ASSESSMENT OF POTENTIAL AND IMPACTS OF AFFORESTATION IN THE LETABA CATCHMENT, LIMPOPO PROVINCE, SOUTH AFRICA

By

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4465-313-1

Submitted in partial fulfilment of the academic requirements for the degree of Master of Science

in the Department of Geography, University of South Africa

July 2011

DECLARATION

I declare that **Assessment of Potential and Impacts of Afforestation in the Letaba Catchment, Limpopo Province, South Africa** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

The research herein was undertaken in the Department of Geography, University of South Africa under the supervision of David William Hedding. This dissertation has not been submitted in any form for a degree to any other university.

Andile Churchill Mkwalo
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July, 2011

ACKNOWLEDGEMENTS

To the Almighty God be the glory, honour, praise and power unto eternity. To Him I owe everything, including the inspiration and the content of this study. He did not only inspire this study; He also provided the financial, material and human assistance that made this work possible.

I wish to express my sincere gratitude and admiration to my supervisor, David William Hedding for taking time off from his numerous duties to be available to guide and give me directions at all times. The Department of Geography is also worth mentioning for its moral support given to me in this work.

Work of this nature is not possible without information and assistance from various professional fields and institutions. Assistance given by the following individuals and their institutions is highly valued:

- Stephen Mallory of Water for Africa for his assistance and providing license of the model.
- Bradon Mashabane of the Working for Water Programme at Tzannen Office.
- Mahlangu also of the Department of Water Affairs (DWA) in Tzannen
- Helen also of the Department of Water Affairs (DWA), National office.
- Johanna Makinta of the Department of Agriculture, Forestry and Fisheries

My friends – Solly, Batandwa, Sibongile, Makhosazana, Ntandazo, Thobile, Gregg and Xolani should be thanked, for assistance they had given.

Finally, a word of gratitude and appreciation is due to my parents, wife, three children and other members of my family who supported me with their understanding, love and prayers throughout the long and tedious hours of work.

ABSTRACT

The plantation forestry is economically a very important industry in South Africa because it promotes the upliftment of many rural South African communities. However, afforestation has significant impacts on water use and biodiversity in a catchment. Thus, understanding the effects of afforestation on water resources at the catchment level is fundamental for optimal water resource allocation, long-term sustainable use, development and conservation. Much of the Limpopo Province is climatically and physiographically suitable for plantation forestry but it only contains approximately 4.7 % of the total existing plantation area in South Africa. For example, the size of the Letaba Catchment of the Limpopo Province is 13 669 km² but only approximately 484 km² of it is currently afforested. This study aims to identify potential areas for further afforestation in the Letaba Catchment using the Water Resources Modelling Platform (WReMP) model to determine if afforestation can be expanded here to promote development in South Africa’s poorest Province.

Key terms: Letaba; Limpopo; South Africa; Afforestation; Biodiversity; Catchment; Reserve; Streamflow; Sustainability; Water Resource Model; Water Allocation.

ACRONYMS

APS	Afforestation Permit System
CARA	Conservation of Agricultural Resources Act
CSIR	Council of Science and Industrial Research
DoA	Department of Agriculture
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environment Affairs
DEAT	Department of Environment Affairs and Tourism
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EIA	Environmental Impact Assessment
EIS	Ecological Importance & Sensitivity
GDP	Gross Domestic Product
GGP	Gross Global Products
GISP	Global Invasive Species Programme
GN	Government Notice
FIS	Forestry Invasive Species
FPA	Forestry Protection Association
FPO	Forestry Protection Officer
FAO	Food and Agriculture Organisation
IDP	Integrated Development Programme
IFR	Instream Flow Requirement
ISP	Internal Strategic Perspective
IUCN	International Union for Conservation of Nature and Natural Resources
IWRM	Integrated Water Resource Management
Km	Kilometer
KNP	Kruger National Park
Ltd	Limited
MAR	Mean Annual Runoff
NEMA	National Environmental Management Act
NEMBA	National Environmental Management: Biodiversity Act
NVFFA	National Veld and Forest Fire Act
NWA	National Water Act
NWRS	National Water Resource Strategy
PDEA	Provincial Departments of Environment Affairs
Pty	Proprietary
QC	Quaternary Catchment
REC	Recommended Ecological Category
RSA	Republic of South Africa
SFRA	Stream Flow Reduction Activities
SI	Socio-Cultural
WARMS	Water Use Registering and Licensing Management Systems
WFW	Working for Water
WMA	Water Management Area
WR 90	Water Resource of South Africa 1990 Study
WR 2005	Water Resource of South Africa 2005 Study
WRC	Water Research Council
WReMP	Water Resource Modelling Platform

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Chapter One: Introduction

1.1 Introduction

South Africa is no longer well-endowed with indigenous timber resources. The country's natural forests were heavily exploited during the first decades of the 20th Century, necessitating the introduction of large scale commercial forestry. Commercial forestry provides wood to pulp mills, sawmills and factories which process the raw materials into products for mining, construction and industrial markets. Forest plantations contribute to many aspects of the economy by adding value, primarily in the form of resources, such as: construction timber and pit props for mining; components for houses and commercial buildings; poles for electricity and telecommunications distribution; furniture, pulp and paper for manufacturing; and fuel wood for energy generation and cooking.

South Africa's demand for wood is met predominantly from commercial plantation forests, rather than natural forests, or imports. Commercial forests also contribute to the alleviation of poverty, by offering employment opportunities through the growing of trees, local wood processing or harvesting and processing the other products of the forest. Commercial plantation forestry employment opportunities are accessible to people with limited educational skills and other resources, since high skills levels and/or financial investment may not necessarily be required. This sector, therefore, offers poor, and predominantly rural, people the opportunity to become involved in economic activities through initiatives such as the Department of Water Affairs and Forestry's (DWAF) Participatory Forestry Management (PFM) programme and the Broad Based Black Economic Empowerment (BBBEE) Charter. The BBBEE Charter ensures equity goals, both in growing trees and throughout the value chain, whereby DWAF works in partnership with Forestry South Africa (FSA), as well as contractors' associations and the sector as a whole, to achieve these goals.

Water is acknowledged to be a key constraint for economic growth in South Africa and there is considerable pressure for efficient and sustainable use of the limited water resource (Le Maitre *et al.*, 2002). Increased demands on the limited water resources of South Africa are primarily driven by the growth in population, industrial development and increasing levels of agriculture. The demand for wood products, and consequently the rate of afforestation, is also growing. Yet afforestation leads to a reduction in catchment water yield and this causes a conflict between managing catchments for both sustained water and timber yields (Smith & Scott, 1992 and Schulze *et al.*, 2001). For instance, it has been clearly demonstrated that changes in vegetation cover have marked effects on catchment hydrology and that these effects may manifest themselves at different times after treatment. Previous studies have established that afforestation causes a reduction in low flows and that clearfelling of forest causes an increase in low flows (Smith & Scott, 1992).

The reduction of water yield varies in proportion to the area planted and experiments by Le Maitre & Scott (1997) show that water yield may drop from about 50 percent of pre-afforestation levels to a complete loss of low flow. Importantly, Le Maitre & Scott (1997) also show that the reduction in low (dry season) flow is more than the total annual streamflow, when in-stream water may be needed most critically. Therefore, the impact of afforestation on these flows is of particular interest since the effect on low flows (dry season) may be more important than the overall impacts on stream flow (Le Maitre & Scott, 1997 and Smith & Scott, 1992). The impact of a reduction in surface water is extremely important because South Africa has a mean annual rainfall of only approximately 450 mm and less than 10 percent of this becomes surface runoff (DWAF, 2000).

1.2 Natural forests (types of forestry)

Natural forests in South Africa are surprisingly limited in their extent. Grasslands or shrublands typically cover areas that receive in excess of 800 mm of rainfall annually, at altitudes below 2000m, while similar areas in other parts of the world would support natural forests. In South Africa, there are about 492 700ha of natural or indigenous forests, which geographically occur mainly along the Southern and Eastern Escarpment, the coastal belt and in sheltered kloofs or ravines (Mondlane *et al*., 2001). This is less than 0.4 % of the total area of South Africa, but these forests have a high biodiversity per unit area (0.418 species/ha). Almost three quarters of the natural forests are conserved either as declared State forests or within formal protected areas. Despite the high levels of biodiversity in South African natural forests the lack of a natural source of fast growing timber trees led to the plantation of alien species (*Pinus spp*, *Eucalyptus spp*. and *Acacia mearnsii*). These plantations have brought about many negative and positive impacts in South Africa (Mondlane *et al*., 2001).

South African natural forests can be classified into seven forest groups, further subdivided into 20 forest types and 4 azonal forest types. In terms of sub-aerial extent, the Eastern Cape has the largest percentage of natural forests 46 %; KwaZulu-Natal has 29 %; Western Cape has 13 %; Mpumalanga has 7 % and Limpopo only has 5 %. However, only 4.75 % of the total area of natural forests found in the Eastern Cape is protected (GCIS, 2004).

1.3 Importance of forestry in South Africa

South Africa is a wood-scarce country and forestry has developed in South Africa because it has a developing economy with escalating wood product requirements, it has some areas exhibiting favourable growing conditions (*e.g*. climate, *etc*.) and it has world-class forestry knowledge and expertise (DWAF, 2000). Forestry is an industry which is based in rural areas and is one of the few ways to make productive use of land that is not suitable for farming (Kasrils, 2001). It is a rural industry that allows manufacturing to take place in rural areas and, therefore, it makes a significant contribution to the economy of South Africa and plays important role in job creation and poverty relief (DWAF, 2000).

The turnover of the forestry sector is approximately R2 billion *per annum*, which equates to approximately 7 % of Agricultural Gross Domestic Products (GDP). It employs almost 70 000 people, mainly in rural areas, and has an employment multiplier of almost six in downstream activities. The area planted in South Africa is 1 518 138 ha (1.2 percent of the total land area). Approximately 400 000 ha of this land is owned by the Forestry Industry and remains unplanned due to restrictions imposed by the Afforestation Permit System (APS) because it is being managed primarily for the conversion of indigenous flora and fauna (including water). The APS requires timber growers to apply for permits to establish commercial plantations on new land or sections of land. However, the establishment of these plantations has not been without cost to the environment. For example, the negative impacts of afforestation include significant reductions in surface streamflow, substantial impacts on biodiversity and the functioning of the natural ecosystem (Bosch and von Gadow, 1990; Le Maitre *et al*., 2002). In addition, many of the species used for plantation forestry have become invader species and Le Maitre *et al*. (2000, cited by Mondlane *et al*., 2001) estimates that these invasions use almost 6.7 % of the country’s runoff, and would cost approximately R 6.88 billion to clear over 20 years.

1.4 Motivation for the study

The availability and quality of water in many regions of the world are increasingly being threatened by overuse, misuse and pollution, and it is increasingly recognized that both are strongly influenced by forests. Moreover, climate change is altering forest’s roles in regulating water flows and influencing the availability of water resources (Bergkamp *et al.*, 2003). Therefore, the relationship between afforestation and water use is a critical issue that must be accorded high priority in South Africa, particularly since it is an arid country which is vulnerable to both floods and droughts.

South Africa only receives approximately 450 mm of rainfall *per annum*; as opposed to the world-wide average of approximately 860 mm *per annum* (DWAF-National Water Resource Strategy, 2004). Therefore, South Africa has limited water resources, which need to be managed through prudent management strategies which ensure sustainability as well as enable equitable access to all. One of the challenges in managing the limited water resources in South Africa lies in managing various aspects of commercial forestry and water use. Plantation (commercial) forestry is to all intents and purposes a permanent change in landuse from relatively low water use, to higher water use. These permanent changes of a natural area to forest plantation demands higher water use, which necessitates a conservative approach in a water-scarce country like South Africa. There is approximately 1.35 million hectares of plantation forests, of almost entirely exotic species as opposed to only about 530 000 hectares of closed canopy indigenous forest. These remaining indigenous forests are considered to be extremely precious and various efforts are being implemented to protect them.

The plantation forestry has brought about job opportunities and development to underdeveloped rural areas. It is an important economic activity and one which the South African government hopes to see grow over the next period of time. Nonetheless, as a water scarce country, researchers such as Scott *et al.* (1998) have recognized that the dense planting of trees in the areas that were previously grasslands, or open canopy woodlands, increase water used by vegetation in that area. In other words, a plantation typically uses more water than a grassland area of the same size, simply because of the volume water lost by trees through evapotranspiration. In South Africa, according to the National Water Act (Act 36 of 1998), the conversion of grassland to forestry plantations now requires a Water Use License. It also requires the assessment of water availability in a catchment.

In times of normal rainfall, the use of water in the catchment should be in balance with availability. However, during drought conditions, where water availability decreases, DWAF is compelled to impose restrictions on water users. It is, therefore, very difficult in a heavily afforested catchment, to impose water restrictions on plantation forestry. Simply because trees use whatever water is available. The only solution would, therefore, be to cut down the trees. This is something that DWAF has never resort to because it might have an implication on the yield of wood should there be early harvesting of timber.

Plantation forestry is found in the higher rainfall regions of South Africa (*i.e*. in areas where rainfall exceeds 800 mm *per annum*) and being a water scarce country (average annual rainfall <500 mm p.a.) this is inevitably within mountain catchment areas. South African plantation forests are almost entirely made up of three genera- all exotic: *Pinus spp.*, *Eucalyptus spp*. and the *Acacia mearnsii* and *Acacia dealbata*. All of these genera have water resource implications, namely the significant reduction in both total water yield and low flow in the rivers. This impact of plantation forestry on water resources has been recognized since the (British) Empire Forestry Conference of 1936 (Wicht, 1965).The debate over the reduction in streamflow due to afforestation in South Africa started as far back as 1915 (Van der Zel, 1990) In the past, there was considerable confusion over the impact of forests on rainfall, versus the impact of rainfall on forests. Nowadays it is accepted that in South Africa, natural forests occur where there is sufficient rainfall, temperature, and soil depth to support them, rather than vice-versa. South Africa is one of the few countries in the world, where water use by the plantation forestry is monitored, and where forestry is a strictly controlled form of water use and thus forestry is currently one of the better researched water users.

