Box 6-2 were repeated several times with various groups or individuals until the set of final weed infestation maps were produced. As the mapping process progressed, various issues were raised by community members, e.g., various new weed species were found, errors in identification detected, and other information was suggested for inclusion, such as rabbit infestations, and locations of large piles of garbage and truck tires inside the forest. These issues were discussed and some included in the database, for attention of local groups and management agencies.

Figure 6-2 Example of a hand-drawn map of weed distribution around Barry's Reef area of the WSF prepared by community members (reduced version). Such maps were digitized and the data stored in a GIS database

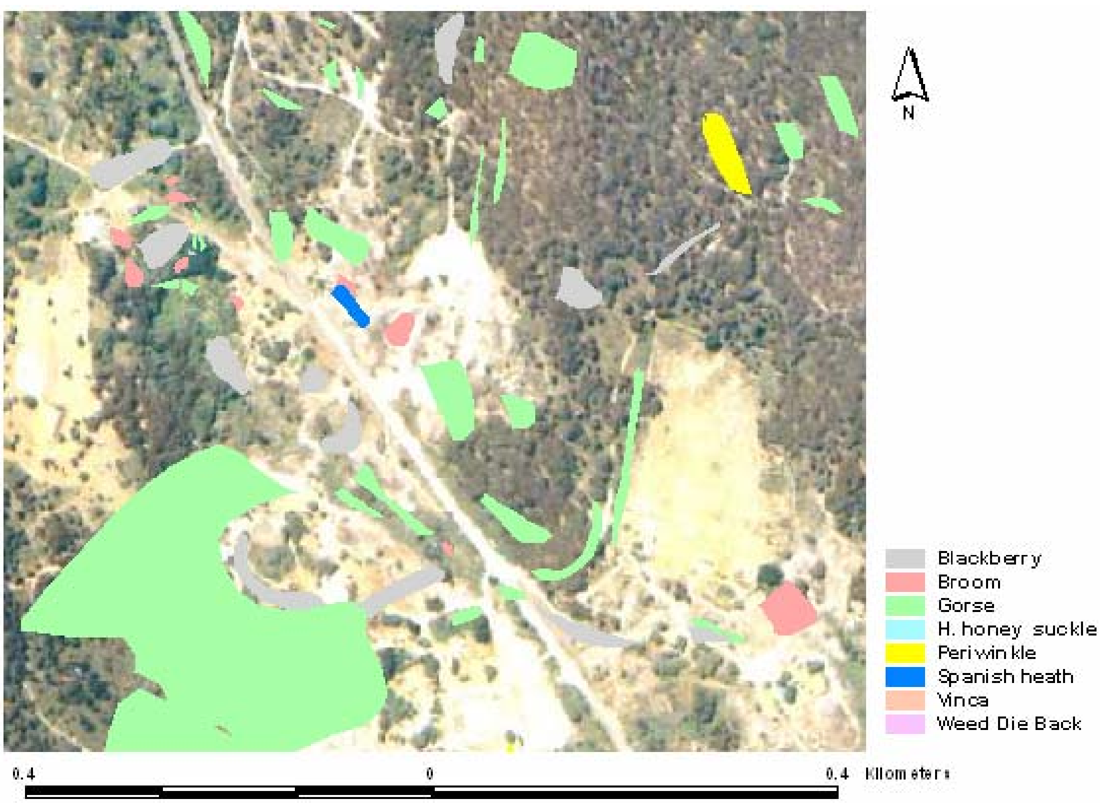


Figure 6-3 Digital version of map in Fig. 6-2 overlaid on aerial photograph

Accuracy, limitations and feedback: Because the digital database and hard copy paper weed maps produced were mainly based on maps hand-drawn by community members, there may have been some inconsistencies between parts of the maps. However, using the knowledge of local people enabled weed infestations to be much more efficiently located and mapped than would have been possible without major resource inputs. A GPS unit was used to check difficult locations where participants requested such assistance (see Box 6-2). Where a GPS was used, this was a low cost, handheld GPS receiver, which is not as accurate as a 'mapping grade' GPS, but the accuracy of 10 - 20 m (see Box 2-2) was adequate for the purpose.

The community mapping process involved the researcher in considerable time in scheduling and meeting participants, collecting information and obtaining feedback on digital maps. Establishing a standardised procedure and mapping symbols and on weed identification was very important. Such a process was not possible without strong interest from local community members. The Blackwood community has requested a continuation of the mapping process, as the initial maps were considered very valuable and the process has improved community interest in solving their problems (P. Liffman [Blackwood/Barrys Reef Land Care] pers. comm. July 2004).

6.4 GIS Application III: Mapping of Soaks (wetland) around Newbury

Location: Newbury Region of the Wombat State Forest.

Origin and purpose: Members of the Water and Hydrology working group of the Wombat CBFM initiative (see Figure 5-1) expressed interest in developing maps showing 'significant soaks' at the head of the Coliban River watershed. This river is the main water supply for a major regional city (Bendigo) and irrigation areas. The intended purposes for the mapping were stated as:

- Improved community awareness and understanding regarding sensitive vegetation and sources of good quality water in the WSF
- As a basis for preparing future management plans for management of sensitive natural vegetation and soaks
- To prevent further damage and desiccation of watershed soaks and hence protect water quality for a large population.

Form of final product: Digital and hard copy maps showing 'significant soaks' around Newbury at the head of the Coliban River (see Figure 6-4).

Commenced: February 2004 **Completed:** March 2004 (part completed)

Distribution: The final product was distributed to the Water and Hydrology Working group of Wombat CFM, which will continue this work on the Coliban and other river systems.

Data, software, hardware and equipment:

Data:

- GIS data layers, i.e., roads, watercourses, contours and property parcel
- 1:20 000 colour aerial photographs.

Software:

- ArcView GIS 3.2 software, DNR Garmin Extension for ArcView
- GPSUtility for downloading GPS data to a PC.

Hardware:

- Pentium IV Desktop computer, Printer.

Field equipment:

Garmin Hand held GPS, Cannon Power-shot digital camera.

Method: The method for collecting field information on ‘significant soaks’ was developed with an energetic member of the Water and Hydrology Working Group who knew the location and significance of soaks around Newbury. This community member guided the researcher to significant soaks and the position was recorded with a handheld GPS. The soaks were also recorded on photographs taken with a Digital Camera (see Plate 3-5 in Appendix 9-1). The steps in this process are summarised in Box 6-3.

Box 6-3 List of steps on community-based ‘significant soak’* mapping

Step 1: Meeting to determine process for data collection.

Step 2: Visit soak sites around Newbury known to a community member (by vehicle and then walking).

Step 3: Capture location by hand held Garmin GPS and record site condition using digital camera.

Step 4: Download GPS data to PC using PC interface cable and free GPS software and convert to ArcView Shape file.

Step 5: Import the shape file of ‘significant soaks’ to ArcView GIS and overlay with topographical maps.

Step 6: Print draft maps of ‘significant soaks’ to the communities for feedback.

Step 7: Finalize soak mapping and overlay with aerial photography.

* A ‘significant soak’ was loosely defined in this study as an area of semi-permanent wetland with high biological diversity.

The communities found this trial process useful and they were interested to continue this project (see WNL 2004b).

Accuracy, limitations and feedback: The recreation grade, low cost, handheld GPS receiver used is not as accurate as a ‘mapping grade’ GPS but within 20-50 m accuracy in open country. Only a few soaks were mapped in this trial process. After overlaying aerial photography, some of these soaks mapped were found to be a considerable distance from the source of drainage line/river. Future work is needed to explore the extent of soaks higher on each drainage line and community members are keen to continue that work (Faulks 2004).

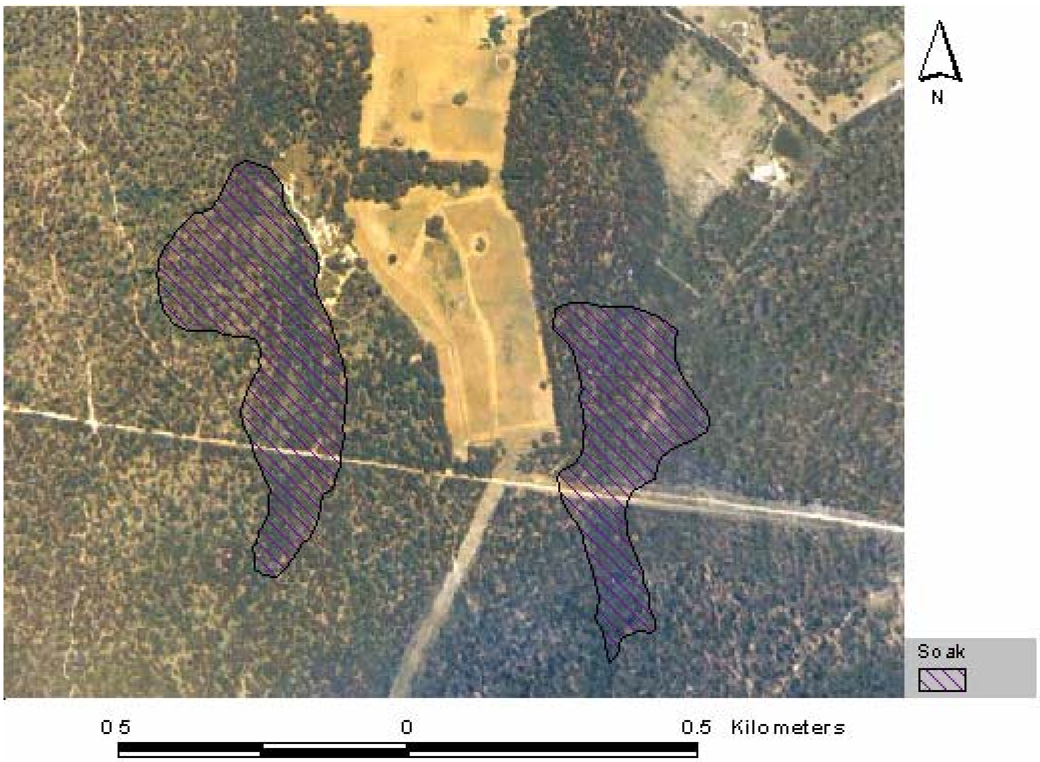


Figure 6-4 Map showing significant soaks around Newbury area of the WSF overlaid on aerial photograph

6.5 GIS Application IV: Mapping Historical Sites

This section is divided into two sub-sections: (i) historical tramways, and (ii) historical goldmines, water races and watercourses. The first section involved on-screen digitising (known as *heads-up*) digitising of old paper maps at the FRI section of the DSE, Melbourne. The second involved standard (or *tablet*) digitising of historical paper maps at Creswick Campus, Melbourne University.

6.5.1 Historical tramways

Location: Daylesford and its surrounds

Origin and purpose: The Wombat Forest Society, Great Dividing Trail Association and other community members around the WSF were interested in having access to maps showing historic sites (see Box 5-1). Historic tramways used in timber haulage in the 1860s-1880s are considered one important historic features of the WSF, and the intended purposes for mapping were stated as:

- To prepare future management plans of historic sites of WSF
- To include on the maps of walking trails that would promote ecotourism
- To include on Forest Explorer and other maps that can be used by tourism organisations.

Form of final product: Digital and hard copy paper maps of historical tramways.

Commenced: September 2003 **Completed**: September 2003

Distribution: The final product was distributed to the dataset custodian, DSE Biodiversity and Natural Resources (BNR) and a variety of stakeholders around WSF. This product was also included in the Forest Explorer CD of the WSF.

Data, software, hardware and equipment:

Data:

- GIS data layers, i.e., roads, watercourses, contours and property parcel
- 1:20 000 colour aerial photographs.

Software:

- ArcView GIS 3.2 software, GPSUtility for downloading GPS data to a PC.

Hardware:

- Pentium IV Desktop computer, Printer.

Field equipment:

- Garmin Hand held GPS, Cannon Power-shot digital camera.

Method: Old paper maps were converted to digital form primarily by 'heads-up digitising' because this was much easier and faster than 'head-down digitising' (see Appendix 6-1 and 6-2). A person from the BNR section of the DSE, knowledgeable about the exact locations of historic tramways, guided the researcher during the digitising process. Digitising was carried out at the GIS laboratory in the Melbourne office of the DSE and the process is summarised in Box 6-4.

Box 6-4 Steps in creating a digital database of historical tramways of the WSF

Step 1: Collect old paper maps showing historical tramways from DSE, Biodiversity and Natural Resources.

Step 2: Digitise using 'heads-up digitising' process in ArcView GIS 3.2 (see Appendix 6-2).

Step3: Erase overlaps using corporate database.

Step4: Attribute the new spatial features, e.g., name location.

Step 5: Finalize and provide to FRI section of the DSE to include in the Forest Explorer CD of the WSF which is ultimately available to all community groups.

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Accuracy and limitations: As the positions of historic tramways were taken from copies of old paper maps, the accuracy is unknown and will need to be checked in the field. This dataset may not include all historic tramways in the Wombat State Forest, but forms a good base on which further mapping can be done. The historical associations in the Daylesford area are collecting further information on old tramways, which could be combined with these maps.

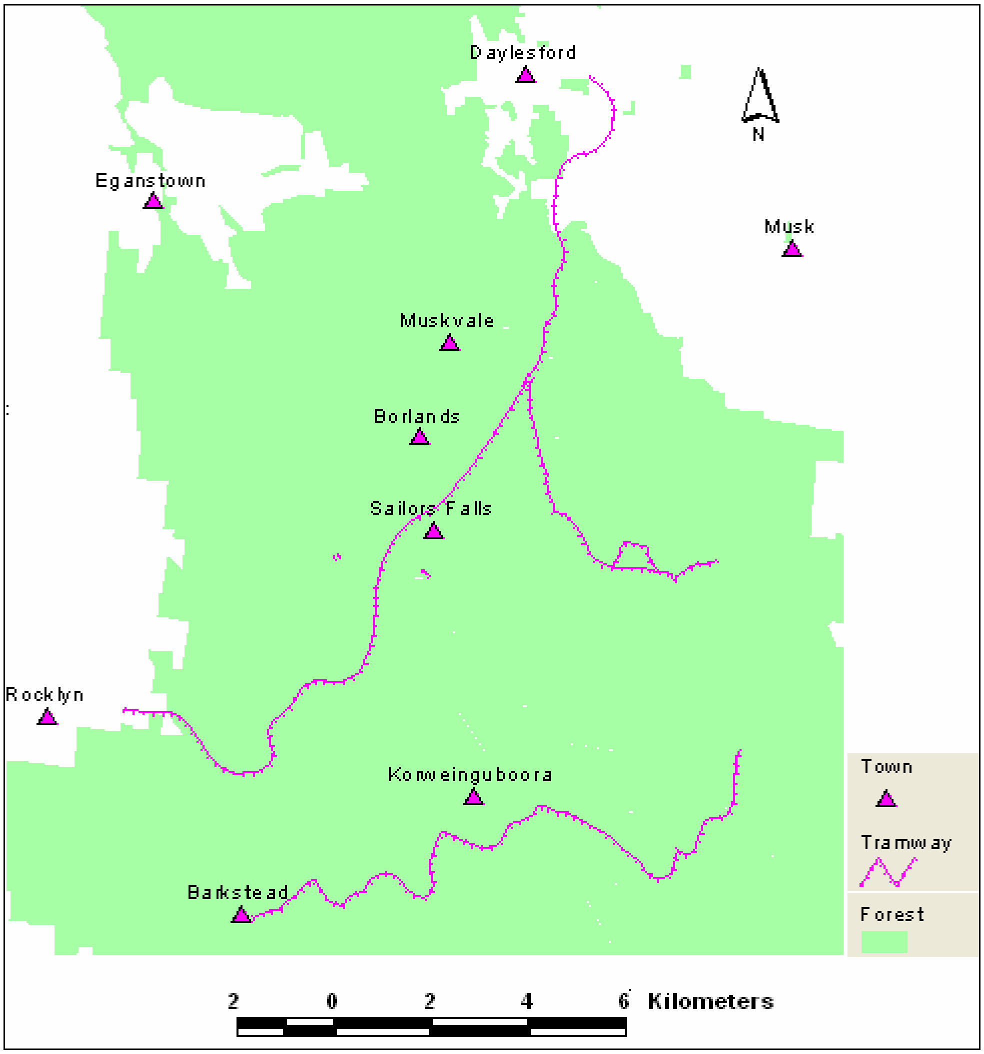

Figure 6-5 Map showing some historic tramways in Daylesford-Barkstead area of the Wombat State Forest

6.5.2 Historical goldmines, water races and water courses

Location: Blackwood, Simmons Reef and surrounds.

Origin and purpose: Community members around Simmons Reef and Friends of River Lerderderg were interested in having access to a map showing historic goldmines, water races and water courses. The intended purposes for mapping were stated as:

- Planning of a heritage trail around historic places
- To promote eco-tourism in the WSF.

Form of final product: Digital and hard copy paper maps of historical goldmines, water races and water courses around Blackwood and Simmons Reef area of WSF.

Commenced: February 2004 **Completed**: March 2004

Distribution: The final product was distributed to the community groups of Simmons Reef, Friends of River Lerderderg and Weed and Pest Animals Working Group of the WSF.

Data, software and hardware:

Data:

- GIS data layers i.e., roads, watercourses, contours and property parcel
- Historic paper maps available from community members.

Software

- ArcView GIS 3.2.

Hardware

- Pentium IV Desktop Computer, Printer, Digitiser, and Plotter.

Method: Old paper maps showing 35 goldmines and associated water races around Blackwood and Simmons Reef were digitised using a digitising tablet and ArcView GIS 3.2 (see Appendix 6-1). The digitised maps were overlayed with other topographic maps and printed A3 size paper (scale 1: 20000) and sent to members of the interested groups for feed-back, and the maps were then edited and finalised based on comment and suggestions. The overall process was similar to that for mapping of historical tramways but standard (or *tablet*) digitising was used here because of the higher level of detail. Box

6-5 shows the process of converting old paper maps with historical information to digital database.

Box 6-5 Steps in creating digital database of historical goldmines, water races and watercourses around Blackwood Simmons Reef area of the WSF

Step 1: Collect old paper map showing historical goldmines, water races and water courses, from community member.

Step 2: Digitise using topographical maps of the area as a base map using ArcView GIS (see Appendix 6-1).

Step 3: Attribute the added spatial features, e.g., mine and water races name.

Step 4: Print different sized maps and seek feed-back from community members on suitability and accuracy.

Step 5: Finalize the historic maps and overlay with other topographic maps.

Accuracy, limitations and feedback: The original source map of water-races was old (and of unknown origin) yet appears to show greater detail and accuracy of smaller streams than more recent topographic maps This dataset may not include all historic goldmines and water races in the WSF. The community members who requested this work are very pleased to have the digital map for their purpose in planning heritage trail and ecotourism (J. Davies [Simons Reef] pers. comm. June 2004).

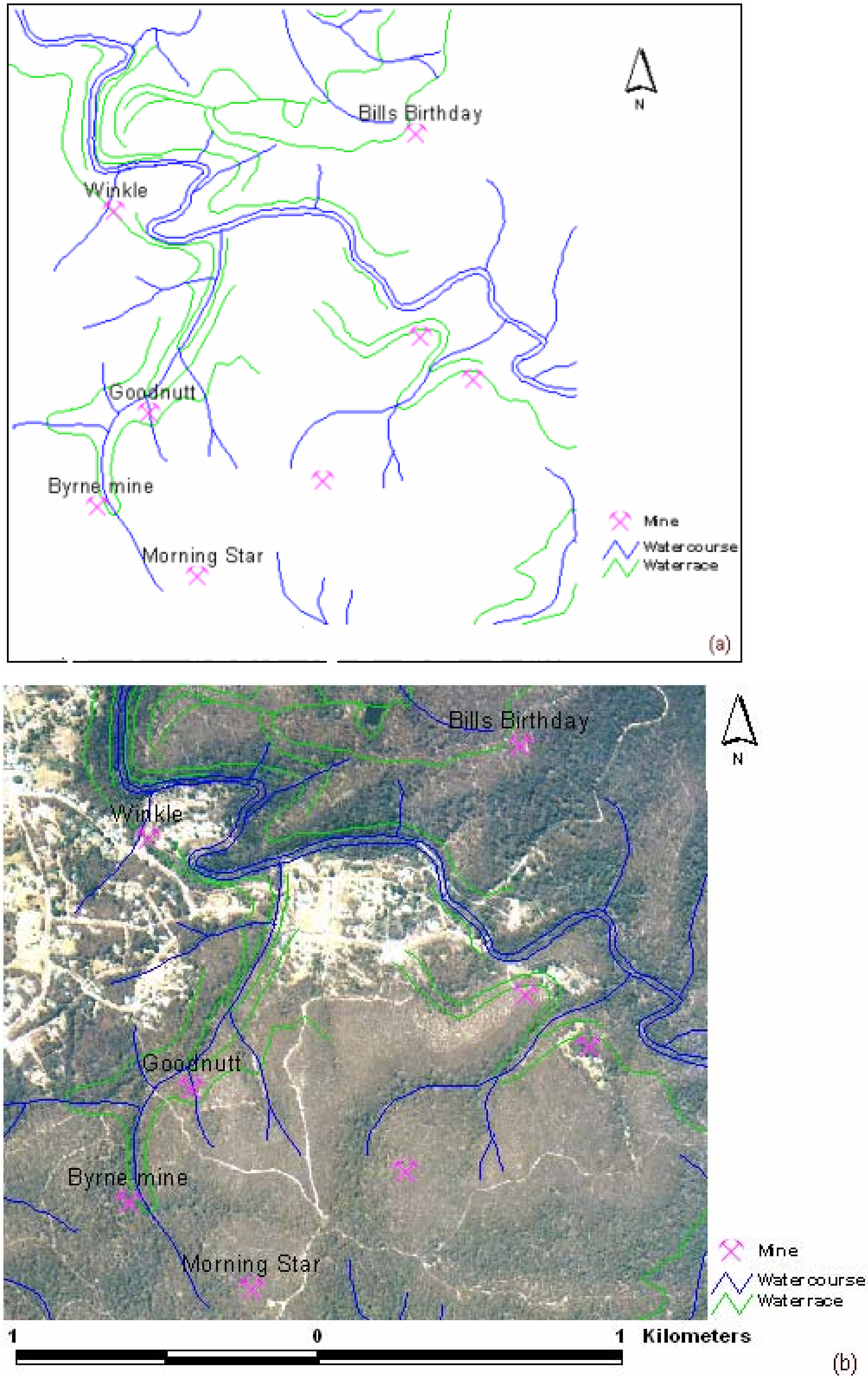

Figure 6-6 (a) Map showing historic goldmines, water races and watercourses around Blackwood and Simmons Reef in WSF, and (b) overlaid on aerial photograph

6.6 GIS Application V: Forest Health Monitoring

Location: Bullarto area of the Wombat State Forest

Origin and purpose: Some parts of the WSF are seriously infected by *Armillaria luteobubalina* (root rot disease), which occurs naturally in many forests of Victoria (DPI, 2004). There is controversy concerning the handling of materials from infected sites, and little is known about the pattern of spread in the WSF. The DSE was planning to remove the trees affected by *Armillaria* to stop further spread. The dead, dying and diseased trees would be utilised for saw logs by local mills. However, some community members opposed such a plan as they believe the dead trees are important for bio-diversity value, e.g., habitat for wombats and for insect, reptiles and some bird species.