1.5 Research problem, aim and objectives

1.5.1 Research problem

The Department of Water Affairs and Forestry’s vision puts people and their development at the heart of forestry (DWAF, 1998). In line with its overall goals of human rights, social justice, equity and prosperity, the forestry function within DWAF is moving from the management of state forests towards developing the potential of the forestry sector to relieve poverty. Forestry can play a leading role by creating an enabling environment for economic and social development through sustainable commercial forestry.

In South Africa, the components of the hydrological cycle (rainfall, evaporation, plant water use, infiltration and runoff) show great spatial and temporal variation, which is prompting a major concern about the use of water by alien invasive species such as *Eucalyptus spp.*, *Pinus spp.* and *Acacia* species. These alien invasive species are creating a major problem by limiting the availability of water within South African catchment rivers.

In South Africa, forestry plantation has typically replaced natural grassland. The problem with transformation of natural grassland to forestry plantation is that afforestation reduces streamflow in South African catchments. When natural vegetation is replaced with exotic trees, the following responses can be recorded:

- Interception losses increase slightly, as the first 2 to 4 mm of every rainfall event is lost to interception by trees in an afforested area, compared with losses of only 1.5 mm in most areas of indigenous grassland

- Transpiration increases greatly compared with grassland. Large trees develop much deeper and larger root systems, enabling them to access moisture from soil layers that are unavailable to shallower- rooted vegetation.
- Low flows in rivers are reduced.
- Groundwater recharge is reduced or limited (Schulze *et al*., 1995).

The abovementioned factors affect the flow regime of rivers in catchments, impacting on the water quantity (availability) and quality of water. This may be particularly significant during critical low flow periods (dry seasons).

1.5.2 Research aim

The main aim of this study is to understand the impacts that potential afforestation may have on the water resources in the Letaba Catchment, Limpopo Province, South Africa. This study will, therefore, aim to predict the reduction in streamflow, associated with potential afforestation in the Letaba Catchment. The Department of Water Affairs and Forestry's National Water Resource Strategy (2004) has already indicated that most catchments in South Africa are water stressed. Physical factors such as soil depth, slope as well as the availability of water limit the potential for additional afforestation in South Africa. The National Water Resource Strategy indicates that most catchments are water stressed and thus the availability of water is expected to be the major constraint for additional afforestation in the Letaba Catchment. An ancillary aim is to explore whether forestry is a better land use in the Letaba Catchment as compared to the current land use types and to make recommendations regarding more suitable types of forestry in the development of any new forestry plantation projects within this catchment.

1.5.3 Research objectives

The objectives are as follows:

- Determine what impact afforestation may have on water availability and use, as well as biodiversity, as compared to current and other future uses, such as commercial agriculture which according to National Water Act (Act 36 of 1998) do not represent stream flow reduction activities;
- Identify areas that may be appropriate to develop new plantation forestry rather than commercial agricultural;
- Determine the ecological requirements for water needs of the Letaba Catchment in different seasonal flows using Spatial and Time Series Information Modelling (SPATSIM). SPATISM was used as a framework for the hydrological information

used within the process and to capture the Ecological Water Requirements (EWR) results and based from the existing data;

- Determine the extent to which plantation forestry will compete with existing land uses and other potential commercial land uses, such as agriculture;
- Determine and assess the influence of different types of species or genera on stream flow reduction; and
- Review literature to determine the most appropriate afforestation model for the Letaba Catchement. The WReMP model was then used to carry out time series simulations to calculate the flow in each component of the water resource within the catchment.

1.6 Outline of chapters

This study consists of six chapters, each covering different aspects of the objectives. Chapter one provides the background information related to water resource use and forestry in South Africa. The aim and objectives of this study are also discussed in this chapter. Chapter two focuses on the conceptual framework on water and forestry. The conceptual framework represents the literature review of the study. Related legislation on afforestation and water is also reviewed in chapter two as also part of the literature review. Chapter three provides a physical description of the study area. Chapter four describes the approach or methodology which was used for the study. The discussion on the analysis and the interpretation of results is discussed in chapter five..In chapter six is the summary of the study and recommendations.

Chapter Two: Literature review

2.1 History of plantation forestry in South Africa

The increasing demands for timber, created primarily by mining operations and urbanization, instigated the establishment of the exotic *Pinus spp.* and *Eucalyptus spp*. species forestry plantations to augment the meagre natural timber supplies. The first exotic timber plantation was established at Worcester in 1876 to produce fuelwood for the early steam locomotives (Steyn, 1982; Hinze, 2004). Subsequently, small-scale plantings were extended to the east and the north as sample plots. About 1 000 species were tested over many years. The results of these plots proved valuable for later afforestation programmes. The main three genera, which were used in the early commercial plantings, were *Pinus spp.*, *Eucalyptus spp.* and *Acacia* species. *Acacia mearnsii* was cultivated in the Cape regions for poles, fuel and shelter for stock (Olivier, 2009). By 1880, a number of wattle plantations had been planted in the KwaZulu-Natal Province and bark from these plantations has been sold to local tanneries. In 1886, the first consignment of tanning extract material was sent to London, where after the industry developed rapidly and by 1917 there was an estimated 65 000 ha of *Acacia mearnsii* (Poynton, 1990).

The Union Forestry Department was founded in 1910 (Steyn, 1961). At this early stage the Department of Forestry had established 13 500 ha of plantations and the railway sector had 5 000ha. The timber from the railway plantations was used for the building of coaches and wagons and timber was also sold to the mines (Pirie, 1982). During the First World War, the economic life of the country was disrupted by the timber famine, which arose, when the importation of timber supplies were cut off. Timber prices soared and this situation triggered renewed Government interest to make South Africa self-sufficient in terms of timber resources (Anon, 1973). At this stage, the private sector was not interested in such long-term investments and the Government took the lead in establishing exotic pine plantations for saw timber production. Private investors concentrated on short rotation products such as wattle bark, pole production, *etc.* The depression years of the late 1920s and early 1930s added an additional incentive for afforestation. Unemployed families were housed in “forestry settlements” where they were employed to plant trees. When timber became available from the thinnings of the early pine plantations, there were no sawmills to process the timber and the private sector was again reluctant to invest large amounts of money in wood processing plants. The Government built the first sawmill in 1915 at Fort Cunnynghame to saw pine timber (Steyn, 1982). South Africa was extremely successful in the establishment of exotic plantations. Dr Ian Craib who, in 1939, published his well known “Thinning, pruning and management studies on the main exotic conifers grown in South Africa” made one of the most important contributions. Many of the South African principles were also implemented in other southern hemisphere countries like New Zealand, Australia and various countries in the South America.

Afforestation was accelerated again after the Second World War but the private sector still concentrated on the short rotation products. The production of saw timber from State plantations increased progressively and the Government was forced to build the following sawmills (Steyn, 1982): -

- Elandshoek (1935);
- George (1937);
- Weza (1939);
- Sabie (1940);
- Nelspruit (1942); and
- Others like Timbadola followed in 1946.

However, the private sector started to catch up and by 1960 close to 900 000 ha commercial plantation had been established in South Africa (Hinze, 2004). The breakdown by ownership and species is shown in Table 2.1.

Table 2.1: Afforested area in South Africa by species and owner during 1960 (Anon, 1973).

Species	**Public Ownership**	**Private Ownership**	**Total**
Pinus spp.	224 000 ha	150 000 ha	374 000 ha
Eucalyptus spp.	30 000 ha	130 000 ha	160 000 ha
Acacia meansii	5 000 ha	356 000 ha	361 000 ha
Other	1 000 ha	2 000 ha	3 000 ha
Total	260 000 ha	638 000 ha	898 000 ha

Table 2.1 shows that by 1960 there was a well-established private forest industry with a planted area that was more than double that of public ownership. Over half (56 %) of the private area was planted with wattle whilst only a relatively small area of 130 000 ha (20 %) of privately owned forests was, at that stage, planted with *Eucalyptus spp.*. These areas were mainly planted by entrepreneurs, predominantly for use in the mining industry. This was the peak of the wattle industry. Due to an over-supply of tannin on the local and world markets in the 1960s, wattle became unprofitable and part of the wattle plantations were converted to other products (Poynton, 1990).

The period after 1960 marked the maturation of the forestry industry in South Africa. The private sector became more involved in the longer-term forestry initiatives of saw timber and processing plants. It was also the period in which the mining timber sector peaked to the detriment of the Wattle bark industry. In 1970, there was an area of 471 000 ha planted to Pinus *spp*., 289 000 ha to *Eucalyptus spp.* and 191 000 ha to Acacia mearnsii (Black Wattle), while other commercial species covered an area of 7 000 ha with a total afforested area equalled 958 000 ha. This value doubled to about 1 140 000 ha with an estimated value of R1 231 million, in 1976. Thus, although afforestation was slow to start with at the beginning of the 1900s the massive expansion in the forestry sector by the 1970s led farmers and the general public to become increasingly concerned about the effect(s) of afforestation on the water resources and the environment during this period (Anon, 1973; Hinze, 2004; Olivier, 2009).

2.2 Current distribution of plantation forestry in South Africa

Forestry plantations currently cover approximately 1.26 million ha of the country and over 80 % of them occur in the three Provinces of Mpumalanga, KwaZulu-Natal and the Eastern Cape. Approximately 68 % of the area covered by plantation estates in South Africa is planted with exotic tree species. The balance of these estates contains natural vegetation, including natural forests that have to be protected. The applicable mechanisms for the protection of such natural forests are Forest Management Unit (FMU) forest protection plans. All forestry plantations in South Africa which have achieved Forestry Stewardship Council (FSC) certification (82 % of all plantation estates) have FMU plans. This means that currently, sustainable plantation management is practiced on at least 82 % of the total area of forestry plantations. This is the highest percentage of certified plantations in the world. Figure 2.1 below shows the FSC certified plantations by ownership percentage. Most of the South Africa’s larger plantations have been leased and the remaining smaller plantations (about 61 183. 4 ha) are still managed by the government (DWAF, 2008).

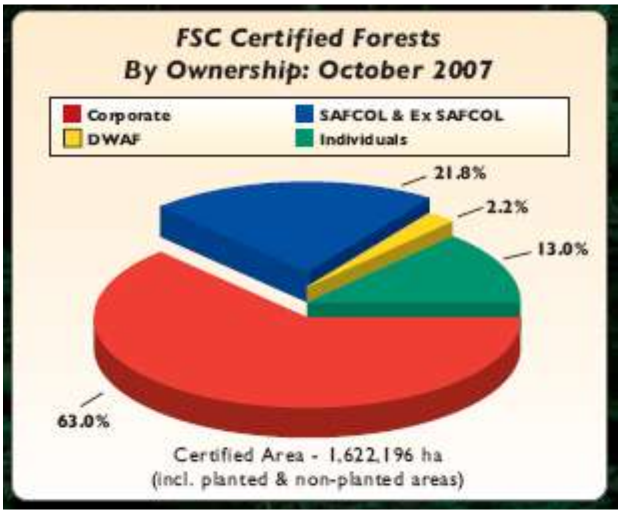

Figure 2.1: FSC certified forests by ownership (Department of Water Affairs and Forestry, 2008).

Although forestry plantations constitute a relatively small percentage of the total land area of South Africa, in 2007 it contributed R22 billion *per annum* to the Gross Domestic Product (GDP) (DWAF, 2008). According to DWAF (2008), forestry plantations produce more than 22 million cubic meters of round wood worth an estimated R5.1 billion annually and this sector is also a net exporter of goods, with exports of forest products valued at R12.2 billion *per annum*, whereas imports total only R9.8 billion. The constitution, composition and distribution of these commercial forestry plantations are shown in the tables below (Tables 2.2 and 2.3).

Table 2.2: Plantation area by species/ownership (Department of Water Affairs and Forestry, 2008).

Species	Ownership 2006/07			Percent Privately Owned	Percent Publicly Owned
	Private	Public	Total		
	Hectares				
Softwood	513 587	163 492	677 079	75.9 %	24.1 %
E. grandis	234 920	34 274	269 193	87.3 %	12.7 %
Other Gum	197 391	11 121	208 511	94.7 %	5.3 %
Wattle	98 912	4 106	103 018	96.0 %	4,0 %
Other	6 414	1 979	8 393	76.4 %	23.6 %
Total	**1 051 223**	**214 971**	**1 266 194**	**83,0 %**	**17.0 %**

Table 2.3: Plantation area by Province/ownership (Department of Water Affairs and Forestry, 2008).

Province	Ownership 2006/07			Percent Privately Owned	Percent Publicly Owned
	Private	Public	Total		
	Hectares				
Limpopo	25 403	22 693	48 096	52.8 %	47.2 %
Mpumalanga	386 533	128 297	514 830	75.1 %	24.9 %
NW Province	0	126	101	0,0 %	100.0 %
Gauteng	0	0	0	0,0 %	0,0 %
Free State	0	0	0	0,0 %	0,0 %
KZN	454 721	32 245	486 966	93.4 %	6.6 %
E Cape	124 030	31 049	155 079	80.0 %	20.0 %
N Cape	0	0	0	0,0 %	0,0 %
W Cape	60 535	562	61 097	99.1 %	0.9 %
Total R.S.A	**1 051 222**	**214 972**	**1 266 194**	**83,0 %**	**17,0 %**

There is also a recent rapid development of black ownership and management in the form of out grower timber schemes, which registered with the Forest Stewardship Council (FSC). Out grower timber schemes are community-based plantations, normally in the form of small woodlots occurring in patches operated by private companies such as Mondi, Sappi and the SA Wattle Growers Union. Most of the out grower timber schemes that collaborate with the FSC are sustainable managed to ensure that the customers especially the large buyers of timber buy timber from sustainably managed forest operations.