Other community members are in favour of the DSE's plan to utilize the infected material to stop further spread of *Armillaria*. Since good decision making on pest and disease management depends on the availability of sound information on diseases, distribution patterns and density, members of the Wombat CFM Stewardship Council expressed interest in locating sites affected with *Armillaria* root rot, to use as long-term trial plots. The monitoring data would provide valuable data in future decision-making on this topic. The intended purposes for the mapping were stated as:

- Monitoring the area affected by *Armillaria* root rot disease on a long-term basis
- Use aerial photography to record and study the distribution
- Integrate the data on area infected with *Armillaria* with other environmental data, so as to model the spread and likelihood of infections.

Form of final product: Digital data and hard copy maps showing areas affected by *Armillaria* root rot disease near Bullarto, and spread under different conditions and treatment.

Commenced: October 2003 **Completed:** October 2003 (continuing)

Distribution: The final product was distributed to interested CFM stewardship council members in the WSF.

Data, software, hardware and equipment:

Data:

- GIS data layers, i.e., roads, watercourses, contours and property parcel
- 1: 20,000 scale colour aerial photographs.

Software:

- ArcView GIS 3.2 software, GPS Utility software to download GPS data to a PC.

Hardware:

- Pentium IV Desktop computer, Printer.

Field equipments:

- Garmin hand-held GPS with PC interface cable
- Portable Toshiba notebook computer
- Cannon Power-shot digital camera.

Method: Information was collected on vegetation disease infection in the field, using a Garmin hand-held GPS unit, a digital camera. A community member who has good local knowledge of the areas infected by *Armillaria* rood rot disease, guided the researcher in field. The major steps in this process are summarised in Box 6-6.

Box 6-6 Steps in locating areas infected by *Armillaria* root rot disease (proposed trial plots)

Step 1: Meeting to determine process for data collection.

Step 2: Visit *Armillaria* affected sites around Bullarto with knowledgeable community member (by vehicle and then walking).

Step 3: Capture location by hand-held GPS and record site condition using digital camera, and number of trees affected at each location.

Step 4: Download GPS data to PC using interface cable and free GPS software, and convert to ArcView Shape file.

Step 5: Import the shape files on *Armillaria* affected sites to ArcView GIS and overlay with topographical maps and aerial photographs.

Step 6: Print *Armillaria* affected site maps and send to the stewardship council members for feedback.

Step 7: Finalize the location map of proposed trial plot areas affected by *Armillaria* and overlay with aerial photography – for future development and us in long-term monitoring.

Accuracy and limitations: The recreation grade, low cost hand-held GPS receiver used is only accurate to within 20-50 metres in this forest, so the maps are only useful to identify the approximate location of proposed trial plots and cannot be used to identify individual infected trees. In the initial stage, only two trial plots with approximately 50 dead, dying or diseased trees were identified and further work is needed to find more sites affected by *Armillaria*. The map is being used by the Wombat CFM Stewardship Council members in forest harvest planning.

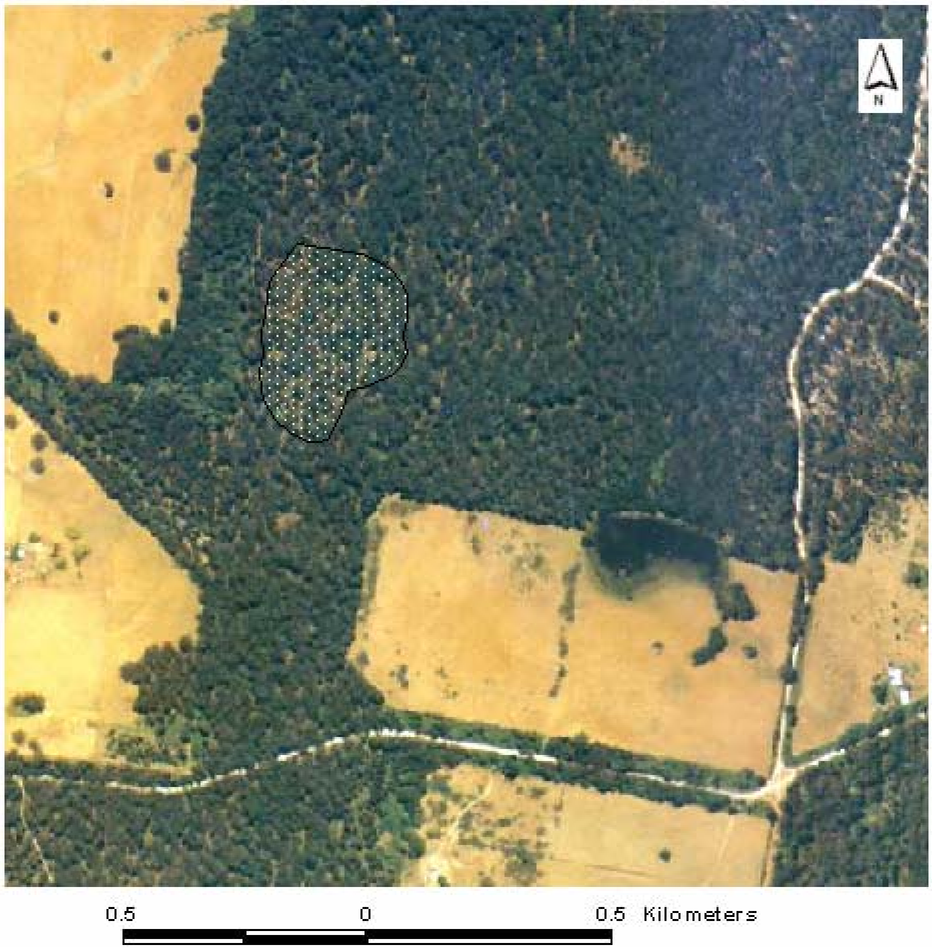

Figure 6-7 Map showing area affected by *Armillaria* root rot disease (green dotted area) near Bullarto south in the WSF, overlaid on aerial photograph

6.7 GIS Application VI: Slope (and Aspect) Map of the Wombat State Forest

Location: Wombat State Forest Midlands, Victoria.

Origin and purpose: Community members associated with CFM in the WSF expressed interest in having a slope (and aspect) map of the Wombat State Forest and its surrounds, for various purposes:

- Planning for developing walking trails throughout the forest
- Road routing for timber extraction
- Soil and water conservation planning, identifying potential soil erosion hazards.

Form of final product: Digital and hard copy map showing the slope (and aspect) for the entire Wombat State Forest.

Commenced: September 2003 **Completed:** September 2003

Distribution: The final product was distributed to interested Wombat CFM members and the final aspect map was included in the Forest Explorer CD of the WSF.

Data, software and hardware

Data:

- GIS data layers, e.g., topographic maps mainly 10m interval contours maps.

Software:

- ArcView 3.2 GIS software with 3D Analyst and Spatial Analyst.

Hardware:

- Pentium IV desktop computer, Printer.

Method: GIS data layers on topographic maps were available from the Education Resource Centre library of The University of Melbourne. Initially a Triangulated Irregular Network (TIN) was derived from 10m interval contour maps (see elevation map Figure 6-8) and then slope and aspect maps were derived from the TIN. The major steps in deriving TIN, slope and aspect maps are summarised in Box 6-7.

Box 6-7 List of steps on preparing slope and aspect maps of the WSF

Step 1: Collection of topographic data from ERC library, The University of Melbourne.

Step 2: Start ArcView GIS and open the project and a new view.

Step 3: Set the working directory and add contour themes to the view.

Step 4: From file menu select the extensions 3D Analyst and Spatial Analyst.

Step 5: From surface menu build TIN using contour theme in active feature theme.

Step 6: Derive slope from surface menu and classify in slope classes from analysis menu.

Step 7: Derive aspect from surface menu.

Step 8: Choose the geo-processing then clip slope and aspect theme based on the WSF map.

Step 9: Save and export final slope and aspect files to JPEG format.

Accuracy, limitations and feedback: The accuracy of the slope and aspect maps derived from 10m contours interval was not be determined in the field. Information regarding spatial accuracy for source data, i.e., Vicmap elevation, is available from Land Information Group, Land Victoria of the DSE, Melbourne. It is envisaged that the slope and aspect maps produced will be useful to community groups in forestry and resource conservation purposes (in the absence of other mapping of this type). Favourable comment was received by Tim Anderson (see Appendix 8-3) and other members of WSF Stewardship Council who have used this data.

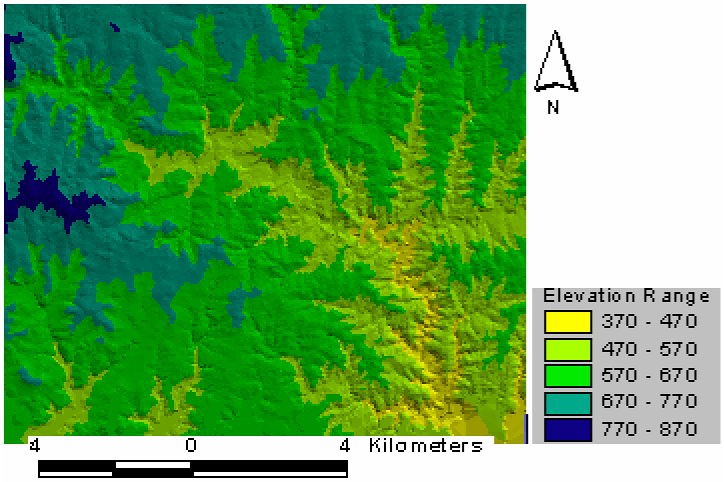

Figure 6-8 Elevation map of land around Blackwood in the WSF (figures are in meters above seal level)

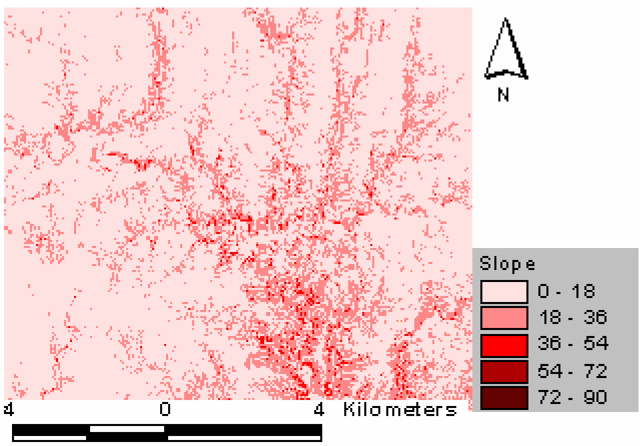

Figure 6-9 Slope map of land around Blackwood in the WSF: derived from Fig. 6-8

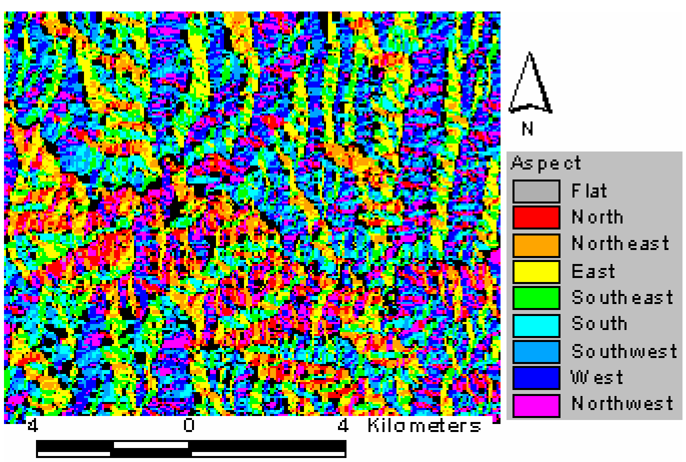

Figure 6-10 Aspect map of land around Blackwood in the WSF: derived from Fig. 6-8

6.8 Lessons from the Practical Applications of GIS

The demand for GIS and the practical applications developed for and with various groups in the WSF demonstrated the feasibility and potential for using GIS and related technologies in community forestry. Some lessons drawn from the examples of GIS with WSF communities outlined in Sections 6.2 to 6.7 are discussed below, and then Section 6.7 provides a summary of strengths and weaknesses of using GIS with communities, drawn from the international literature and field experience.