2.3 History of forestry plantations as a form of water use

2.3.1 1900 – 1970s

Van der Zel (1995) provides a history of the forestry and water use debate for South Africa. His report suggests that conflict over decreases in runoff following afforestation first arose in South Africa in 1915. The expansion of the area for commercial afforestation in the first half of the past Century led to the initiation of forest hydrological research following the 1935 Empire Forestry Conference in South Africa (Wicht, 1965). This initiative resulted in the establishment of the Jonkershoek Forest Hydrological Research Station in 1935, followed by stations at Cathedral Peak in 1945 and Mokobulaan in 1955. However, despite the initiation of these research programmes, the two world wars overshadowed the conflicts over water use and afforestation. But the severe drought of the 1960s once again brought the matter to the fore.

In 1966, two committees were appointed to investigate the effect(s) of afforestation on water supplies. According to Water Matters Committee (1970), the findings of the first committee published in 1968 recommended that forestry be allowed to develop freely, except in areas where water resources were already “committed” and development could be threatened, until natural and economic checks became effective (van der Zel, 1995). The 1970 report of the second committee, recommended that where expansion of afforestation was endangering established irrigation or other water utilization developments, restrictions should be imposed (Water Matters Committee, 1970). The findings and recommendations of these two committees were incorporated in an amendment of the Forest Act (Act No. 72 of 1968) by adding specific articles on the Control of Afforestation. These required timber growers to apply for permits to establish commercial plantations on new land or sections of land, which, after harvesting, had not been planted with trees for a period exceeding five years (van der Zel, 1995). This legislation became known as the Afforestation Permit System (APS) and determined where, when and in what quantities trees could be planted by the allocation of planting permits. The basis of the APS was a series of curves developed by Nänni (1970), which related streamflow reduction to afforestation.

2.3.2 The 1980s

In 1986, the Department of Water Affairs (DWA) published “Management of the Water Resources of the Republic of South Africa”, a comprehensive report on the management of the country’s water resources at the time. This report also provided estimates of water availability and water use in South Africa, with the provision that all figures should be considered provisional, as they were constantly being revised and updated. At the time, DWAF estimated that the mean annual total runoff for South Africa was 53 500 million m^3, but that only 33 000 million m^3 could be considered exploitable. The estimate of the country’s mean annual runoff was derived by combining estimates obtained by an analysis of runoff records obtained from gauging stations in each of the country’s 22 drainage regions and “naturalizing” them to obtain an estimate of virgin runoff (*i.e*. runoff that may be expected if the impact of man is not considered). By using measured runoff as the basis of these estimates, it was assumed that evaporation losses were accounted for. Prior to 1970, estimates of total national water use were expressed as the sum of direct uses that were physically supplied by water works. Since 1970, first afforestation, and subsequently ecological water requirements have been considered as indirect water uses. Indirect water use must be estimated as it obviously cannot be measured. The 1986 a DWA publication estimated the country’s total water use in 1980 to be 16 291 million m^3, and the “forestry runoff reduction” to be 1 284 million m^3, or 7.9 % of South Africa’s total water use in 1980. This seems to be the first appearance of the 8 % value. However, it must be noted that this value equates to a 2.4 % reduction of total runoff. Clearly, it is important to make the distinction between a contribution to total water use and runoff reduction. The estimate of water use by forestry was calculated from estimates of plantation water use per drainage region according to the curves developed by Nänni in 1970.

The limited data base from which the Nänni Curves were developed became a major source of concern. These curves were developed from experimental results for one tree species, viz. *Pinus patula* at a single site. The original land cover was assumed to be grassland and the catchment under consideration was assumed to be in pristine condition. Furthermore, restrictions on forestry were based on expected impacts on mean annual flows, rather than on low season flows around which most conflict arose. The Nänni Curves were subsequently improved upon by the incorporation of additional catchment experimental data from the USA and elsewhere - a revision which resulted in the publication of the “van der Zel Curves” (van der Zel, 1990), which replaced the Nänni Curves as the basis of the APS. Further discussion about the APS is highlighted in the section on legislation below.

2.3.3 The 1990s

In the early 1990s, South Africa, being a water-stressed country, opted for a new approach in water demand management. The approach aimed at meeting water demand by making its use more efficient and by putting water to more productive uses (Gleick, 2000; Tewari, 2005). In 1995, the Green Paper on Sustainable Forest Development in South Africa stated that “Currently, commercial forestry plantations are estimated to reduce available surface water by about 3.5 % (equating to about 7.6 % of total current demand).” These values were absent when the green paper became a white paper, but obviously, a value of approximately 8 % was still reflected as the water use by commercial forestry. The recognition of the significance of low flows when managing water resources, the need to account for differences in climate, tree species and forest management practices, and the availability of updated catchment forestry data, led to the development of a further set of runoff reduction curves - the so-called CSIR curves (Scott and Smith, 1997). These curves were derived from the results of five paired catchment experiments in four different forestry regions of South Africa, and reflected runoff reductions from observations following planting (Le Maitre, 2002). These generalized curves expressed a percentage reduction of mean annual runoff and “low flows”. *Pinus spp*. were distinguished from *Eucalyptus spp*. (Eucalypts), and separate curves were derived for “optimal” tree-growing sites as opposed to “sub-optimal”.

In 1998, an estimate of national water use by commercial forestry was provided by Scott *et al*. (1998). This estimate is generally considered the most accurate estimate of all available national estimates thus far. It provides an estimate of 1 420 million m³, which is an increase from the 1 280 million m³ value provided by the DWAF in 1986. Scott *et al*. (1998) estimated that total runoff reduction was 3.2 % and the reduction in low flows was 7.8 %, but pointed out that they had revised the estimate of mean reduction per unit plantation downward and that the increase in total water use was a result of the increased area of commercial forestry. These estimates are dependent upon an accurate estimate of the area of commercial forestry in the country. It is likely that the estimates were not entirely accurate, but the estimate of 1 462 000 ha was accepted as the best available at the time, and given that the development of a comprehensive database developed from former DWAF and forest industry sources is unlikely, it will continue to form the basis of estimates of water use by commercial forestry in South Africa.

2.3.4 Post 2000

In 2002, the former Department of Water Affairs and Forestry (DWAF) summarized South African's water availability as 56 000 million m³ *per annum*, with 50 000 million m³ considered runoff and 6 000 million m³ from groundwater resources. The total water requirement estimate for all users, including "the environment" in the form of Instream Flow Requirements (IFR), is 21 000 million m³ (South Africa Yearbook, 2001/02). The basis for these estimates varies according to the water user. Estimates of commercial forestry are based on the curves derived by Scott and Smith (1997). IFR are estimated from a model developed by Hughes *et al*. (1998). Industrial, domestic and irrigation water use is estimated according to existing water use licenses. The estimate for forestry water use is 1 680 million m³ of water (Gush *et al,* 2001). This is an increase over the estimate of Scott *et al*. (1998), who estimate a value of 1 368 million m³, but later there was an increase of 27 % that has occurred in the area occupied by forestry.

Using an estimate that forestry extracts an amount of 1 680 million m³ from the national water use *per annum* (*i.e*. 2 100 million m³) results in the conclusion that forestry accounts for 8 % of the country's total water use and reduces total runoff by 3.3 %. It is pertinent to highlight at this stage that, given the ongoing and sustained research into the water use of commercial forestry in South Africa, the estimates of forestry water use may be more accurate than those of the other sectors, as well as the estimates for the impact on national runoff (Scott *et al*., 1998). In terms of allocating water use licenses under the National Water Act (Act 36 of 1998) it is quite clear that at least two other factors must be considered. First, large areas of commercial forestry are found in the high rainfall and associated high runoff areas of the country, and the runoff reduction in these areas will be higher than average national figures. Second, these values must vary according to whether the period under consideration is considered wet, dry or just "average". To this end, the most recent and comprehensive study of water use by forestry on a national basis (Gush *et al*., 2001) makes no attempt to provide a national estimate of water use by forestry. This was based on a comprehensive modelling exercise where, following extensive verification on gauged catchments, the Agricultural Catchments, the Agricultural Catchments Research Unit's (ACRU) Agrohydrological model was used to provide unique tables of estimated annual and low flow runoff reduction for three different three different tree types (*Eucalyptus spp.*, *Pinus spp*. and *Acacia* species) for shallow, medium and deep soils, for each quaternary catchment in the country with Mean Annual Precipitation (MAP) greater than 650 mm as such, provides a fairer basis for the regulation of commercial water use (Table 2.1). Estimated streamflow reductions per unit area of forestry, relative to an Acocks Veld Type baseline, range between 50 and 150 mm for *Eucalyptus spp.* and between 50 and 100 mm for *Pinus spp.* (Pines) and *Acacia* (Wattle) genus trees, respectively. Reductions in low flows range from 5 to 15 mm, but often reflect a relative reduction of over 90 %. Streamflow reductions for both annual and low flows can then be calculated per quaternary catchment according to the area under forestry in that catchment.

2.4 Impact of plantation forestry on the water cycle

South Africa is not blessed with an overabundance of natural forests and it relies heavily on commercial plantations for its timber. Furthermore, South Africa is being considered as semi-arid region. Raw material projections for timber in all its forms (including fibre, board and paper) for the future indicate a required growth rate of the South African forestry industry of 70 %, or 25 000 ha *per annum*, over the next 20 years (Schulze *et al*., 1995). This equates to the increase of 39 000 ha to a total of 1.8 million ha by the end of the 20^{th} Century. The question is whether South Africa will be able to provide such an area, which is climatically and physiographically suitable for forestry, without a drastic reduction of surface runoff (Schulze *et al*., 1995).

Previous research has shown that stream flow is adversely affected by the increased afforestation of catchments. Thus there is conflict between *in situ* use of rainfall for timber production, and downstream demands for irrigation, industrial and domestic use. The increasing afforestation of marginal land using improved site preparation techniques has exacerbated this problem (Schulze *et al*., 1995).

Table 2.4: Summary of the areas of the basic forestry types in South Africa in relation to annual rainfall (Scott *et al*., 1998).

Plantation Type	**Annual Rainfall**	**Area**	
		Ha	**Percent**
Acacia species (Wattle)	<800	9009	8.12
	800-1000	94999	85.58
	>1000	6995	6.30
Total Wattle		**111003**	
Pinus spp. (Pines)	<800	109738	13.38
	800-1000	434820	53.04
	>1000	275337	33.58
Total Pine		**819895**	
Eucalyptus spp.	<800	31414	6.12
	800-1000	338529	66.93
	>1000	135842	26.85
Total *Eucalyptus*		**505785**	
All species	<800	150161	10.45
	800-1000	868348	60.44
	>1000	418174	29.11
Total		**1436683**	

A change in land cover from grassland, or agriculture use, to forestry can affect various hydrological responses. Compared for example with grasslands, commercial forests provide:

- A greater surface area for canopy interception as well as for re-evaporation and transpiration of water;
- Evergreen surfaces can transpire throughout the year;
- Deeper root systems enable trees to survive when shallower rooted grasslands are water stressed;;
- A protective litter layer affects various hydrological process such as runoff, evaporation and *etc* (Schulze *et al*., 1995).

2.5 The effect of Invasive plants on water use

An alien species is a species, sub-species or member of a lower taxon that has been introduced outside its normal past and present distribution; the definition includes the gametes, seeds, eggs, propagules or any other part of such species that might survive and subsequently reproduce (GISP, 2008). Also an invasive alien species is an alien species which becomes established in natural or semi-natural ecosystems or habitats. Importantly, it is an agent of change and threatens native biological diversity (IUCN, 2000). According to Sharma (2008), this is the kind of species that is able to move aggressively into a habitat and monopolize resources such as light, nutrients, water and space to the detriment of other species. An invasive species typical of a forest ecosystem is referred as a Forest Invasive Species (FIS).

The lack of a natural source of fast growing timber led to the establishment of forestry plantations of alien species, beginning in the 19th Century. Forestry plantations of alien trees, primarily *Pinus spp.* and *Eucalyptus spp.*, now cover 1.52 million ha in South Africa (FOA, 1998). These plantations have brought many benefits. Forestry plantation contributed R2400 million, or 2 %, to the GDP and employed over 100 000 people in 2002. Downstream industries, based on forestry, produced products worth a further R12.8 billion (at an exchange rate of R8 to $1), much of which was exported and earns valuable foreign exchange (FOA, 1998; Le Maitre *et al*., 2002).

The problem of invasive alien trees is that if they are not properly managed they spread very quickly, and compete with the indigenous vegetation. They invade catchment areas that might not have enough water to support the indigenous vegetation that is already there. Invasive alien plants are a huge problem in South Africa, affecting almost 10 million hectares (8.28 %) of the country, and spreading rapidly. Thus, these invasions come at a considerable cost to our economy and our environment, and they affect the lives of all South Africans, either directly or indirectly (Jordan, 1998). Therefore, in South Africa, growing invasive alien species, which include some species that are used in forestry, raises some concerns. For example, South Africa is a semi-arid country, it has been estimated that IAPs cause the loss of almost 7 % of the annual flow in South Africa's rivers each year (Versfeld *et al*., 1998). In terms of water resource management these species are, therefore, highlighted as posing a threat to semi- arid regions such as South Africa. Much of the focus of management in this regard has been on IAPS growing in riparian zones, where it is believed that plants transpire more water than their counterparts elsewhere in the catchment (Mack and d'Antonio, 1998; Dye *et al*., 2000).

2.6 Effects of site preparation for plantation forestry

Site preparation involves disrupting the soil. The extent to which site preparation affects hydrological responses depends upon its intensity and the method used. Site preparation has an impact on the following hydrological processes:

- The amount of water that may infiltrate into the soil and the rate at which it does depend upon the intensity of site preparation. Ploughing or ripping of the soil surface is likely to increase the permeability and facilitate a higher proportion of rainfall to enter the soil.
- The movement of soil water is likely to be affected by ripping, which breaks down the soil structure. Thus the rate at which water is redistributed from the top- to the subsoil when soil water content in the topsoil exceeds that of the subsoil, is likely to increase following a deep rip.
- Tilling of the soil has significantly influences the soil water retention at porosity that is saturation content of the soil. Thus, intensive site preparation will increase the porosity of the tilled soil horizons at the afforested site, a factor which will decrease stormflow potential (Schulze *et al*., 1995).

The sitting of a forestry plantation within a catchment may be particularly important for production (Bosch and von Gadow, 1990; Schulze *et al*., 1995). Schulze *et al*., 1995 also suggested that plantations on the valley floors are likely to have a greater impact on streamflow than plantations on the hill tops. Bosch and von Gadow, (1990) believed that good site quality and subsequent high leaf areas in the valley bottoms would result in high total evaporation, especially when considering the higher moisture levels present on the valley floor due to lateral soil moisture movement. Bosch and von Gadow, (1990) also suggest that a catchment can be divided into high and low productive areas, coinciding roughly with areas of high and low total evaporation, when considering the potential afforestation of a catchment.

2.7 Effects of tree species and age on water use

The most common commercial plantation trees in Southern Africa are those of the *Eucalyptus spp.*, *Pinus spp.* and *Acacia* genera. These genera have different characteristics in terms of water usage, leaf attributes, and litter build up. The decrease in water yield following afforestation is directly proportional to growth rate of a certain tree species (Schulze *et al*., 1995).

Forest hydrologists in South Africa agree that *Eucalyptus spp*. has the highest consumptive use of water for the genera highlighted above. The pine species have the lowest use of water by virtue of their needle like leaf structure. Pines are generally more conservative water users and reduce transpiration rates at higher soil water contents than trees of either *Eucalyptus spp*. or *Acacia* genera (Schulze *et al*., 1995).

Smith (1991) as quoted by Schulze *et al*., (2001) suggest that catchments planted to *Eucalyptus spp*. show the negative effects on stream flow from the third year of tree growth onwards, while the pines exhibit from the fifth year onwards. After eight years, genera differences decreases as the pine stands become well established. This also confirms that the effect of afforestation to *Eucalyptus spp*. (90-100 %) stream flow reductions is far greater than that of *Pinus spp*. (40-60 %) in the first eight years after changing the land use (Schulze *et al*., 2001).

Water use by wattle is estimated to lie between that of *Eucalyptus spp*. and *Pinus spp.*, although *Acacia* is capable of extracting soil water at the same rates as *Eucalyptus spp*. Despite these relative water use differences, indications are that water use by different genera may more or less equal out over an entire rotation period (Schulze *et al*., 2001). The density of the tree's canopy will also affect the amount of rainfall intercepted at canopy level. Mature *Pinus* have a very dense canopy and by virtue of the high surface tension of the needles, they have the highest value of interception loss. In general, the older the tree, the denser it's canopy, irrespective of genus, and thus the higher the interception loss (Schulze *et al*., 1995).

The thickness and nature of the litter layer on the forest floor will differ according to both genus and age. In *Acacia*, the litter build up is virtually absent. *Pinus* plantations exhibit a large litter build up particularly in cool areas where the decomposition of needles is slow. *Eucalyptus spp*. show a moderate build up of litter, depending on climatic conditions. In general the older the plantation, the greater the build up litter and higher the litter interception is likely to be. The distribution of the roots also differs with both age and genus. Rooting distribution changes as trees mature and it will be affected by the method of site preparation (Schulze *et al*., 1995).

According to Van Lill *et al*. (1980, cited by Schulze *et al*., 2001) the maximum reduction in annual flow due to afforestation with *Eucalyptus spp*. is between 300-380 mm *per annum*, while stands of mature *Pinus spp*. can use about 300-600 mm *per annum* of rainfall. In areas where the annual runoff is less than 300 m, afforestation of a headwater catchment is expected to cause streamflow to cease completely (Schulze *et al*., 2001). The effect of forestry plantations or invasive alien species on streamflow in riparian zones is even more severe.

2.8 Impacts of plantation forests on biodiversity

Forestry plantations have negative impacts on biodiversity because they are always planted in areas where they replace native grassland or woodland (indigenous forest) habitat. Many grassland ecosystems, for example, are rich in endemic species; in the Mpumalanga Province of South Africa, the expansion of commercial plantations (*Eucalyptus spp*. and *Pinus spp*.) has led to significant declines in several endemic and threatened species of grassland birds (Allan *et al.*, 1997).

South Africa is rated third among the countries in the world richest in biological diversity (mega diverse countries). A substantial portion of this biodiversity is represented by species occurring in forests and woodlands (including thickets) and the diversity of plant communities within these biomes. The forest biome exhibits a high plant species diversity per unit area and therefore plays a substantial role in contributing towards national conservation targets. There is limited information on the value attached to the ecosystem services of South Africa's forests and where some estimates have been made, they have not apportioned what fraction of the benefits is captured exclusively or primarily by rural communities and what proportion by society at large. However, such services are of importance to the rural poor, in part as the related costs are borne disproportionately by such people. Society, at large, can, however, benefit from the role forests play in climate change.

Commercial forestry and water yield is a significant issue in a 'dry' country like South Africa. Commercial forest plantations cover 1.2 % of the total area of South Africa, but reduce the total mean annual stream flow by about 2.7 %. Pulp and paper mills are the largest users of water (± 250 million m^3 *per annum*) among the forest industry processing plants and also produce the largest volume of waste (GCIS, 2004). Generally, plantation forestry can have positive effects on water quality, when well managed, by reducing surface run-off, evaporation and loss of topsoil. However, poor management of certain forest operations (*e.g*. road construction, timber extraction and site preparation) can result in large qualities of suspended sediment being discharged into river systems. Plantation fires, although infrequent, can also result in the release of sediments to streams raising sediment yields by up to 20 times (Schulze *et al*., 2001).

2.9 Plantation forestry and the riparian zone

Riparian zones are physically dynamic areas where changes in stream flow, especially during floods, can alter river beds by exposing bare soil for colonization by weeds. They are the transition areas between water and riparian vegetation and adjacent vegetation, which often are important for their high biodiversity (Versfeld *et al*., 1998). However, riparian zones are also prone to invasions because they are long and narrow and vulnerable to the impact of changes in landuse and cover in adjacent areas.

Many plantation species have become major invaders, by invading riverine areas and using waterways to distribute their seeds far beyond the afforested areas. The forest industry is aware of these problems and subscribe to a code of conduct which, among other things, requires that riparian zones and non-afforested areas within the forest estates are kept clear of invading alien plant species (Mondlane *et al*., 2001). The purpose of this is to reduce the risk of soil erosion close to the stream channel, and to decrease the water use by the invading species. In South Africa about 10.1 million ha or 6.8 % of the country is invaded by alien species to some degree (Mondlane *et al*., 2001). It is suspected that forestry plantations growing in riparian zones have direct access to water and can use water at substantially enhanced rates. According to Le Maitre *et al*. (2000, cited by Mondlane *et al*., 2001) invasions are estimated to use almost 6.7 % of the country's runoff. Exotic, invasive tree species are rapidly spreading into riparian areas, eventually forming dense thickets, which are expensive to eradicate. Researchers such as Dye & Poulter (1995) and Mondlane *et al*. (2001) have concluded that streamflow in afforested catchments are sensitive to the presence or absence of invasive, exotic trees in riparian zones, and that a significant increase in streamflow may be expected when dense thickets of such trees are removed. Currently afforestation licenses require that zones of 30 m on either side of streams and 50 m around vleis or standing water be not planted. This limitation is based on theory that trees in these zones will use a disproportionately greater amount of water because of its greater availability (Scott & Smith, 1997 and RSA-NWA, 1998).

2.10 Relevant legislation on forestry

2.10.1 The National Water Act (Act 36 of 1998)

Forestry plantation is the only Stream Flow Reduction Activity (SFRA) declared in terms of the National Water Act (Act 36 of 1998). According to the Act, SFRA is regarded as any activity that diminishes the potential of a water resource to support any further incremental usage. According to the National Water Act, the use of land for forestry is regarded as a Stream Flow Reduction Activity (SFRA) and it is clearly identified as a water use (Section 21(d)). A SFRA is any dryland use practice, which reduces the yield of water (with reference to yield from natural veld in undisturbed conditions) from that land to downstream users. Such activities may be declared as SFRAs if they are found to be significant. The significance is judged relative to the demands for water in that region. Whether or not an activity is declared to be a SFRA depends on various factors, such as the extent of stream flow reduction, its duration, and its impact on water resources. The National Water Act (Act 36 of 1998) makes forestry liable to pay for their water use as a stream flow reduction activity (RSA, 1998).

The NWA requires any water use to have a license. Furthermore, the National Forest Act (No. 84 of 1998) requires the plantation of forests to be licensed in terms of the National Water Act (Act 36 of 1998) and these should meet prescribed minimum standards of sustainable forest management. The Water-use licenses for any SFRA are issued for the periods of up to a maximum of 40 years and are reviewed, at least, every five years. The license is not transferable to another property except in the way determined by NWA, and succeeds to any new owner, lessee or occupier of the land (DWAF, 1999).

There is history behind the issuing of water-use licenses in South Africa. It dates back to 1932 when the then Department of Forestry began to restrict afforestation close to perennial streams and other surface water sources in an attempt to conserve and management water for forestry purposes. Subsequently, all new afforestation was subject to restriction in instances where national water resources required protection. These policies were eventually enforced through the Afforestation Permit System (APS) under the 1972 amendment (Act 46 of 1972) of the Forest Act of 1968 (DWAF, 2000).

It took about 26 years for the South African commercial forestry industry to be subjected to the Afforestation Permit System which limits planting of new land to commercial timber (Scott *et al*., 1998 and Van Der Zel, 1995). The Forest Act (Act 46 of 1972) through the Afforestation Permit System (APS) has required timber growers to apply for permits to establish commercial plantation on new land or section of the land which, after harvest, has not been planted to trees for a period exceeding five years. The APS was designed to ensure that forestry (post- 1972) used no more than a pre-determined percentage of the water in a catchment by requiring land owners to obtain permits to establish a new plantation (Scott *et al*., 1998). Such an application could then be rejected on the grounds that afforestation would use an unacceptably high proportion of water in a catchment (Smith and Scott, 1997).

The first impacts of forestry plantations on stream flow were estimated for APS using a modification of a simple but robust model of plantation water use developed by Nanni. The reductions in Mean Annual Runoff (MAR) can be read directly from the curves if the mean annual rainfall or MAR of the catchment concern is known (Scott *et al*., 1998 and Van der Zel, 1995).

About 500 000 ha of forestry plantations have been authorized through this measure (DWAF, 1999). This means that more than 4 300 afforestation permits have been handled using this system. About one million hectares of forestry plantations had been established prior to the implementation of the requirements for the permits. Parts of these areas were allocated in former homelands, where no permits were required. That is, the APS was not applicable to former homelands, although these areas had indicated that they would adhere to afforestation control in the same spirit as that prevailing in South Africa (Van der Zel, 1995).

Through the APS, new plantations (about 500 000 ha) have been kept at least 20 m away from perennial streams and wetlands. The APS also contributed towards silviculture, which is about cultivation and management of forest trees and tree breeding research aimed at obtaining more volume per hectare by using far less water (Van der Zel, 1995). According to Van der Zel (1995) and Schulze *et al*. (1995), South African catchments were divided into three categories through the Afforestation Permit System as follows:

- Category 1: these are the catchments where no new afforestation has been permitted since 1972. These areas include the White River and Letaba catchments in the former Eastern Transvaal.
- Category 2: these catchments are those in which competing water demands limit new afforestation to areas that will not reduce the catchments Mean Annual Runoff (MAR), as estimated in 1972, by more than five percent.
- Category 3: comprise the remainder of the catchments not categorized in 1 or 2. The new afforestation is permitted, provided it will not impact on the 1972 estimate of MAR by more than ten percent.

The institution of the APS has taken afforestation out of the emotional and political arena into the scientifically based arena. This system (APS) has several shortcomings. Firstly, it is important to note that the Nanni Curves were developed or based on limited data. The curves were developed from experimental results for one tree species, namely *Pinus patula*, at a single site. Therefore Nanni curves are unable to predict adequately the water usage of *Eucalyptus spp*. for such short rotation periods. Furthermore, the effects of coppicing cannot be accounted for by the Nanni Curves. These curves also assume the existing vegetation to have a stable water use over time (Van der Zel, 1995). Restrictions on forestry plantations have, in the past, been based on expected impacts on mean annual flows, rather than on low season flows. This is impractical since it is the period of low flow, which is actually critical to water resource planning (Schulze *et al*., 1995 and Van der Zel, 1995).

Furthermore, the Afforestation Permit System didn't require any forest management practices. It was applied to primary catchments. If the accumulated coverage of afforestation in primary catchment is not judged to reduce streamflow by the specified amount, a permit may be granted, despite the possibility that this may result in the almost total afforestation of a minor catchment. The quaternary catchment units are realistic and practical sizes to consider. Another limitation of this system was that the APS did not address the question of whom the water was being saved for. Forestry was simply restricted to save water for other users, without questioning whether these users would be able to offer more of a "productive or beneficial" return for that water allocation and even if these users were less "productive" that water still had to be reserved.