Firstly, this research project showed that GIS and related technologies have high demand among community groups and potential to address a range of needs in mapping and understanding natural resources, e.g., weed mapping, historical sites mapping, rainfall modelling.

Secondly, these technologies provide a range of opportunities for analysis and extraction of biophysical and socio-cultural information about the forest and its surrounds, which can help community organisations and forestry agencies in resource planning and decision support. The integration of biophysical and socio-eco-cultural information is important in the case of the WSF, where only biophysical layers have been used in the past.

The third lesson concerns the potential use of GIS in capturing local knowledge and integrating this with modern information and technology. The community weed mapping process described in Section 6.3 provides such an example, and has led on to requests from community groups for further work with community-GIS.

Fourth, the concept of community empowerment is an important aspect learned from the practical applications discussed in Section 6.3. GIS 'empowered' local people by providing them with greater access to data about their own areas, and in a form that they are able to use in seeking support and funding for priority resource management projects.

Fifth, an important potential use of GIS is in conflict situations – to provide spatial information to all stakeholders on resources in a clear, visual manner. For example, the weed maps produced (Section 6.3) will be very important in developing an integrated weed management plan – which should serve to reduce the conflict between the community and government agencies.

6.9 Some Outcomes from Practical GIS Applications

The GIS products of this project were mainly paper maps arising from practical applications developed with community groups. These, and some digital databases developed were included in the Forest Explorer CD of the Wombat State Forest which is accessible to the wider community. Some outcomes of these practical applications are:

- Rainfall maps of the Wombat State Forest and its surrounds were produced for use with other environmental variables in resource planning and by the CBFM initiative.
- Weed maps of Blackwood/Barrys Reef areas were developed with Weed and Pest Animals Working Group and are already being used by community groups and agencies in preparing an integrated weed management plan.
- A process for combining participatory 'action research' and GIS for community weed mapping, developed with Blackwood/Barrys Reef communities can be adapted by other groups in the WSF to suit their requirements.
- A digital database of 'significant soaks' developed with Water and Hydrology Working Group was a useful trial of a process initiated to improve community awareness and prepare management plan for natural water sources.
- Maps produced of historic sites will be used for future management of historic places, and planning of heritage trails around historic places, as part of an ecotourism project.

6.10 Major Strengths and Limitations of Community-GIS

There is general agreement in the international literature that the use of GIS by community organizations can enhance people's participation (and empowerment) in resource management and help to integrate environmental and socio-economic information. However, some authors contend that GIS has the possibility of marginalizing less technologically skilled communities. These and other views are summarised in Table 6-1.

Table 6-1 Major strengths and limitations of community-based GIS

Strengths	Limitations
Can be used to effectively integrate previously isolated qualitative and quantitative information (Abbot *et al.* 1998; Jordan and Shrestha 1999) Can empower local communities by involving them in decision making (Carver 2001; Jordan and Shrestha 1999; Taylor 1990) Can allow incorporation of local knowledge and greater accountability in decisions made(Carver 2001) Information can be easily collated, analyzed and returned to stakeholders(Jordan and Shrestha 1999) Potential to build up skills and expertise with the community (Leitner *et al.* 2002)and a potential aid to conflict resolution(Abbot *et al.* 1998) Is useful practical and cost effective (Orr *et al.* 2003) and provides opportunity of interdisciplinary work (Abbot *et al.* 1998) Allows bottom-up planning, and hence improves democracy (SEI-Y 2003) Gives quick and easy access to official up-to-date information to community groups (Carver 2001; Leitner *et al.* 2002; SEI-Y 2003) Increased transparency of local government decisions (SEI-Y 2003) Allows for multiple viewpoints on a single issue to be identified (SEI-Y 2003) Uses a matured and universally accepted technology for handling and analysing spatial data (Carver 2001)	Difficulties in integrating qualitative and quantitative data due to scale (Abbot *et al.* 1998) There is possibility of excluding less technologically skilled communities (SEI-Y 2003) and to dis-empower disadvantaged groups by not involving (Carver 2001; Jordan and Shrestha 1999; Clark 1998) There is potential to collect 'extractive' data (Jordan and Shrestha 1999) Requires high-technological investment, with high cost and sustainability issue (Abbot *et al.* 1998; Jordan and Shrestha 1999; Leitner *et al.* 2002) Privacy and confidentiality issues can lead to conflicts between diverse communities (Leitner *et al.* 2002) Skill and training required for community groups to handle spatial data (Abbot *et al.* 1998; Jordan and Shrestha 1999) Possibility of data misuse (Jordan and Shrestha 1999) GIS data types do not effectively represent the local knowledge or local perceptions of important issue (SEI-Y 2003)

In the author's assessment of the literature, the strengths of using community-GIS outweigh the limitations mentioned. Most of the limitations can be overcome by proper planning and paying special attention before implementing GIS projects. However, even in relatively affluent societies (such as that around the WSF) it is obvious that there are equity issues that need to be considered and addressed. Although many individuals may be capable of viewing maps on a GIS facility, very few people or groups have adequate computer equipment and skills for effective use of GIS in resource management – so the provision of facilities and training for the use computers and GIS tools in community centres is essential if the potential of GIS is to be utilised. This topic is discussed further in Section 7.2.

In the field work for this study, the main costs and limitations were in relation to the time taken to interact and gain the trust of community members and agencies. The identification of members who have the willingness and ability to spend time on collaborating on development of GIS was a key factor in success of GIS applications. Where such members were identified GIS projects developed rapidly; in other topic areas little progress could be made because no suitable local individual or group could be located in the short time available.

In this short project, the researcher undertook all the technical work on GIS as none of the collaborating groups had access to GIS software. The potential for community members to take on the more technical aspects of mapping and other projects was not implemented. This and the above mentioned need to identify key collaborators, points to the need in community-based GIS for a full time local GIS facilitator, who is known to the community and can foster the necessary linkages and develop local capacity.

7 CONCLUSIONS

7.1 Introduction

This thesis has explored various issues associated with the use of GIS and related technologies in forestry and community forestry, in the international literature and more particularly in the Wombat State Forest in Victoria. This chapter summarizes key findings in relation to the research objectives (see Section 1.5) and suggests future directions for the use of GIS in community-based forest management.

Although the fieldwork for this study was conducted in an industrialized country and in a relatively affluent community setting, i.e., the Wombat State Forest in Victoria, Australia, some of the findings have implications for other parts of the world, including lower-income regions with resource-poor communities.

This research demonstrates the potential for use of GIS in community-based forestry in Victoria. Section 7.2 summarizes key findings and some limitations of this research are outlined in Section 7.3. The main outcomes of this study are summarized in Section 7.4 and conclusions are made in section 7.5.

7.2 Key Findings

The approach in this study was to work with agencies and groups involved in community forestry in Australia with a view to understanding the potential and main issues in developing and using GIS in community forest management. The key findings are discussed under the headings below, related to the five research objectives. However, in action research, many of the results are in the development of capacity of participants (including researchers) in the development of new ideas and directions for the groups involved in improving their situation. The findings are discussed under the following Sections, which relate to the objectives of the research.

7.2.1 Objective 1

Review applications of GIS in forestry and community-based forestry worldwide

Two main categories of literature were found to be valuable: (i) GIS in 'conventional' government-based forest management, and (ii) GIS in forest management with active involvement of local communities. The reviews showed an increasing trend towards use of GIS and related technologies in most sectors of forest management.

Two large volumes of 'GIS applications of in natural resources' edited by Heit *et al.* (1991; 1996) include a wide variety of GIS applications in forestry and natural resource management. A recently published book on 'Community participation and geographic information systems' edited by Craig *et al.* (2002) summarises the work of around 50 authors in the field of community-based GIS. In addition to these two major sources, more than 150 published examples of applying GIS in forestry and community-based forestry and resource management were studied. Some key findings from this literature can be summarized under the following points:

- The use of GIS in the forestry and natural resource management sector has become commonplace during the past 10 years. Collection and efficient handling of spatial information is crucial in any form of forestry and natural resource management, whether industrial or 'participatory' in approach.
- The most common applications of GIS encountered in forest management were in forest resource inventory, forest fire and emergencies, and wildlife habitat modelling.
- Use of GIS in CBFM involves a more diverse range of spatial information than GIS for government-based forest management.
- Most reported applications in forestry combine GIS with other related technologies, i.e., GPS and remote sensing. Such integration can allow more updated and reliable information than using GIS alone. For example, remote sensing offers rapid updating, change detection and unique vegetation indices to GIS.

- A wide range of GIS software is available for forestry and natural resource management organizations, including a range of freeware available on the internet - suited for use by resource-poor community organizations with basic computer facilities.

The nature of forest resource management is changing continuously. The traditional inventories of timber volume and measuring growth are being combined with data on socio-economic and ecological aspects of forests. Several authors claim that the development of GIS and related technologies has influenced the world of forest resource management.

7.2.2 Objective 2

Stakeholders' views on their requirements for the use of GIS in CBFM in the Wombat State Forest

Stakeholders' requirements for the use of GIS in the WSF were diverse and broader than in 'conventional' government-based forest management (see Section 5.2). Prior to the introduction of community forestry in the WSF, mainly 'bio-physical' and 'quantitative' information were maintained by the DSE and used in 'internal' GIS. After the declaration of community management status for the WSF by the Government in 2003, a variety of stakeholders sought to have access to various types of data for use in the WSF and its surrounds (Section 5.2). A list of 84 different data layers were listed (see Table 5-1) as desirable by community groups involved in CBFM in 2003.

In response to community interest, two approaches were initiated to make GIS available to WSF stakeholders. The FRI Section of the DSE took on a task of developing a 'GIS tool' to support Wombat CFM, just after commencement of community forest management. A second, smaller community-GIS was created by this university-community project in response to requests for specific types of data, mainly from issue based working groups of the WSF. Some key findings from these community-based GIS database creation processes in the WSF were:

- Local communities willingly participate to generate databases that they need if GIS technical support is available. For example, in the WSF, community groups and individuals participated actively in weed mapping around Blackwood and Barrys Reef, and in the mapping of soaks around Newbury.
- As local people knew their area better than outsiders, active community interest and participation of community members was invaluable in creating certain GIS databases for the WSF. The challenge was to establish close coordination between agencies and to develop appropriate processes to capture peoples knowledge and integrate this with into GIS.
- Community groups around the WSF expressed interest in having access to a wider variety of data than that directly related to the specific objectives of their group (see Box 5-1 and Table 5-1). This finding is similar to that of Jordan and Shrestha (1999) working in Nepal.
- The collection of spatial information from diverse sources is often a laborious, time-consuming and costly process. However, active support from local communities can reduce the cost in time and money and also increase the reliability, validity and ownership of the data for local level participatory planning.

GIS and related technologies can be provided to local groups by outside agencies, to help address stakeholders' needs for specific spatial information, or communities can generate local databases themselves and convert these to digital format for analysis in a GIS with technical support of external organizations.

7.2.3 Objective 3

Prepare and demonstrate various practical applications of GIS requested by community groups in the WSF

Various practical applications requested by community groups around the WSF were developed in this project (Sections 6.2- 6.7) and some of those were incorporated into the Forest Explorer CD of the WSF produced by DSE (see Section 5.5). Other GIS databases and maps were made available directly to community stakeholder groups. Some key findings from working with community groups in developing GIS applications were:

- Local knowledge concerning natural resource related issues can be captured in various ways, and such data integrated within a GIS for resource planning and management. For example, information regarding weed infestation around Blackwood was recorded on paper maps by local people and later this information was digitized and integrated into GIS (see Section 6.3).
- Local individuals and community groups voluntarily devoted much time to developing a community-GIS database, where this served their needs.
- Old paper maps were valuable sources of otherwise unavailable information for community management, and were digitized for use in GIS and hence integration with other information. For example, historical maps on goldmines and water races were converted to digital format and for use by communities in construction of heritage trails in the WSF.
- GPS units were an important tool for creating new GIS databases. For example, a low cost, handheld GPS unit was used to locate and map weed infestations, signification soaks and areas affected by *Armillaria* root rot disease in the WSF Such information was integrated with GIS for community-based resource planning (see Section 6.3, 6.4 and 6.6).
- Detailed, large scale maps were considered more useful for community groups than (more readily available) small scale state maps. For example, the community wanted a large scale rainfall isohyets map of the WSF showing major towns and natural resource features. State-wide rainfall maps of Victoria and Australia can be purchased from BOM, but these were too general and not useable for local level resource planning (see Section 6.2), according to community members.

The community groups were mainly interested in developing relatively simple and practical applications for GIS at this early stage of community forest management in the WSF. The simple maps and other applications and the community-based GIS that was developed with DSE should allow community groups and related agencies to develop management plans from a position of shared understanding. Training for community members in GIS has growing enhanced local interest and for developing future GIS applications for their needs.

7.2.4 Objective 4

Identify strengths and limitations of GIS applications in community forestry

This study identified a number of strengths and limitations of GIS for use in community-based forest management in the WSF. A major strength was the capacity for GIS to promote active participation by community members and groups in management-related activities. It seems unlikely that such active participation of community groups would have been achieved without the aid of GIS and the GIS support provided.

A second strength of GIS was in the way it allowed the integration of local knowledge with forest science and information technology – in dealing with local resource management issues. For example, local knowledge regarding 'significant soaks' and their vegetation at the head of the Coliban River was incorporated in a GIS database which is now available for use by the Water and Hydrology Working Group of the Wombat CFM in preparation of their water management plans for the forest.

A major advantage of having developed a GIS for the WSF was the improved (potential) availability of data on a wide range of topics to all members of the community. At this stage a limited number of groups and individuals are using the GIS databases, but this number is increasing rapidly as people and groups become more familiar with GIS and realize its potential for their particular purposes (T. Anderson [DSE, Daylesford] pers. comm. June 2004). Recent training sessions on GIS use, run by DSE for community members at locations the WSF, have helped to improve awareness of the benefits of GIS. The 'transparency' arising for having information freely available seems to reduce conflict over forest management and to encourage community participation.

The development of a community-based GIS has been valuable in establishing links between DSE and various Working Groups in the WSF and other agencies (for instance

The University of Melbourne). An important link was also established between the university project and the FRI section of DSE – which provided an opportunity for joint work in developing a GIS database. The Bureau of Meteorology provided rainfall information free of cost, and the DSE at Daylesford shared field information, and information regarding interest groups around the WSF.

Lack of pre-existing knowledge and skills in using GIS (or even computers) among the participating communities, lack of computers and GIS software, and lack of time (or time management) were the major constraints in developing of GIS that were identified while working with communities around the WSF. However, these are not limitations of GIS software itself, and there is potential to overcome these constraints in many situations. Limitations of this research project are discussed under section 7.3.

7.2.5 Objective 5

Relate findings on the application of GIS in Australia to community forestry in Nepal.

Current and potential uses of GIS in community forestry in Nepal and factors hindering its use were discussed in Section 4.5. Some findings from this study (from both literature and field studies) that seem to have importance for use in CF in Nepal are discussed below.

Limitations and prospective of GIS use in CF in Nepal

Although this study showed high potential to use GIS and related technologies in community forestry, it is not feasible to develop and implement an in-house GIS for each community forest user groups (CFUGs) in Nepal for various reasons. As the average size of Nepalese community forests is only 30- 40 ha (Subedi 2004), setting up a GIS for such a small forest areas is not economical. Most CFUGs do not have access to computers and lack of skills and knowledge to use computers and GIS software. Absence of government policy for implementation of such technologies and lack of coordination between various agencies is another major constraint to GIS development. Some other constraints are lack of electricity supply, poor spatial data availability and limited access to data for CFUGs.

There is also lack of awareness about GIS and consequent hesitation to adopt such technologies. Even many foresters who are responsible for managing forest resources and providing technical support to communities may not fully understand the benefits and limitations of this rapidly developing technology. Likewise, technical experts in GIS may not understand the needs and constraints of GIS use in forestry and community forestry.

Nevertheless GIS is already being used in less remote forest areas and particularly in donor-supported projects (see Section 4.5 and Appendix 5-1). These sites could be used as training sites for CFUG members and for supporting government staff to observe and learn the use of GIS so that the advantages can be transferred to more remote areas as the necessary service become available. Instead of developing in-house community GIS, other possible models, e.g., map rooms or neighbourhood GIS centres (see Section 5.3) or modification for local situations, could be adopted. A logical process may be for GIS to be developed for several CFUGs under one Range Post or *Ilaka* Forest Office in a cooperative arrangement. Other potential uses and lessons drawn for Nepal from this field study and the literature are:

Availability and use of free software

The wide range of free GIS and GPS software is available on the Internet (see Appendix 2-2 and 2-3) could be used by community forestry organizations that have computers. The cost of personal computers (PCs) is decreasing rapidly, the number of internet service providers is increasing, and the cost of services is dropping. A PC that can be utilized for basic GIS use can be purchased for NRs 50,000.00 (less than AUD 1000.00). Even where no internet facility exists, community organizations can obtain software on CD-ROM and utilize this in villages, if they have electricity and appropriate technical support. Such free software is relatively easy to use and has extensive tutorial materials - so that any computer-literate person can use the programs with a little practice. Forest Rangers could be trained to advise CFUGs on GIS and GPS use as part of their extension role.

Potential for partnerships with research organizations

Community groups can access GIS data and technical support by collaborating with research organizations, e.g., universities and research institutes (see Section 5.4) that need access to field data for students and research. Various community groups around the WSF utilized such opportunities (Section 6.2 to Section 6.7) and this research showed high potential to develop such partnerships in other regions. Nepalese community groups could benefit from GIS by developing partnerships with skilled local NGOs, local universities and research institutions and various international donor supported forestry projects.

Human resource development with in CFUGs

The feedback from training sessions organised by DSE showed that many community members can already use GIS to view and query simple spatial datasets (see Appendix 8-2). This lesson is encouraging in the Nepalese context because there are many computer literate, young people involved in community forestry. If appropriate support and data kits are made available to community groups from government authorities or other supporting organizations, it should be possible to develop capacity within communities for using simple GIS.

Dissemination from pilot study

A finding from the 'action research' approach adopted with WSF community groups was that the interest in participatory mapping and GIS related activities grew as time progressed. This means that in Australia (and probably in the Nepalese context) pilot projects supported by outside organisation at the beginning could lead to greater interest and self-sustaining community GIS projects in the longer term.

Simple to complex

The WSF community showed interest in having mainly simple GIS applications, rather than complex spatial modelling, at this stage. In Nepal to date, GIS has been used mainly in research applications and by outsiders. There would be great scope for using GIS in the preparation of community forest management plans – for mapping and inventories, and with involvement of community members in data collection.

The community forest operational plans have been based mostly on low intensity ground sampling of vegetation and visual assessment of forest resources. Maps are produced from ‘conventional’ chain and compass surveying and cannot be relied on by the communities in preparing management plans, or for estimating resources and predicting future changes. Many authors reported that the use of large scale photographs with participatory resource inventory is very useful tool. Therefore a GIS-based resource inventory developed with community groups could provide reliable information about their forest, which would improve interest and communication and ultimately increase the effectiveness of forest management. Once communities and support agencies develop confident complex modelling could be applied.

The potential for use of GIS in the Nepalese context of community forestry would be dependent on the strong support of government authorities and donor organizations, including rural development agencies that promote expansion of the national electricity grid to rural areas.

7.3 Limitations of the Research

Some limitations of this research and some difficulties faced during this study are listed under 7.3.1 and 7.3.2 below:

7.3.1 GIS-related Limitations

- The research, which initially focused mainly on GIS technology, developed progressively into a participatory research approach, because of the need to interact with members of community and various agencies. This evolving framework meant that the researcher had to adjust his work schedule according to local community needs. This required high expenditure of time on communication compared to independent research on GIS without community participation.
- Computers, internet and GIS facilities were not accessible to all community groups in the WSF, so the researcher conducted nearly all the GIS technical work.
- Access to appropriate GIS software was delayed by administrative and other problems – so some software was not available for the project, e.g., ArcView GIS 3.2 and ArcGIS 8.1. The researcher managed by using an evaluation version of ArcView GIS software and some other free software available on the internet, while waiting for the licensed and full version of ArcView GIS 3.2. The simplicity and practical nature of the GIS applications desired by the community meant these could be managed using the available software.
- A recreation grade GPS unit was used, i.e., Garmin GPS 76, which was available at The University of Melbourne, Creswick Campus. This limited the use of GPS for certain purposes (e.g., identifying individual trees affected by *Armillaria* root rot disease). However, the use of a more expensive GPS unit would be unrealistic for most community-based GIS projects due to cost and sophistication.
- Although it was originally intended to develop some advanced modelling applications of GIS for community-based forestry using Spatial Analyst (e.g., visual impact assessment, recreation and ecotourism planning and wildlife habitat suitability modelling), all applications developed in this study were rather simple

because the community groups were mainly interested in having access to maps and simple databases.

- It was intended to include with this thesis all GIS databases and resulting maps (including detail of the GIS process) on a CD-ROM that could be operated by a freeware program (Appendix 2- 2 and 2-3) so that participating community groups could utilise this information for future use. Copyright regulations have prevented this. The Map Collection Section of the Education Resource Centre has permitted only the inclusion in the thesis of some images derived from the data they provided for this research. Other maps and data produced in this research are however available through the Forest Explorer CD produced by the Forest Inventory Section of the DSE.

7.3.2 Limitation of PAR Practice

Perhaps the most serious limitation of this research was in the inability to conduct a full action research cycle in the work on all applications of GIS with community groups. Because of limited time and remoteness from the groups, it was not possible to ensure that groups undertook proper reflection on the results and process of their activities. While planning and action was usually completed effectively, the reflection stage was sometimes rather weak. Hence, it could be argued that a classical PAR approach not conducted, and that the approach used could be more correctly termed ‘participatory mapping’. However, the principles and literature of action research provided a valuable guide throughout the research process.

Other constraints (e.g., transportation, funding, data availability, and logistics) were overcome with support from academic supervisors and Creswick Campus administration. Having to qualify for a Victorian driving license was one requirement faced by the researcher, for this work among isolated rural communities. Another was the time needed for a foreign student to gain the trust of local rural community groups.