As result of the above shortcomings, the previous minister of Water Affairs and Forestry (Prof. Kader Asmal) introduced a new procedure for the APS, known as the Stream Flow Reduction Activity (SFRA), which is any dryland land use practice that reduces the yield of water from that land to downstream users. SFRA is regulated by means of a licensing system in terms of Chapter 4, Section 36 of the National Water Act (NWA; Act 36 of 1998) (DWAF, 1999). The NWA requires any water use to be "licensed unless it is listed in Schedule 1; is an existing lawful use; is permissible under a general authorisation; or if a responsible authority waives the need for a licence" (Section 22). In the case of an activity being declared an SFRA it then becomes a water use. Existing use will have to be registered but not licensed (it will eventually be licensed along with all other water users under the Compulsory Licensing Programme). Any expansion of the activity will be a new water use and will require licensing unless excluded under any of the above provisions.

In South Africa it is clear from the National Water Resource Strategy (NWRS), which looks more closely at resource availability in Water Management Area (WMA) and catchment scale that most catchments are under water stress (DWAF, 2004). Any further decline in availability of water would be significant in these catchments.

2.10.2 Agricultural legislation

According to Conservation of Agricultural Resources Act (CARA) (Act 43 of 1983), Section 6, Control Measures: "in order to achieve the objects of this Act the Minister may prescribe control measures, which shall be complied with by land uses to whom they apply". Such control measures exist for the activities such as afforestation and they are regulated as follows:-

Regulation 2: Cultivation of virgin soil, written permission is required from the Department of Agriculture (DoA) if a land user wants to cultivate any virgin soil. However, this authorisation is not required in respect of virgin land for which an approval has been granted in terms of Section 4A of the Forest Act (Act No 68 of 1972). This Act was repealed and this authorisation is now issued for forestry in terms of section 21(d) of the NWA (RSA, 1998a).

Regulation 3: Cultivation of land with a slope, written permission is required from the DoA if a land user wishes to cultivate land with a slope of more than 20 % and even stricter control is implemented for land with a slope of more than 12 %. CARA provides guidelines for the control of the above mention activity (RSA, 1983).

Regulation 7: Utilisation and protection of vleis, marshes, water sponges and water-courses. Land users may not utilise the vegetation in a vlei, marsh or water sponge or within the flood area of a watercourse or within 10 m horizontally outside the flood area in a manner that causes or may cause the deterioration of or damage to the natural agricultural resources. The written permission is required from the DoA if the land user wishes to-

- drain or cultivate any vlei, marsh or water sponge or a portion thereof on his farm unit; or
- cultivate any land on his farm unit within the flood area of a watercourse or within 10 m horizontally outside the flood area of a watercourse.

The DoA authorisations therefore also address the distance that the applicant may plant from a watercourse.

Regulation 13: Restoration and reclamation of eroded land, in terms of this regulation, every land user must take as many of the measures set out in regulations (4), (5) and (9) as are necessary in their situation, to effectively restore or reclaim land on their farm unit on which excessive soil loss due to erosion occurs or has occurred. According to CARA, additional measures, greater than those prescribed, may also be required (RSA, 1983). This regulation is also applicable on land for which afforestation is proposed.

Regulation 15: Declared weeds and invader plants, this regulation in the original Act (CARA) was repealed by Government Notice R22166 of 30 March 2001. The new regulation categorizes invader plants and has certain requirements in terms of the various categories. Detailed information for each declared invader plant or weed species is provided in a table with plant name, plant type, (i.e. weeds or invaders), the category, applicable control measure, and special conditions for each species.

Category 2 plants are plants that are useful for commercial plant production purposes but are proven plant invaders under uncontrolled conditions outside demarcated areas. Species from the *Pinus spp.*, *Eucalyptus spp.* and *Acacia* genus are categorized under this group.

2.10.3 Environmental and developmental legislation

Any proposal for changing land use like afforestation requires an Environmental Impact Assessment (EIA) in terms of the National Environmental Management Act (NEMA) (Act 107 of 1998) (RSA, 1998b). Anyone proposing afforestation needs to satisfy a diverse range of statutes in order to get permission for this activity (DWAF, 1999). The National Department of Environment Affairs and Tourism (DEAT) and Provincial Departments of Environment Affairs (PDEA) administer the National Environmental Management Act (NEMA) (Act 107 of 1998). The aim of NEMA is to provide for co-operative environmental governance. In terms of SFRA, the provincial and conservation authorities have a role to play in the management, protection and regulation of the ecological environment. This role and mandate would, however, also link to the functions of other Departments responsible for environmental resources. An example of such acts is the Mpumalanga Nature Conservation Act (Act No 10 of 1998).

Listed activities in terms of Section 24(5) of NEMA read with Section 44 of NEMA were published on 21 April 2006 as the Government Notice (GN) No. 386 and 387 (DEAT, 2006). GN No. 386 lists activities for which a basic assessment is required and procedures to be followed as described in EIA regulations 22-26 (2006) were promulgated in terms of Section 24(5) of the NEMA. While GN No. 387 lists activities for which a comprehensive assessment (*i.e*. scoping and EIA) is required and the procedures that have to be followed as described in EIA regulations 27-36 (2006) was promulgated in terms of Section 24(5) of the Act.

The following activities are relevant to SFRAs and require authorisation in terms of NEMA. Firstly, the authorizing process is determined by the scale of the proposed activity, and would either be a basic assessment process, or a scoping/EIA process. For the basic assessment process, the transformation or removal of indigenous vegetation including grassland or any indigenous plant cover, from areas of 3 ha or more, or for areas of any size where the transformation or removal is within a critically endangered or an endangered ecosystem listed in terms of Section 52 of the National Environmental Management: Biodiversity Act (NEMBA) (Act10 of 2004) (RSA, 2004). This means that, in terms of NEMA, a basic assessment is required if the area to be transformed by afforestation is currently composed of indigenous vegetation, and larger than 3ha. If the area to be transformed is an endangered or critically endangered ecosystem, then development or transformation of any size (in terms of hectares) would require authorisation.

Secondly, even if it is the transformation of undeveloped, vacant or derelict land (even if it is no longer virgin land) to residential, mixed, retail, commercial, industrial or institutional use, where such development does not constitute infill and where the total area to be transformed is bigger than one (1 ha) hectare, a basic assessment must be undertaken. This means that, should the applicant propose to transform any undeveloped, vacant, or derelict land to afforestation, regardless of whether it is virgin land or under indigenous vegetation, a basic assessment must be undertaken for all areas larger than 1 ha. According to the Western Cape Environmental Authority's guideline (2006) on the interpretation of the listed activities, land is regarded as undeveloped, vacant or derelict in circumstances where such land has, at no time during the preceding nine (9) years, been lawfully developed, occupied or zoned for the purpose of residential, mixed retail, commercial, industrial or institutional use. According to this guideline, this definition is also applicable to cultivation.

The scoping/EIA process is for any development activity, including associated structures and infrastructure, where the total area of the developed area is, or is intended to be, 20 ha or more. A scoping/EIA is therefore required for all proposed afforestation projects larger than 20 ha. National Environmental Management Biodiversity Act (Act 10 of 2004)**,** section 52 of this Act lists the critically endangered or endangered ecosystems for which a basic assessment is required irrespective of the size of the area proposed for afforestation.

National Heritage Resources Act (Act 25 1999)**,** a heritage resource in terms of this Act is any place or object of cultural significance. The Act aims to introduce an integrated and interactive system for the management of national heritage resources and to promote good governance of these resources at all levels. Its aim is to empower civil society to nurture and conserve their heritage resources so that they may be bequeathed to future generations. The Act lays down general principles governing heritage resources management throughout the Republic and also introduces an integrated system for their identification, assessment, and management. It also sets norms and maintains essential national standards for the management and protection of heritage resources. Therefore this Act also requires assessment in an area proposed for afforestation.

At a local level, decisions on land based development activities in an area are strongly influenced by statues such as the Development Facilitation Act (Act 67 of 1995). The Development Facilitation Act (Act 67 of 1995) requires principle based local development planning, with Land Development Objectives as an output. It is important to note that the Integrated Development Programme (IDP) Manual specifies the NWA as one of several statutes that must be considered by local authorities when developing their plans (DWAF, 1999).

2.10.4 Forestry legislation

The purpose of the National Forests Act (NFA) (Act 84 of 1998) is to promote the sustainable management and development of forests for the benefit of all. In terms of section 4, the NFA promotes the development of criteria to determine whether sustainable management occurs, indicators to measure the state of management, and appropriate standards in relation to the indicators. The NFA further aims to provide special measures for the protection of certain forests and trees, but it also promotes the sustainable use of forests for environmental, economic, educational, recreational, cultural, health and spiritual purposes (RSA, 1998c). There is also evidence that suggest that afforestation has beneficial effect on erosion. According to Water Research Commission (WRC) (2000) cited in DWAF (2000), in degraded areas afforestation can assist in stabilization of soils. More in line with the aim of the afforestation, the NFA promotes community forestry and also a greater participation in all aspects of forestry and the forest products industry by persons who have been disadvantaged by unfair discrimination (RSA, 1998c).

The purpose of the National Veld and Forest Fire Act (NVFFA)**,** (Act 101 of 1998), is to prevent and combat veld, forest and mountain fires throughout South Africa. The Act applies to the open countryside beyond the urban limit and puts in place a range of requirements (RSA, 1998d). All owners on whose land a veldfire may start or burn or from whose land it may spread must:

- prepare firebreaks on their side of the boundary if there is a reasonable risk of veld or forest fire;
- have such equipment, protective clothing and trained personnel for extinguishing fires as are:
    - prescribed (in the regulations);
- if there are no regulations, reasonably required in the circumstances;
- take all reasonable steps to notify the Fire Protection Officers (FPO) of the local Fire Protection Associations (FPA) (should one exist) when a fire breaks out;

- do everything in their power to stop the spread of the fire.

The placement of firebreaks and ensuring that landowners realise their fire management responsibilities are very important where new afforestation is considered.

2.11 Chapter summary

It is clear that the planting of any of the species either *Eucalyptus spp*. or *Pinus spp*., there is impact in the consumption of water by these species as well as loss of biodiversity and habitat. The best way to reduce the impact of afforestation may, therefore, be to reduce the proportion of a planted catchment and keep any riparian or wetland areas free of trees. Plantation forestry in South Africa is a form of land uses that replaces pristine ecosystems, and impacts on both biodiversity and water resources (in terms of streamflows). It is also a source of alien or invasive trees. Therefore, primary data on biodiversity is needed that would support quantitative decision models for the determination of conservation priorities and targets. Conservation of natural biodiversity is a competency that should be shared among different spheres of government and thus requires co-operation and co-ordination among different government departments. It is important to note that the forestry industry plays a vital role in the economy of the country. The management of forestry industries and the existing legislation or statutes needs to ensure that forestry remains a sustainable economic activity in this country. Forestry needs to be managed properly in order to reduce its negative impacts on water resources and the environment such as loss of biodiversity and habitat.

Chapter Three: Physical characteristics of the study area

3.1 Location of the study area

The Letaba Catchment is found in the Limpopo Province of South Africa. The catchment is part of the Luvuvhu / Letaba Water Management Area (WMA) (Figure 3.1). The Luvuvhu / Letaba WMA broadly consists of two sub-regions, namely the Luvuvhu/Mutale sub-region and the Letaba / Shingwedzi sub-region, which is consists of the Groot Letaba, Klein Letaba, Lower Letaba, and the Shingwedzi sub-areas, as defined in the National Water Resource Strategy (NWRS, 2004). The Luvuvhu / Letaba WMA lies within primary drainage regions such as A and B, and consists of secondary drainage regions A9, B8 and B9 and includes a total of 45 quaternary catchments.

The Letaba Catchment falls within the Limpopo Basin, which is shared by South Africa, Botswana, Zimbabwe and Mozambique (Figure 3.2). The Letaba River joins the Olifants River which flows through the Kruger National Park (KNP) and into Mozambique. In South Africa, the KNP is a major tourist attraction and hence the operation of the water resources in the Letaba Catchment is of major importance to not only the KNP but also downstream Mozambique. The eastern part of the Letaba Catchment encompasses the KNP and extends to the border with Mozambique and represents a significant source of water for KNP. The whole Letaba Catchment consists of three tertiary catchments, namely, B81, B82 and B3 (Figure 3.2), which enable the Letaba River system to be divided into three sub-systems as follows:

- The Groot Letaba River sub-system stretching down to its confluence with the Klein Letaba River.
- The Klein Letaba River sub-system stretching to its confluence with the Groot Letaba River.
- The Lower Letaba River sub-system which stretches from the confluence of the Klein and Groot Letaba Rivers to the confluence with the Olifants River; just upstream of the border with Mozambique.

The tertiary catchment B81 consists of six quaternary catchments with a total catchment area of 4 952 km². Tertiary catchment B82 drains the Middle and Klein Letaba Rivers, which are the major tributaries of the Letaba River. The total catchment area of B82 tertiary catchment is 5 453 km². The lowest catchment within the study area, tertiary catchment B83 is the smallest tertiary catchment and comprises an area of 3 264 km². It facilitates little economic activity takes and is mainly characterized by game farms and nature conservation areas, such as the Kruger National Park.