7.4 Main Outcomes of the Research

The researcher and his collaborators (from DSE and community groups) learned particularly to collect, collate, and synthesize some useful GIS data on the WSF in participatory ways. Some outputs of this research have already been used by community partners to prepare community-based plans and monitoring programs (e.g., of weed infestations), in applications for funding for community projects, and for other purposes faced in CBFM in the WSF. Major outcomes of this research were:

- Many potential applications of GIS and related technologies were identified for use in different areas of CBFM from work in the WSF, and other parts of the world.
- Some GIS databases and applications created during this research are included in the Forest Explorer CD of the Wombat State Forest, which is now available to various community groups and interested stakeholders through DSE.
- Freeware (software) available on the Internet was examined and made available to some community groups. Some such freeware is likely to be useful for community-based forestry and resource-poor, non-profit community organizations in Australia and other countries (see Appendix 2-2 and 2-3).
- Some GIS databases and hard-copy paper maps were produced and made available to community groups, and these are now being used towards their objectives in community forest management in the WSF.
- A partnership was established between local communities around the WSF and The University of Melbourne (Creswick Campus) which could be continued in future for mutual benefits, i.e., for postgraduate research and experience, and in support of the new CBFM initiative in the WSF.
- Experience and skills were gained in the use of GIS with community groups in the WSF, which will be useful in developing community-based GIS in Nepal.

The participatory action research conducted with some communities had other important impacts. As a result of this PAR process, other groups and individuals have shown enthusiasm to work towards developing GIS for CBFM in the WSF (Baral and Petheram 2004). The experience and results of this study should offer encouraging scope for future use of GIS for forest-local communities, and there are prospects for the community's requests for continued partnership in GIS to be taken up by the university and other students and staff.

7.5 Conclusions

This project has shown that GIS and related technologies can help foresters and community-based organizations, e.g., forest user communities and issue-based working groups (in the case of the Wombat CFM) to meet the challenges of integrating biophysical, socio-economic and cultural information for community forest management. In working closely with various community groups around the WSF, it was found that GIS can help address the disparate information needs of CBFM and also to promote enthusiasm among community members to be actively involved in data gathering and developing GIS applications. The presentation (on computer) of spatial data seems to attract people, who are encouraged by seeing the output of their work presented in graphical forms. In the planning and decision making processes directed towards sustainable management of forest resources it is essential that a wide range types of information is available to the community management entity.

Walker *et al.* (2002: p.150) observe that GIS has not been generally adopted in rural Australia, that GIS data are too expensive to collect and maintain, and that GIS requires human and financial resources beyond the capacity of many community groups. This may be true of GIS operated by community members or groups. However, the 'action research' approach taken with rural forest communities in this study showed high potential for use of GIS and related technologies in a 'facilitated project'. In this case the costs were low and did not require high technical capabilities of the communities.

On the other hand, it could be argued that the capabilities of the community were hardly utilized because the technical GIS work was done by a postgraduate student. There would seem to be great scope for developing the capacity of communities to run their own GIS, with some support from locally based facilitators (or students). This points to the advantages of communities developing partnerships with government agencies and other institutions for mutual advantage, and hence to reducing the cost of developing and maintaining GIS databases for natural resource management.

As pointed out by Grove and Hohmann (1992), GIS is mainly a tool, a means by which to solve problems. Community foresters and community-based organizations must understand that GIS is not a cure for all problems. Although this study showed great potential to develop GIS at comparatively low-cost and without high technical expertise with communities at the initial stages, it will not be feasible for all non-profit community organizations to update and maintain GIS data-bases in remote settings, without strong support from outside agencies.

Some obvious needs in providing support for GIS for community-based forest management are: (i) training in use of GIS software and hardware, (ii) provision of on-going technical advice and facilitation of GIS units set-up by community groups, and (iii) the setting up of GIS facilities in communities for use by different community groups. The latter type of support could take a form similar to the Community Internet Cafes that have been established in many rural areas in many countries (UNESCO 2004). While the use of a GIS may initially be costly, it is important to consider the accessibility to data which it offers, and the many other advantages to be gained from local level resource management related information. In countries like Nepal where many rural people do not have access to computers or electricity, the expansion of GIS facilities will be a lower priority that many other issues in development programs, but offers important potential for some community forest user groups.

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Apendix 1-1

Glossary of Terms Used in Working with GIS and Related Technologies (from GIS Literature)

The main purpose of this Glossary is to help users and readers understand the meanings of terms, concepts and techniques that have been used in this thesis.

Accuracy	The ability of a measurement to describe a landscape feature's true location, size or condition.
Analysis	The stage in science when measurements are sorted, tested, and examined visually for patterns and predictability.
Application	A task addressed by a computer system.
Aspect	The directional measure of slope. Usually referred to in compass directions (e.g., southerly, or degrees of the compass).
Attribute data	Data that describe the characteristics of spatial features.
Base map	Refers to those layers of map information (e.g., topography, roads, watercourses, property parcels) used for geo-referencing layers of thematic information (e.g., weed infestation, forest stands, land use).
Buffer	A zone of specified width surrounding a point, line or area feature.
Cartography	The art and science of drawing charts and maps.
CD-ROM	Compact Disc-Read Only Memory. A computer peripheral that employs compact disc technology to store large amount of data for later retrieval. The capacity of a CD-ROM disk is over 600 megabytes, the equivalent of over 250,000 typewritten pages.
Command	A specific instruction to a computer program, issued by the user to perform a desired action.
Contour	A line connecting points of equal value (e.g., elevation), often in reference to a horizontal datum such as mean altitude above sea level.
Contour interval	The vertical distance between altitudinal contour lines.
Control points	Points with known values in spatial interpolation.
Coordinate	The position of a point in space with respect to a Cartesian coordinate system (*x, y*, and/or *z* values). In GIS, a coordinate often represents locations on the earth's surface relative to other locations.
Data model	A logical way of organizing and representing data in an information system.
Data set	A named collection of logically related data items arranged in a prescribed manner.
Database	A collection of information managed and stored as a single entity. A spatial database includes information regarding the spatial coordinates of all landscape features in the database, as well as information regarding the attributes of each landscape feature, usually in tabular (spreadsheet) form.
Datum	The basis for a coordinate system and derived from spheroid.
Decision support system (DSS)	A computer application that analyzes natural resources data and presents it so that users can make resource management decisions more easily.

Digital elevation model (DEM)	A data file containing an array of elevation values.
Digitizer	An electronic device for capturing digital data from paper maps. Small-sized digitizers are usually referred as *digitising tablets*, and large ones are called *digitising tables*.
Digitising	The process of converting data from analog to digital format.
Digitising table	A table with a built-in electronic mesh that can sense the position of the cursor and can transmit its *x, y* coordinates to the connected computer.
Disk	A storage medium consisting of a spinning disk coated with a magnetic material for recording digital information.
Download	To move a file across a network for eventual residence locally.
Editing	The process of modifying and updating graphics and attribute data.
Format	The organization or structure of a digital data file.
Freeware	Software applications that are made freely available to anyone who wants to use it. Number of freeware including entire operating systems and GIS packages are available on the Internet.
Geographic information system	A computer system for capturing, storing, querying, analyzing and displaying geographic data (GIS).
Geo-referencing	The process of registering a geographic data set to an accepted coordinate system.
GIS modeling	The process of using GIS in building models with spatial data.
Global positioning system (GPS)	A system allowing one to locate one's position on the Earth's surface by receiving signals from satellites. The signals are used to calculate a position based on triangulation.
Grid	A geographic data model representing information as an array of equally sized square cells arranged in rows and columns. Each grid cell is referenced by its geographic *X, Y* location.
Ground control points	Physical points on the ground whose positions are known with respect to some horizontal coordinate system and/or datum that can be used to establish the exact spatial position and orientation of the image on the ground.
Hardcopy	A copy of a graphics of map image on paper or other stable material.
Hardware	The physical components of a GIS- the computers, plotters, printers, scanners.
Import	The process of getting data from an external source into a particular GIS.
Input device	A hardware component for data entry, e.g., digitizer, keyboard, scanner.
Internet	A logical super system of local, regional, national and international communication networks. Computers on the Internet can access the resources of one another by using common communication protocols such as the World Wide Web.
Isohyet	A line on a map connecting locations with the same value (e.g., annual rainfall).
LANDSAT	Land resource assessment satellite system; a series of earth resource scanning satellites launched by the USA.
Layer	A subset of a geographic database containing data associated with a particular theme.
Line	A spatial feature that is represented by a series of points and has geometric properties of location and length.

MacGRIDZO	A gridding and contouring software developed by RockWare Inc., runs under Macintosh operating system, and commonly used for preparation of contour maps and 3D perspective plots.
Map projection	The process of transforming from the spherical geographic grid to a plane coordinate system.
Metadata	Data that provide information about spatial data.
Model	A simplified representation of a phenomenon or a system.
Onscreen digitising	The process of acquiring vector graphics by tracing the raster image displayed on the computer screen and also known as *'heads-up digitising'*.
Operating system	The suite of software programs and utilities necessary for the control and use of a computer, including a minimum the management of files and the use of computer's processor.
Orthophotograph	A vertical aerial photograph from which the distortions due to varying elevation, tilt, and surface topography have been removed, so that it represents every object as if viewed directly from above.
Output (GIS)	The results of processing data in a GIS; maps, tables, screen images.
Overlay	A process in geographic data processing that involves registering and combining layers of thematic data to form a new composite layer.
Pixel	A term derived from 'picture element' that is the smallest unit of resolution in raster data storage and display.
Point	A spatial feature that is represented by a single coordinate and has only the geometric property of location.
Projection	An orderly system of lines on a plane representing a corresponding system of imaginary lines on a terrestrial datum surface. For the Earth, a projection consists of lines representing parallels of latitude and meridians of longitude on a grid.
Proximity	The closeness of one item to another.
Punk	A hand-held device for entering data from a digitizer which usually has a window with accurately engraved cross-hairs, and several buttons for entering associated data.
Random access memory (RAM)	The part of a computer's memory that may be accessed more rapidly than the regular memory.
Raster	A data structure that is based on the use of grid cells.
Raster data model	A spatial data model that uses a grid to represent the spatial variation of a feature.
Rasterisation	The process of converting an image of lines and polygons from vector representation to a gridded representation.
Real time (images)	Refers to images or data made available for inspection simultaneously with their acquisition.
Remote sensing	Acquiring information about an object without contacting it physically and methods include aerial photography, radar, and satellite imaging.
Rendering	Adjustments of appearance of a theme (e.g., from solid to opaque colour)
Resolution	The minimum distance between two objects that can be measured or distinguished by a data capturing or imaging device (e.g., table digitizer and image scanner).
Satellite	An object in orbit around a celestial body.
Scale less	The characteristic of digital map data in abstract form of being usable and displayable at any scale, regardless of the scale of the map used to geocode the data.

Scanning	The method of converting hardcopy documents into the digital form using an electronic data capture device known as scanner.
Shape files	The file format for graphical data used by ArcView GIS.
Slope	The rate of change of elevation at surface location, measured as angle in degrees or as percentage.
Software	General name for computer programs and programming languages.
Surfer	A contouring and 3D surface mapping program developed by Golden Software Inc., runs under Microsoft Windows. It converts data into outstanding contour, surface, wireframe, vector, image, shaded relief and post maps quickly and easily.
Thematic map	One type of map used to emphasize the spatial distribution of theme, such as a map that shows the distribution of population densities by county in a state.
Topology	Refers to the way in which geographical elements are linked together, e.g., the topology of a line includes all of its to- and from- nodes, and its left and right polygons. Some spatial modeling operations in GIS do not require coordinates, only topological information.
Triangular irregular network (TIN)	A vector data model that describes the landscape using a set of triangles. Each corner of each triangle is described by a value, such as elevation.
Triangulation	The process of subdividing a two dimensional geographic space into triangular-shaped units in digital terrain modeling.
Update	Any replacement of all or part of a data set with a new correlated data.
UTM coordinate system	Universal Transverse Mercator coordinate system, which divides the Earth's surface between 84ºN and 80ºS into 60 zones, with each zone covering 6º of longitude. A widely used map projection system.
Vector data model	A spatial data model that uses points and their *X, Y* coordinates to construct spatial features of points, lines and areas.
Vectorisation	The conversion of point, line and area data from a grid to a vector representation.
Waypoints (GPS)	A position stored in the unit's memory. Waypoints are used for direct navigation or to build a route.
Zoom	To focus more (or less) closely on an area of a spatial database, or to enlarge (or make smaller) an area of spatial database, showing more (or less) detail.

Appendix 2-1

Major GIS Software Packages, their Developers and Main Features

Software	Developer	Main features
ArcView GIS	Environmental System Research Institute, Inc. (ESRI) www.esri.com	• Desktop mapping/GIS package works with tables, maps and charts all in one application • Operates on standard Windows, easy-to-use interface, dynamic data updating, integrate images, CAD, map data, tables • Includes extensions: Spatial, 3D and Network Analyst.
ArcInfo	ESRI Inc. www.esri.com	• Workstation GIS software package that provides a suite of data automation and conversion tools, advanced modeling capabilities and high quality cartography • Provides built-in functions for sharing and processing geographic data, plus integrated extensions for performing specialized tasks • Possesses various data types including tabular DBMS data, vector, raster, photographs, scanned documents, satellite images, CAD drawings and sound/video • Include extensions: ARC COGO, ARC GRID, ARC NETWORK, ARC TIN, ArcScan, ArcPress, ArcStorm.
Arc GIS	ESRI Inc. www.esri.com	• An Integrated collection of GIS software products for building a complete GIS • ArcGIS consists of three primary programs - ArcMap (create view and manipulate maps), ArcCatalog (view and organize the various pieces of data that to into making a map) and ArcToolbox (convert data from one format to another).
MapInfo	MapInfo Corporation www.mapinfo.com	• A comprehensive desktop mapping software, combines an easy to use GUI interface with strong tools for geographic analysis and visualization • Facilities provided for address geo-coding, thematic mapping, map object editing, and presentation layout, geographic queries, importing and exporting data.
GeoMedia	Integraph Corporation, www.integraph.com	• Desktop GIS software that provides powerful analysis tools, including attribute and spatial query, buffer zones, spatial overlays and thematics • Data server technology helps to apply analysis across multiple geospatial formats.
MGE	Integraph Corporation www.integraph.com	• A complete GIS that uses micro-station as its graphics engine and design file for graphics storage.

According to a published survey in *GIS World*, ESRI Inc. and Integraph corporation have dominated the GIS software market (Crockett 1997). The software ArcView GIS 3.2 was used for the purpose of this thesis.

Appendix 2-2

Some Free GIS Software Available on the Internet and Considered Useful for Community Forest User Groups

Freeware refers to software and data made available on the internet to any users at no financial cost. A wide variety of freeware, including operating systems and GIS packages are available and some useful freeware for forest user communities and non-profit community organizations are listed below.

Some free GIS software potentially useful for community-based GIS project

Forestry GIS (fGIS™): A compact GIS data viewer, digitizer and shapefile editing program designed for resource manager, field forester and wildlife biologists developed by the University of Wisconsin and Wisconsin DNR – Division of Forestry. It can be used to customize layered views (including aerial photos and other imagery), draw map objects, query and search spatial data, annotate maps for printing (Further information available from http://www.digitalgrove.net/fgis.htm).

ArcExplorer: A lightweight GIS data viewer developed by ESRI Inc. which offers and easy way to perform a basic GIS functions and used for a variety of display, query and data retrieval applications and supports a wide variety of standard data sources (Further information and how to access the software visit http://www.esri.com/software/arcexplorer/).

Geomedia Viewer: Lightweight GIS data viewer developed by Integraph that provides user with a fair bit of functionality including data access, analysis, presentation and printing (Further information available form http://www.imgs.integraph.com/gviewer/).

Map Explorer: GIS software developed by ESRI (UK) that enables to view almost any geographic information. It supports for a wide range of both raster and vector formats, comprehensive set of thematic mapping and query tools, and can be used standalone or alongside other ESRI software(For detailed information see ESRI (UK) homepage http://www.esriuk.com/products).

GRASS GIS: GIS software originally developed by the US Army Construction Engineering Research Laboratories and presently maintained by Baylor University (USA) and University of Hannover (Germany). Its functionality includes raster, topological vector, image processing and graphics production functionality that operates various platforms through a graphical user interface and shell in X-Window (For detailed information see GRASS GIS homepage http://grass.itc.it/index.html).

Appendix 2-3

Some Free GPS Software for Downloading GPS Data to a PC

Software is needed to transfer data from a GPS receiver to a PC, and in other direction, and to put waypoints onto a GPS from the computer (a handy way to transfer waypoints between GPS units). Some GPS units come with such software. We can also use software available free from the Internet. A wide variety of free GPS software is available on the internet that can be used by community groups and resource poor organizations. Most of this is compatible with common desktop GIS software. Some popular free GPS software is listed below.

Some popular free GPS software

EasyGPS: Provides fast and easy ways to create, edit, and transfer waypoints and routes between Garmin, Magellan, or Lowrance GPS. One can manage waypoints and routes and display them in lists sorted by name, elevation or distance (More information is available from http://www.easygps.com/default.asp).

GPS Utility: A utility program that allows mapping, managing and manipulating GPS waypoints, and route and track information and for transferring data between GPS receiver and PC files. It has both freeware and registered versions, freeware versions have limited capability compared to registered versions, but are adequate for use of community forest user groups (For detailed information visit http://www.gpsu.co.uk/).

DNR Garmin Extension for Arcview GIS: This extension gives users the ability to directly transfer data between ArcView GIS and Garmin GPS handheld receivers. This extension was developed by Minnesota Department of Natural Resources and very useful tool to upload point, line and polygon features to the GPS and conversely Waypoints, Tracklogs, and Routes collected using the GPS can be transferred directly to ArcView and saved as Graphics or Shapefiles (For more details visit http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html).

Windmills Free GPS Software (Connecting a GPS receiver to a Laptop PC): Useful software to transfer live data from GPS receiver to a laptop PC; developed by Windmill Software Ltd, UK (Further detail available from http://www.windmill.co.uk/gps.html).

The file obtained when we download from a GPS receiver is a simple text file with data in rows, including the coordinate ID number, the *X* and *Y* data, date, time, and other collected data such as elevation. These files can be stored together in a folder with other files.

Appendix 2-4

Specifications for a Simple GIS Set-up for Community Forestry Project

For the types of work performed by field level foresters and community groups, a standard PC (or laptop computer) is adequate as the basic hardware for a GIS system (Bettinger and Wing 2004). Common desktop GIS software such as ArcVeiw, MapInfo, or Geomedia are sufficient for such systems (Bettinger and Wing 2004), and even the freeware listed in Appendix 2-2 can be used for community GIS projects. The characteristics of a PC needed to run desktop GIS software are listed below.

Hardware needs for a simple GIS set-up for a community forestry project

Basic hardware configuration: Pentium IV processor, 2.0 GHz speed, 40 GB hard drives, CD with read/write capability.

Microprocessor (CPU) speed: The faster the processor the quicker a process is completed (Bettinger and Wing 2004). Experiences has shown that processor speed doubles every 18 months (Lo and Yeung 2002) so that fastest processor is recommended e.g. >2.0 GHz.

Random access memory(RAM): Although many GIS package run on 32 MB RAM (Lo and Yeung 2002) the maximum amount is recommended (Bettinger and Wing 2004) recommends minimum 256 -512 MB.

Printer: Printer should be able to generate information products required by all applications in terms of output quality. Color inject printer with scanning facility is probably the best option.

Video card and monitor: A 32Mb video card is the minimum requirement and a 17 to 19 inch monitor is adequate. In case of laptops a 15 inch screen is adequate.

The specifications listed above provide a general guide only. Other factors, such as network and remote access, system security and warranty matters should be taken in to consideration [see Magurie *et al.* (1991), Lo and Yeung (2002)]. Because the capability of hardware and software is increasing rapidly and their prices are dropping Lo and Yeung (2002) suggest that the purchase of hardware items should be left until the last moment in setting up a GIS.

Appendix 3-1

Brief Description: the Garmin handheld GPS 76 used in this Study

A recreation grade GPS unit designed to provide precise GPS positioning and features a built-in quad helix antenna for superior reception. It provides 1 megabyte of internal user memory to be used for storing downloaded point of interest.

Major features:

- Designed for navigation
- Works very well with collection points
- Small and lightweight.

Accuracy:

- Uncorrected data without Selective Availability: 20 meters
- Under trees 20-50m.

Software:
Various software is available for downloading GPS data to ArcView. The software DNR Garmin extension considered the best by Roper (2003 p.5).

(Source GARMIN, from **www.garmin.com**)

[Further details available from http://www.garmin.com/products/gps76/ (Accessed on 12/4/2004)]

Appendix 3-2

Downloading GPS Data to a PC and Creating an ArcView Shapefile

The steps described below are used with free GPS software (i.e., GPS Utility, see Appendix 2-3) to download GPS data from a Garmin unit and the process of converting into a shapefile format.

Step 1. Turn off the GPS unit and connect it to the computer's serial port (generally COM1) using the PC interface cable.

Step 2. Launch GPS Utility and go to File-Configuration-Modes. Set the coordinates to Decimal Degrees. Go to the File-Datum menu and select AGD 66 and AMG 55.

Step 3. Go to GPS-Port and make sure it is set to the port using (generally COM1).

Step 4. Select Waypoints- Download or GPS-Download from GPS-Waypoints to download your waypoints (or tracks or routes). Save the waypoints as "comma delimited textfile" (File-Save-Waypoint). Make sure to note where the file is saved.

Step 5. Open into Excel. As we are bringing in the file, be sure to select delimited instead of fixed width, and use a comma as the delimiter. Don't import any unnecessary columns. Once it is in Excel, get rid of any extra rows. Bringing it into Excel mostly allows us to make sure that it is in a format that ArcView will read. Save the table in .txt format again (tab delimited is fine). Overwriting the file is generally fine.

Step 6. Open ArcView. Make the tables active and add your .txt file. Then open a view and under the view menu select Add Event Theme. Select your .txt table, and make the longitude field your x field and the latitude field your y field. Hit OK. Now we can see points in our view.

Step 7. Convert this to a shapefile. With the view open, make text theme active by clicking on its legend (it will look like a raised button). Go to Theme-Convert to shapefile, and save it into chosen data folder. At this point we need to do whatever projection and datum conversions are needed to get the shapefile into our system. If using Australian Map Grid (AMG) for other data sources we can select AMG.