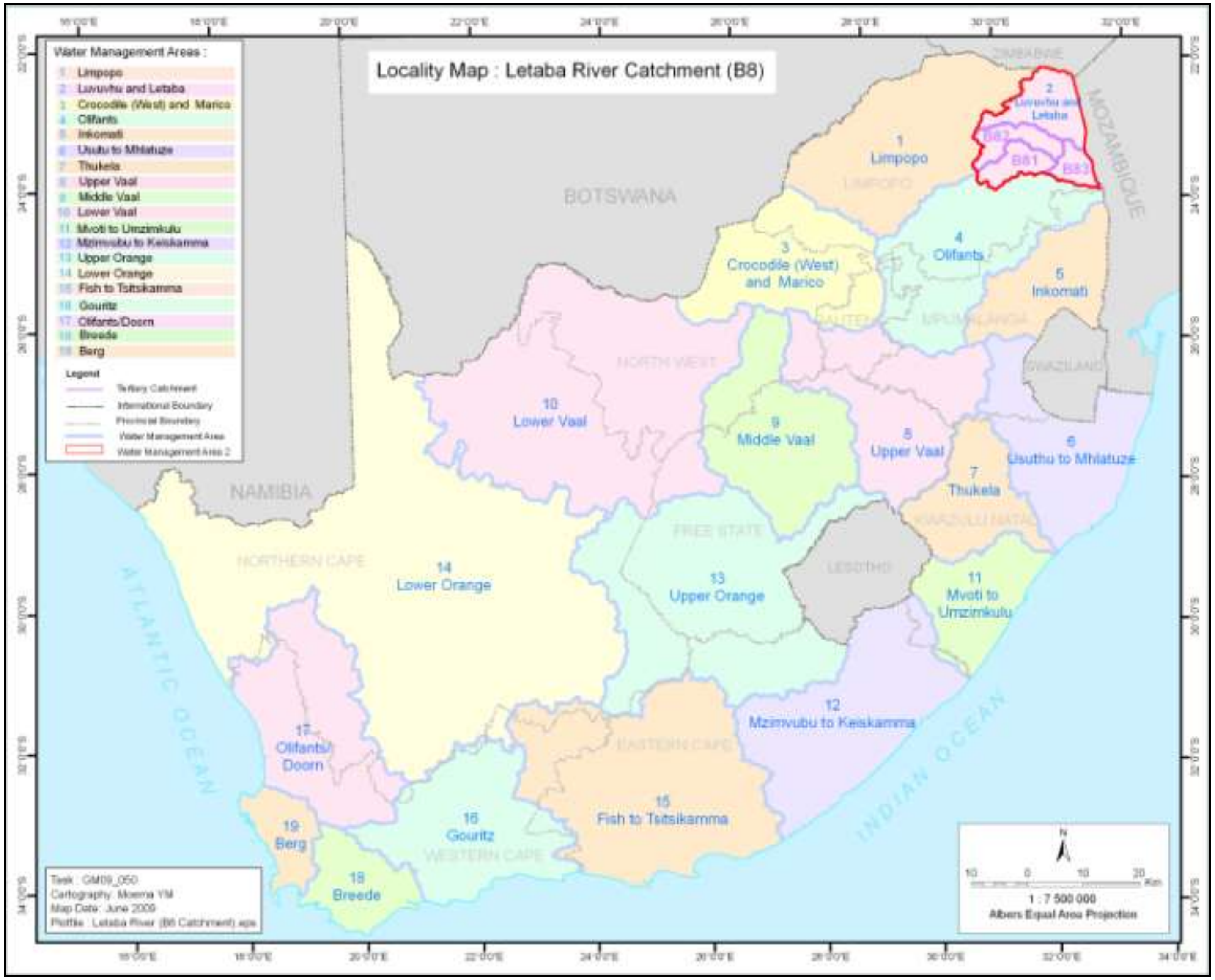

Figure 3.1: Locality map of the Letaba River Catchment.

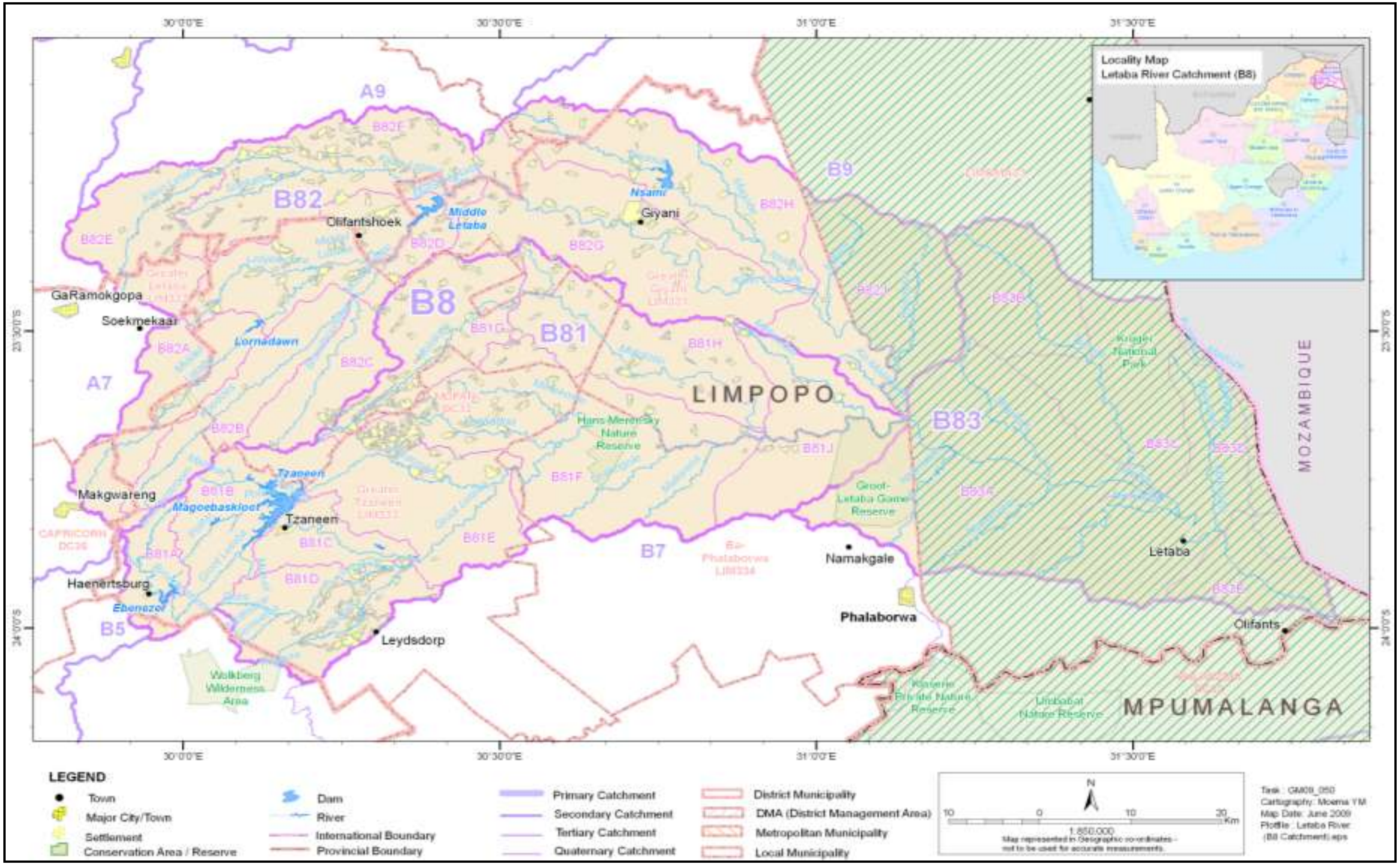

Figure 3.2: Tertiary catchments of the Letaba Catchment.

3.2 Climate

3.2.1 Climate and forestry

The Letaba Catchment is an international river catchment with headwaters in the high rainfall Drakensberg mountain range. The catchment then flows through drier arid regions into the KNP and then on to Mozambique.

Climate is the fundamental determinant of the natural distribution of most forestry species. It is also the overriding strategic factor influencing species choice for commercial forestry (Louw, 1997). For example, temperature appears paramount for the growth of *Eucalyptus spp*. The influence of temperature on soil chemical properties and nutrient cycling in an ecosystem will invariably also have impacts of forest productivity (Louw, 1997).

3.2.2 Rainfall and evaporation

The climate in the Letaba Catchment is largely driven by topography. Moon & Heritage (2001) classify the Letaba Catchment as a semi-arid system. The mountainous topography at the western headwaters of the Letaba Catchment results in a much higher rainfall with the Mean Average Precipitation (MAP) varying between 700 – 1500 mm, whilst the MAP for the remainder of the catchment varies from 450 – 800 mm (Figure 3.3.). For example, the highest rainfall is typically recorded on the eastern-facing slopes of the Strydpoortberg mountain range near the Tzaneen dam.

The rainfall patterns follow a distinct seasonal trend with the majority of the rainfall (85 %) occurring in the summer period, which stretch from October to March. The peak rainfall months are January and February. The dry season begins in April with rainfall decreasing dramatically with June appearing to be the driest month of the year. According to Moon & Heritage (2001), evaporation follows a similar trend to the rainfall, with areas in the central and northern region of the catchment experiencing high evaporation rates of roughly 2100 – 2200 mm *per annum,* which is approximately 60 % of the evaporation occurs during the summer months from October to March. Areas on the eastern slopes of the Strydpoortberg mountains and in the eastern part of the catchment have lower evaporation rates of roughly 1900 – 2000 mm (Figure 3.3). The high evaporation rates and low rainfall figures (400 – 600 mm) in the central and northern areas suggest that agriculture in such areas requires irrigation to survive.

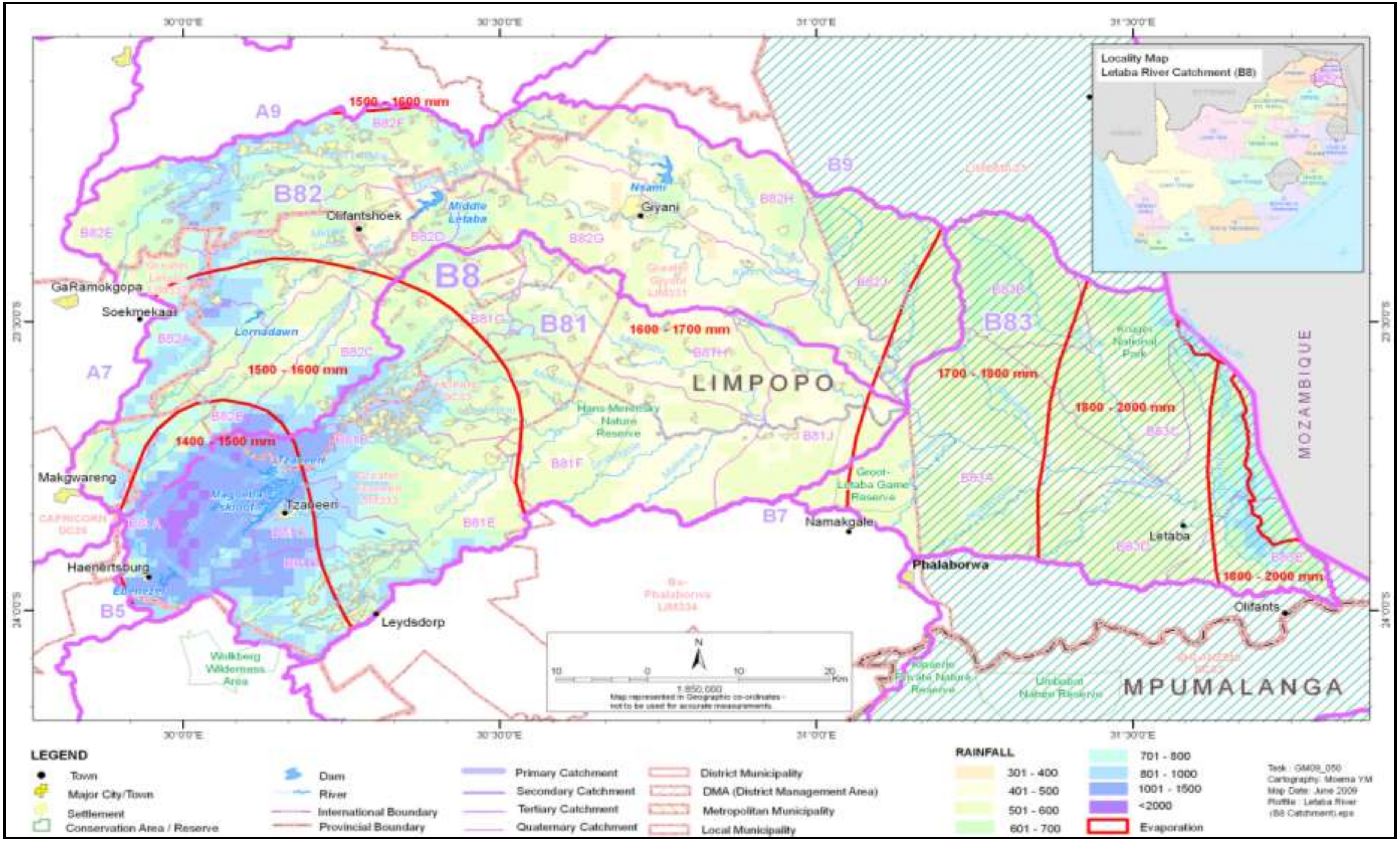

Figure 3.3: Rainfall and evaporation of the Letaba Catchment.

3.2.3 Temperature

Temperature conditions in South Africa are characterised by three main features. Firstly, temperatures tend to be lower than in other regions at similar latitudes, for example, Australia. This is due primarily to the greater elevation of the subcontinent above sea level. Secondly, despite the country spanning of 13°C in latitude, average annual temperatures are remarkably uniform throughout. This is due to the increase in the height of the plateau towards the north-east of the country. The third feature is the striking contrast between temperatures on the east and west coasts. In this region temperatures above 32°C are fairly common in summer, and frequently exceed 38°C in the lower Orange River Valley and the Mpumalanga Lowveld (GCIS, 2004). The mean annual temperatures in the Letaba Catchment range from an average of 21°C in the upper catchments, to an average of 25°C in the KNP. Maximum temperatures are experienced in January and minimum temperatures occur on average in July. Frost rarely occurs in the Letaba Catchment (DWAF, 2004).