Appendix 4-1

Various Issue-based Working Groups of the Wombat Community Forest Stewardship Council

Working Groups	Contact person
Governance	Peter Hall
Education	Tanya Loos
Mudlark Stage 2	Eric Fah
Weeds and pest animals	Pat Liffman
Forest heritage	Chris Murphy
Biodiversity	Gayle Osbourne
Forest resource non timber	Graham Connell
Forest resource timber	Phil Millar
Recreational users	Milton Oliver
Water	Trevor Cookson

(Available from Wombat News and Views, edition 2, 3, 2004)

Appendix 5-1

Some Donor Supported Forestry Projects and GIS Use in Community Forestry, Nepal

Forestry Projects and Supporting Donors	**GIS/GPS/RS use**	**Source**
Livelihoods and Forestry Program - supported by DFID, UK (Department for International Development)	Participatory photo- mapping, Participatory resource inventory	Marther *et al* (1998); Subedi (2004)
Churia Forest Development Program - supported by GTZ (The Deutsche Gesellschaft für Technische Zusammenarbeit)	Use of GPS for community forest boundary surveying, use of aerial photographs for participatory photo mapping	Rana (2003)
Peoples and Rural Dynamic Project (PARDYP) – Supported by ICIMOD (International Center for Integrated Mountain Development)	Use of GPS for boundary surveying, Use of aerial photograph for participatory photo-mapping	Jordan and Shrestha (1999); Bitter and Shrestha (2000)
Dolakha, Ramechap, Okhaldunga Community Forestry Program - SDC (Swiss Development Cooperation	Community forest boundary survey, NTFP resource mapping	Gurung (2004)
Nepal Australia Community Resource Livelihoods Project (NACRLP) – Supported by AusAID (Australian Agencies for International Development)	Use of GPS and aerial photograph for participatory resource inventory with support of PARDYP project	N. Chand pers. comm.[DoF, Nepal] Feb. 2004
Strengthened Actions for Governance in Utilization of Natural resource Program - CARE Nepal with USAID Funding	*	
Natural Resources Management Sector Assistance Program, NARMSAP - DANIDA (Danish Development Assistance)	Use of large scale aerial photograph for participatory photo mapping, potential CF area identification, vegetation type identification	Kunwar (2004); Gurung (2004)

[*information not available]

Appendix 6-1

Process for Standard (or *Tablet*) Digitising in ArcView GIS

Standard digitising is also called semi-automated digitising. In this process, in which geo-coding takes place manually, a map is placed on a flat table and a person traces out the map features using a cursor. The locations of features on the map are recorded by the computer every time the operator of the digitising tablet presses a button.

Materials:

- Digitising tablet
- Digitising cursor (punk)
- Computer mapping software (ArcVeiw GIS 3.2)
- Paper map
- Drafting tape

General process:

Step 1. Affix the paper map to the digitising tablet using drafting tape.

Step 2. Locate and identify tic marks (control points) on the map.

Step 3. Open ArcView GIS, create or open a file which contains tic marks corresponding to the map and will hold the data to be digitised.

Step 4. Using at least 4 control points identified on the map and in the computer file, register the map to the file loaded in ArcView GIS.

Step 5. Check that the RMS error is below the set standard for the project.

Step 6. Enter the location data through a series of steps using the digitiser cursor and the map.

Step 7. Enter attribute information while positions are being digitised or join data attributes to positions after digitising is completed.

Step 8. Check for errors in both the location of the data and each positions attributes.

Step 9. Complete metadata that describe the data set that has been digitised.

Appendix 6-2

Process for On-Screen (or *heads-up*) Digitising in ArcView GIS

On-screen (or *heads-up*) digitising is a method of developing vector GIS database (of points, lines, or polygons), in which a user creates landscape features using the computer's mouse. It is done generally with a raster image or other map layer as a backdrop so as to draw (or point out) those landscape features that are important.

Materials:

GIS software (ArcView GIS)
Computer mouse and keyboard
Mental or paper map of data
Digital base layers

General process:

Step 1. Acquire and load the proper base layers into ArcView GIS.

Step 2. Identify the map parameters (projection, coordinate system, datum, units, etc.) of the base layers.

Step 3. Enter the location data using either a mouse or a keyboard.

Step 4. Enter attribute information while positions are being digitised or join data attributes to positions after digitising is completed.

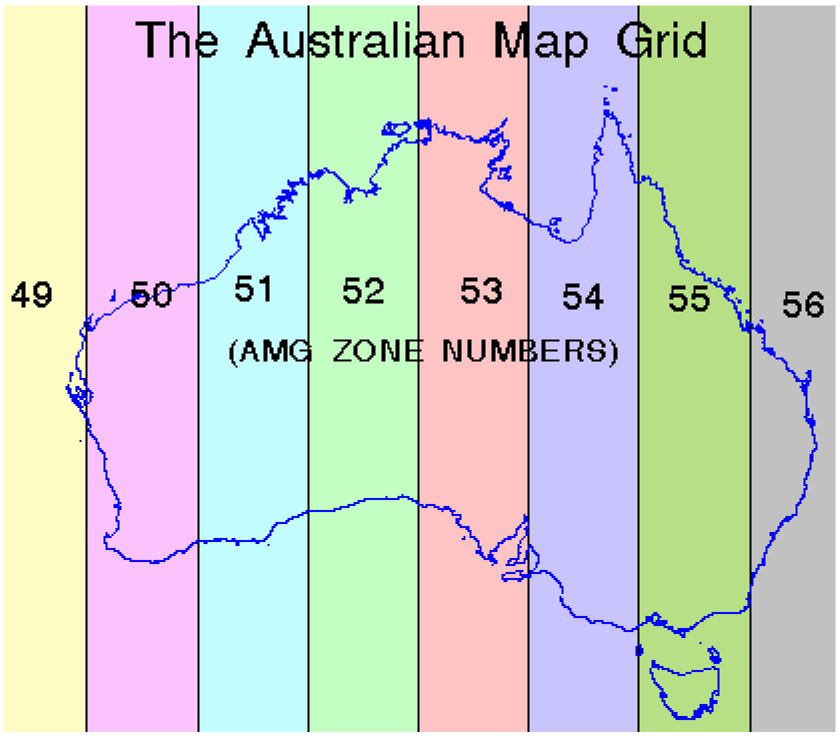
Step 5. Check for errors in both the location of the data and each position's attributes.

Step 6. Complete metadata that describes the data set that has been digitised.

Appendix 7-1

UTM/AMG Zones of Australia

The Australian Map Grid (AMG) is a Universal Transverse Mercator (UTM) projection system. The AMG zones of Australia are shown in the figure. The Wombat State Forest falls in UTM Zone 55.



(Source: Department of Environment and Heritage, 2004)
(http://www.deh.gov.au/erin/tools/amg2geo.html Accessed on 8 July 2004)

Appendix 7-2

Conversion from Geographic Coordinates to AMG

Geographic coordinates were converted to Australian Map Grid (AMG) for this study using the following, link available from the Department of Environment and Heritage. An example is shown in below.

Enter the Latitude and Longitude (in decimal degrees) of the point you want to transform:

-37.654321 Latitude DD

143.925175 Longitude DD

To convert, press this button: Convert

To reset the form, press this button: Reset

This transformation is based upon the **Australian Geodetic Datum 1966**.

(Source: Department of Environment and Heritage, 2004)
(http://www.deh.gov.au/erin/tools/geo2amg.html#convert Accessed on 8 July 2004)

Appendix 8-1

Evaluation Form for Map Explorer Training Session, used by FRI Section of the DSE, Melbourne, Victoria to Assess Community Opinion

EVALUATION SHEET - Daylesford Training Sessions May 2004

Date:__________ Name (Optional):____________________________________

Please answer the following **BEFORE** the session begins:

1. Please rate your confidence with using the Forest Explorer CD, where:
   0 = haven't used it yet, 1 = least confident and 5 = extremely confident:

   0 / 1 / 2 / 3 / 4 / 5 / 6

2. Do you have a home computer? Yes / No
3. How would you rate your computer skills?
   Please circle: never used one / beginner / intermediate / experienced / expert

---

Please answer the following **AFTER** the session is complete:

4. Please overview what you have learned about spatial data. E.g., - do you know what it is? What is can be used for?

5. Please rate your confidence with using the CD, where 1 = least confident and 6 = extremely confident:

   0 / 1 / 2 / 3 / 4 / 5 / 6

* additional comments may go on the back

Appendix 8-2

Evaluation of Map Explorer Training Session by DSE, Victoria

Training Sessions - May 10th, 17th & 24th May 2004 (2 hours)
Overview of Monday 10th Session ~ 15 community participants (~10 at once)
Questions On the Board:

What is your current understanding of spatial data or GIS? E.g., do you know what it is? What is can be used for?

BEFORE:
- Never heard it
- Computer jargon - misleading
- A 3-D view
- Scale of data
- Info on the surface of the earth

AFTER:
- Layers of information
- Maps
- Quantitative and relative
- Scale
- Location
- There's data behind what you're looking at

What was something that you learned *how to do* this evening? **(objective)**
- Put Legends in a map
- Print preview & print maps
- Navigate around the CD
- Saving
- Select related datasets
- Alter legend display - rendering
- Looking inside the data

What did you enjoy about this session? What worked well? **(reflective)**
- Good to be hands-on
- Good knowledge of the presenters
- Changing the presenters around was a great idea - kept it interesting
- Having a variety of presenters and having them available to help as well
- Having the main view projected on the screen was good to follow
- The CD looks user-friendly
- Size of the group (small) was good (wouldn't want it larger)

Extra Notes / Suggestions
- The more you learn, the more you want to learn
- More training, but using real/practical examples e.g. based on Working Group tasks
- Need to go home and practice before more training
- Query Building and Finding

What wasn't good about the training session? What didn't work well? **(reflective)**
- Time - never enough of it!
- Rushed ending to get through it all
- Didn't go through queries (Query Builder)

What new insights do you have about using spatial data? **(interpretive)**
- Superimposing layers - using overlays
- Data as layers - a hierarchy (in the Table of Contents)
- Data currency is important
- Data scale is important

How do you think you now could / will use this CD? **(decisional)**
- Silviculture prescriptions - restoration forestry prescriptions
- Flora & Fauna Management
- Adding data - like the community mapped weeds
- Hydrology buffers / filters
- Testing management hypotheses

Overview of the 9 Evaluation sheets:
- Computer skills ranged from "never used one" to "experienced". Most have home computers.
- Confidence increased by 1 measure = 1 Confidence increased by 2 measures = 4
- Confidence increased by 3 measures = 1 Confidence increased by 4 measures = 1
- Confidence increased by 5 measures = 1

Appendix 8-3

Feedback – on GIS Data Layers Provided for Forest Explore CD and Community Groups from the Wombat Community Development Officer

From: ***Tim.Anderson@dse.vic.gov.au***
To: Mr Himlal Baral *<h.baral@pgrad.unimelb.edu.au>*
Date 25 June 2004

Dear Himlal,

In response to your data layers and their use in CFM, they have and are being used by the community. The rainfall layer appears on many maps I see the community produce. The weed mapping has been an inspiration to many, and the Catchment and Land Management course (Melb Uni) are now carrying out an extension of your work with GPS mapping about to commence in other parts of the forest, contact Tuesday Phelan DSE Daylesford if you want to participate.

The Aspect layer under biophysical features has raised a lot of interest. The way it shows the landform seems to be of interest to many. The request has been to know if the rendering could be adjustable. People want to make it opaque and lay it over a map or other rendering. Is that possible, maybe the color it is rendered as well?

The Forest Explorer concept has proven very very popular. The first run of CD's has run out, with a big waiting list. The relationship between Melb Uni, DSE and the community is very good and I believe a vital aspect to CFM. If you have any ideas for databases I would love to hear them

Thanks for your help, support and participation over the past year so as well Himlal.

Tim Anderson
Wombat Community Development Officer.
Daylesford, Victoria

Appendix 9-1

Some Photographs of work for the thesis around the Wombat State Forest, Victoria

Plate 1 Gorse infestation around Golden Point, Blackwood, represents a serious fire hazard to local communities

Plate 2 The author recording extent of weed (broom) infestations at Blackwood using handheld GPS

Plate 3 A local community member locating 'significance soaks' on the headwaters of the Coliban River around Newbury in the Wombat State Forest. Photo permission from Mary Ann Faulks.

Plate 4 Community member locating significant soaks near Newbury in local mapping exercise.

Plate 5 Community groups wish to protect 'soaks' for water quality and conservation and also as 'hot spots' for biodiversity

Plate 6 Author observing a wombat burrow in the Wombat State Forest near Newbury

Plate 7. The author (left) with community members at a meeting to plan a weed mapping exercise, Blackwood