3.2.4 Soil variables

The soil conditions vary in the Limpopo Province depending on the parent rock. The soils are mainly formed on deeply weathered granites, and are highly leached and well drained. According to Vegeter (2003), the Great Letaba River is mainly underlain by Precambrian granites, gneisses and granitoids.

Soils in the Letaba Catchment are distributed as follows (Figure 3.4):

- In the headwater, as well as in the north eastern part of the catchment, soils with high clay content (>25 %) such as lixisole, acrisole, nitisole and luvisole are dominant.
- The centre and the south east part of the catchment is characterised by medium clay content (between 10 and 25 %) soils such as leptosols and regosols.
- Close to the outlet, in the south western part of the catchment, arenosols can be found, which are high in sand content (FAO, 2003).

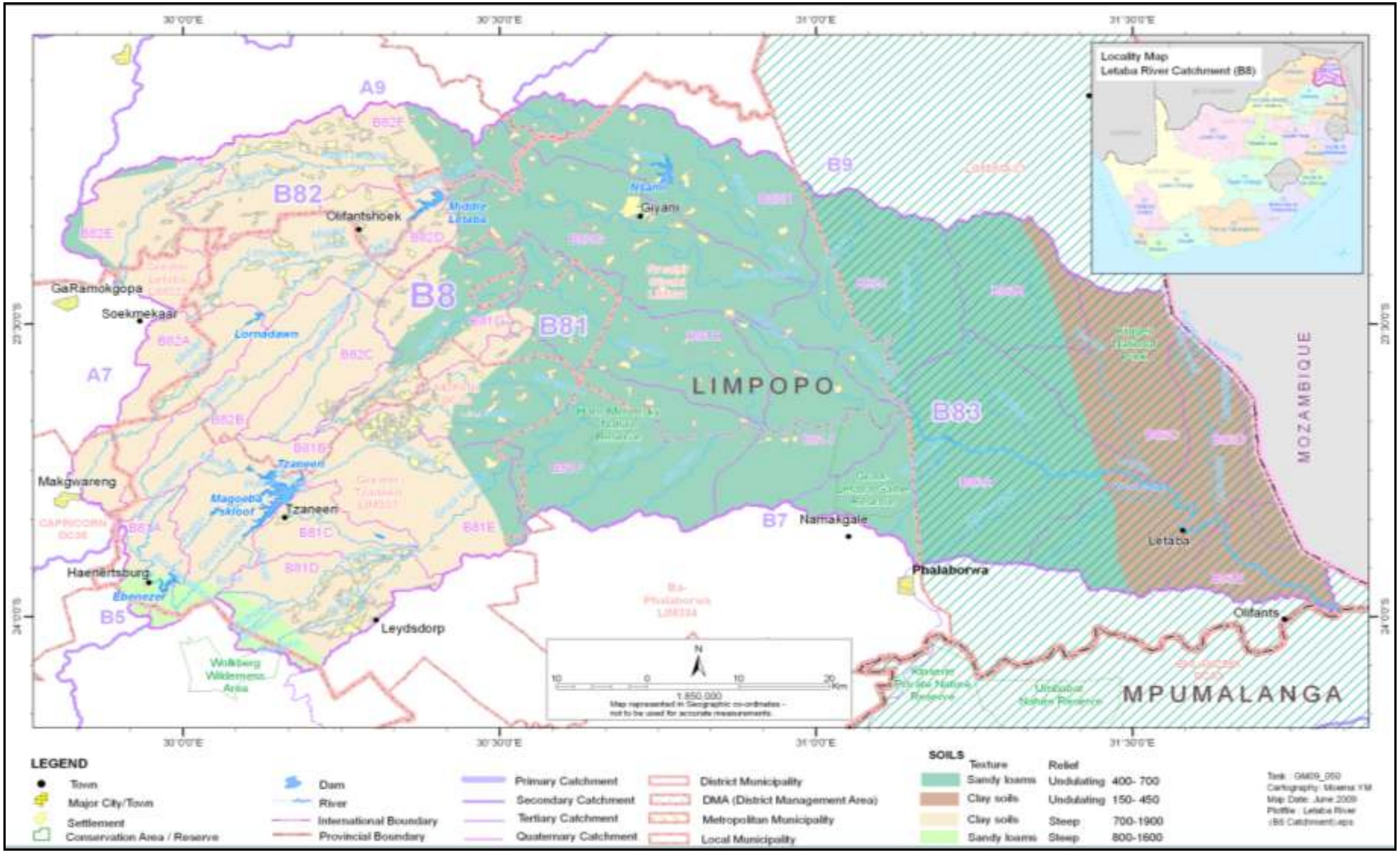

Figure 3.4: Soil types within the Letaba Catchment.

3.3 Water use

3.3.1 Water use

Water use in the Letaba Catchment is dominated by irrigation for the agriculture sector and represents nearly 75 % of the total water requirements within the water management area. Schemes located within the Groot Letaba River catchment utilize water from the Groot Letaba River and its tributaries to supply water to various towns including Polokwane, Tzaneen, Haenertsburg, Duiwelskloof and to a number of rural villages. Large areas of irrigation are also supplied with water from these schemes (Figure 3.5)

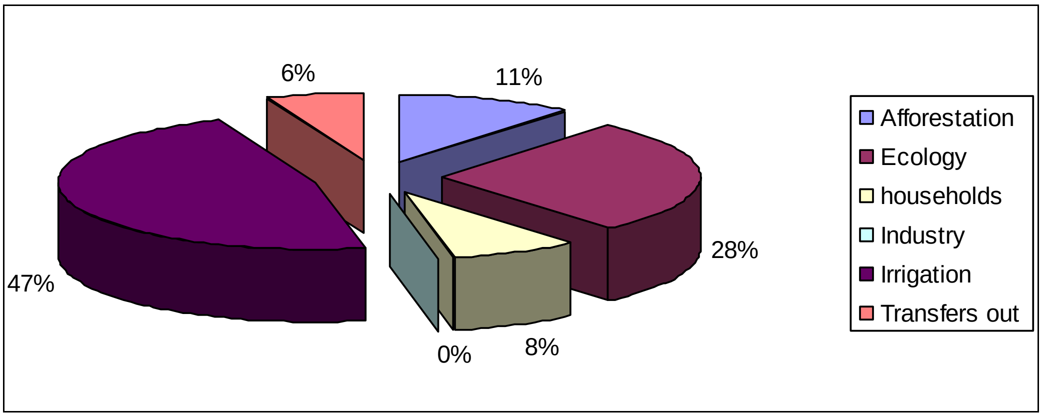

Figure 3.5: Composition of water use in the Letaba Catchment.

3.3.2 Forestry

The plantation area in South Africa has been expanding at a rate of 1.6 % *per annum* over the past 15 years from new plantings and land conversion (JPC, 1999). But since 2007, this percentage has been dropping down to 1.1 % per annum, and as result it has been estimated that plantation area dropping in terms of hectares is 221 000 ha which equates to 14.9 % of total plantation in 2007 (DWAF, 2008) The reason for this drop is that there is not enough land for more plantations. Secondly, forestry is not economical in areas with rainfall of less than 650 mm *per annum*.

The Limpopo Province ranks fifth in terms of forestry activities and encompasses 3.8 % of the total area of forest plantations, while Mpumalanga is the largest forest growing Province with 40.7 %, followed by KwaZulu Natal with 38.5 %, Eastern Cape with 12.2 % and then Western Cape with 4.8 % (DWAF, 2008). According to Limpopo State of the Environment Report (SOER) of 2003, one of the key issues affecting land degradation includes growth of the commercial forestry industry in sensitive landscapes (Limpopo DFED, 2003).

Many areas of natural grasslands have been replaced by commercial forestry. Plantations of hard wood for furniture manufacturing have also been established and much of the rural population practise subsistence farming. According to the DWAF Internal Strategic Perspective (ISP; 2004) about 484 km² have been planted with commercial forests (i.e. Pine and blue gum plantations) in the high rainfall regions (those with more than 900 mm *per annum*) of the Drakensberg escarpment and on the Soutpansberg mountain range (Figure 3.6). A large percentage of afforestation, in terms of area, can be found along the sub-catchment Groot Letaba River as well as the Klein and Middle Letaba Rivers comprise 45 000 ha and 4 300 ha respectively. With this large area being devoted to forestry the total amount of water requirements in these areas for forestry is 36 million m³ (DWAF, 2004).

Forestry in the upper reaches of the Groot Letaba, and Klein Letaba Rivers result in relatively large reductions in streamflow. Reduction in runoff is estimated at approximately 52 million m³/a, this is about 25 % of the natural runoff for those catchments where afforestation has occurred (DWAF, 2004)**.**

3.3.3 Agriculture

The Letaba Catchment, particularly the Groot Letaba sub-area is a highly productive agricultural area with mixed farming that includes cattle ranching, game farming, dry land crop production and irrigated cropping. Agriculture, through the use of irrigation, is the main base of the economy of the region. The total area of irrigated lands measures about 242 km². These areas occur mainly along the Groot Letaba River, and its tributaries, the Middle Letaba, Lower Letaba, and the Letsitele Rivers. Agriculture typically consists of small-scale farming by rural communities and large scale commercial farming. Commercial farming mainly focuses on permanent fruit crops which consist of bananas, papino, paw-paw, citrus and mangoes and amounts to about 47 % of the crop yield and remaining 53 % comes from vegetable and grain cash crops (53 %) are cultivated. The commercial fruit farms are fed by the Middle Letaba canal irrigation scheme.

3.3.4 Other Water users

Besides the water that is used for agricultural purposes in the Letaba Catchment, water is also used for domestic, municipal and industrial purposes. For example, about 6.06 million m³ of water is abstracted in this catchment for domestic purposes.

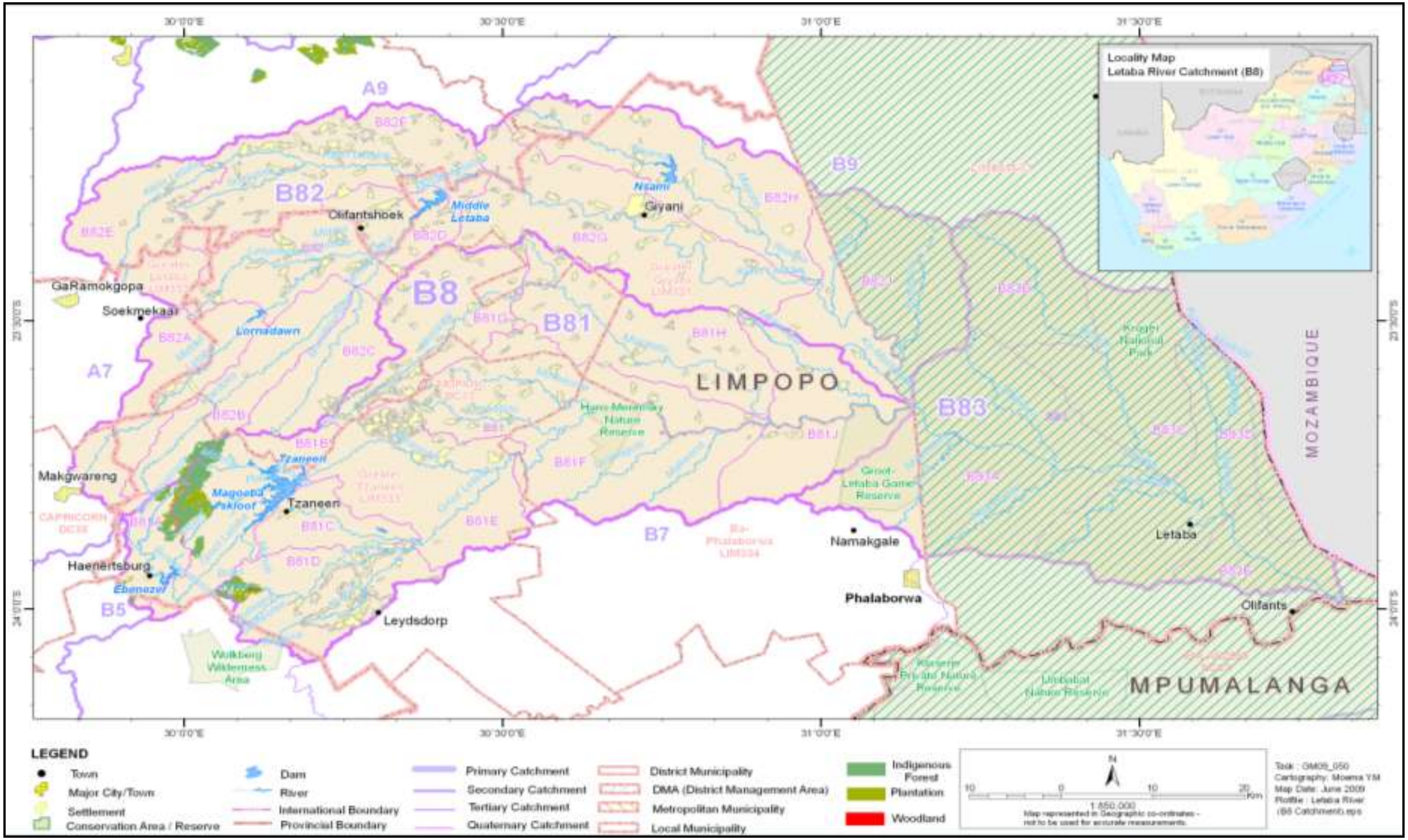

Figure 3.6: Foresty plantations within the Letaba Catchment.

3.4 Economic factors

The economy of Limpopo Province is characterized by a small and concentrated production base and a large consumer population with limited means in terms of income. It has a high potential for economic development and is attractive to various kinds of investment. The agricultural (employment) and mining (income generation) sectors form the backbone of the Limpopo economy. Nature-related tourism in the Province is also a growth sector. The manufacturing sector in Limpopo is relatively small, with significant potential for further expansion. The service sector, especially with respect to government activities, is large and contributes significantly to the economy of the Province (Limpopo DFED, 2003).

The major economic activities take place in the Great Letaba tertiary catchment. The Kruger National Park is located at the lower end of the catchment. Since it is internationally renowned as a major conservation resource, it is responsible for significant tourism activities which contribute to the South Africa's Gross Domestic Product (GDP). In 2000, agriculture was responsible for 11.4 % of GDP in the study area and 8 % of the GDP in the Limpopo Province. Other economic sectors that are related to forest sector in the study area are commerce (10 %) and manufacturing (9.2 %). Due to linkages, agriculture contributes significantly to trade, transport and finance sectors. The Gross Global Products (GGP) per capita per annum in the study area stands at R2 952 and is considered the lowest of all Provinces.

3.5 Chapter summary

Climate, particularly rainfall and temperature, is the main driving force which determines the mass balance in the hydrological cycle. The Limpopo Province is physiographically and climatologically suitable for plantation forestry and further afforestation. Therefore, whilst the impact of plantation forestry on both surface and ground water resources may be severe in this region, the forestry industry is contributing tremendously to the economy of the region. The next chapter focuses on simulating the effect of afforestation on the study area. Different models of simulating will be discussed but only one model is going to be applied in this study.

Chapter Four: Methodology

4.1 Introduction

Forestry always has first access to water in a catchment. Forests are thought to intercept more rainfall than natural grasslands and increase evaporation losses from the soil. Forestry reduces streamflow, whereas other users abstract from streamflow. The other water users that abstract water from the river can be restricted during droughts but this is not possible with forestry water use. It only declines during drought conditions but cannot be controlled or restricted in the same way as the other water uses. Therefore, the allocations for the water use by forestry plantations needs to be treated with extreme caution as the decision cannot easily be reversed once the plantation has been established.

4.2 Modelling

A number of technologies have been developed in South Africa to assist with the measurement, modelling and prediction of changes in streamflow as a result of commercial forestry activities. A first step towards prediction is the measurement and analysis of data from actual situations where the impact of forestry plantation can be measured. The use of the “paired catchment” method of study provides this opportunity. Research of afforestation was initiated in 1935 with the establishment of long-term paired catchment afforestation experiments at the Jonkershoek Forest Hydrological Research Station (Scott *et al.*, 2000). Other forestry research stations later followed at Cathedral Peak in the Natal Drakensberg (1945), Mokobulaan (1955) near Lydenburg in what was then eastern Transvaal, Westfalia (1975) and Witklip (1980).

Following advances in technology since the 1980s, paired catchment are now complemented by other research such as Gush Curves which are discussed below. Over time, the methods used to determine streamflow reduction have been refined and improved in line with new research and the development of improved methods (such as Scott Curves) of collecting and interpreting data. From the Nanni curves which are defined below; through to the Van der Zel, CSIR (Scott) and Gush curves, an increase in sophistication, reliability and accuracy have been generated in the modelling of reduction in streamflow. These are described in detail below.

4.2.1 Nanni and Var der Zel curves

Previously, streamflow reduction under the Afforestation Permit System (APS) was determined using the Nanni (1970) curves (Figure 4.1). The Nanni curves were developed using data recorded at Cathedral Peak using one tree species, namely *Pinus patula*. A single, unrepresentative forest site at Cathedral Peak was used to generate the dataset, limiting the usefulness of the Nanni curves and, thus, making extrapolation to dissimilar areas risky. A major flaw in using the Nanni curves was that they were not able to adequately represent that afforestation effects could be severe on a local scale, yet substantially less for larger catchments. Additionally, the original land use was assumed to be grassland, in pristine condition, with stable water use over time. Further, different plantation management practices were unaccounted for (*e.g*. short *Eucalyptus spp*. rotations in contrast with longer pine rotations). Adding to the Nanni curves' limited usefulness, intra and inter-seasonal differences in water use were not considered. Wattles, for example, use less water in winter, but again, the Nanni curves did not reflect this. In order to improve on the use of only one tree species (*i.e*. *Pinus patula*), Van Der Zel (1990) incorporated data from the USA and elsewhere to improve the model. This revision resulted in the so called 'Van Der Zel' curves.

The Van der Zel curves predicted the effects of two different rotation lengths of forestry; namely 15 and 40 year rotations. Also these curves look at the effects of forestry using Pitman Models that is used to estimate water resources in South Africa. According to Bosch and Von Gadow (1990), the disadvantage with these curves is that they did not take into account differences between species or site conditions.

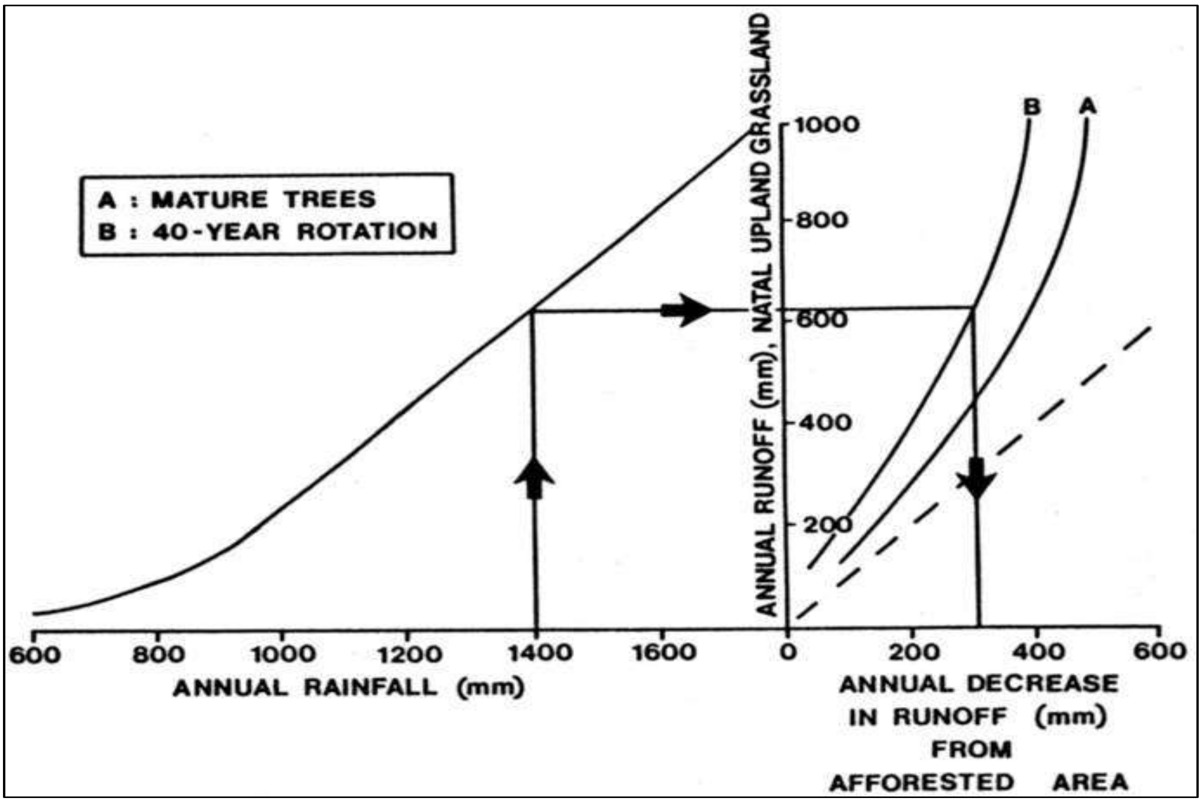

Figure 4.1: The relationship between mean runoff and the expected reduction in runoff as result of afforestation of grassland catchment (after Nanni, 1970).

4.2.2 CSIR (or Scott) curves

Scott and Smith (1997) produced what is commonly referred to as the Council of Scientific and Industrial Research (CSIR) or Scott curves. These reductions in streamflow curves are based on observed streamflow after planting in five paired catchments in South Africa. These curves express the reduction in streamflow as a mean annual reduction and a low-flow reduction. Curves were produced for both *Pinus spp*. and *Eucalyptus spp*. and allowed for both optimal and non-optimal tree-growing sites (in terms of soils, climate and elevation), and accounted for the age of the trees. Despite the use of a wider and more representative dataset, these curves still had certain inherent inadequacies. Nevertheless, these curves were in use until 2001. The curves were derived from experimental sites in high rainfall areas, where the Mean Annual Precipitation (MAP) was in excess of 1100 mm. This is problematic, because forestry is increasingly moving towards marginal or drier areas as more suitable land has already been developed or put to different use. Thus, extrapolation to drier areas can lead to inaccuracies. In addition, modern forestry practices such as thinning, fertilization, intensive site preparation and weed control are not accounted for, and only two site quality conditions were accounted for, whereas as a wide range of site quality conditions exist in practice. Further, recent research shows that tree water use actually diminishes towards the end of longer timber rotations, unlike the extrapolated sigmoid shape of the curves (Figure 4.2 and 4.3).

Although the Nanni, Van der Zel and CSIR (or Scott) curves offer increasing levels of detail in the estimation of streamflow reduction due to forestry, there is, however, a major shortcoming in that the results are aggregated to represent afforestation across the whole country, even though the data upon which the curves were based was derived from, at most, five locations of relatively high rainfall. Thus, for Stream Flow Reduction Activities to be evaluated in a consistent and transparent manner, it is important that local climatic and soil conditions are taken into account.

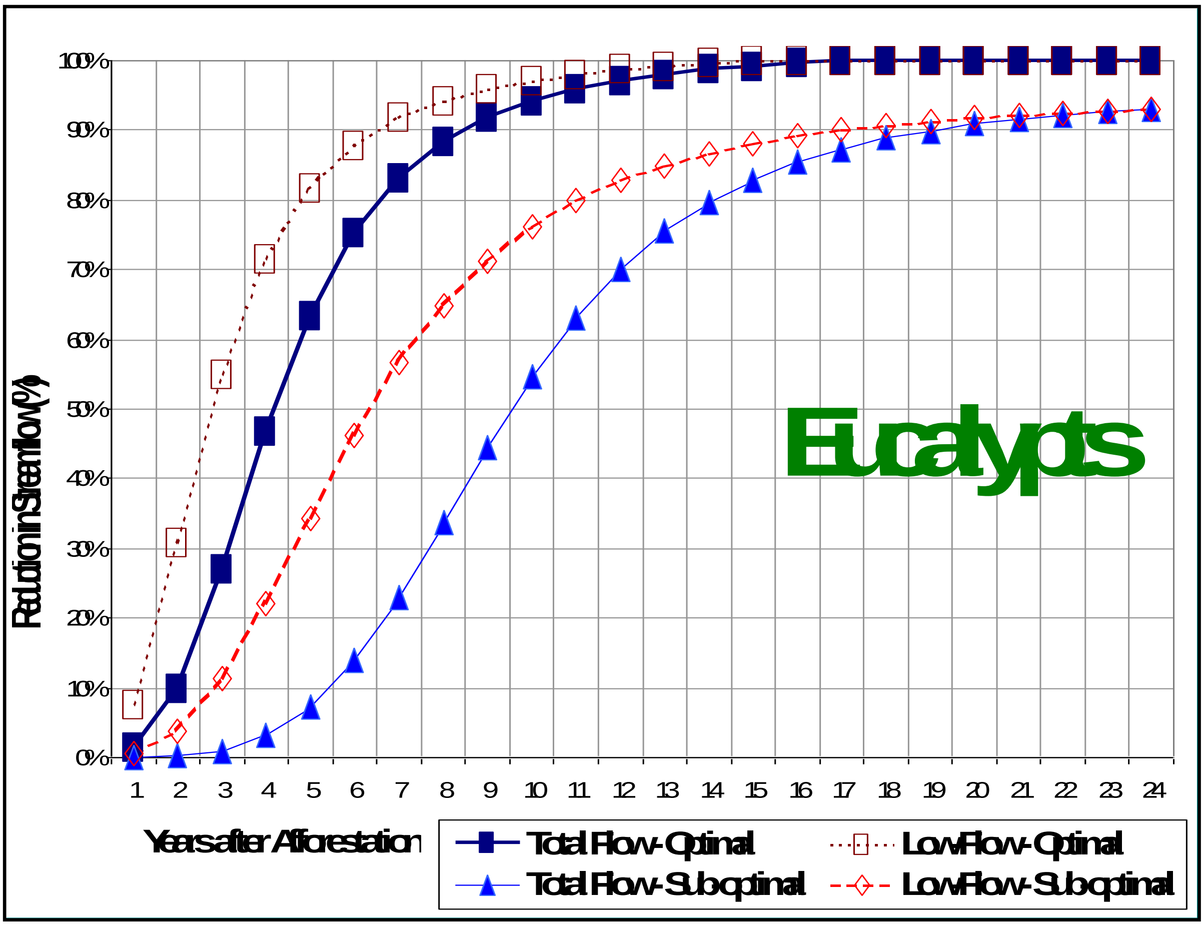

Figure 4.2: Flow Reduction Curves for *Eucalyptus spp*. (Eucalypts) from Scott and Smith (1997).

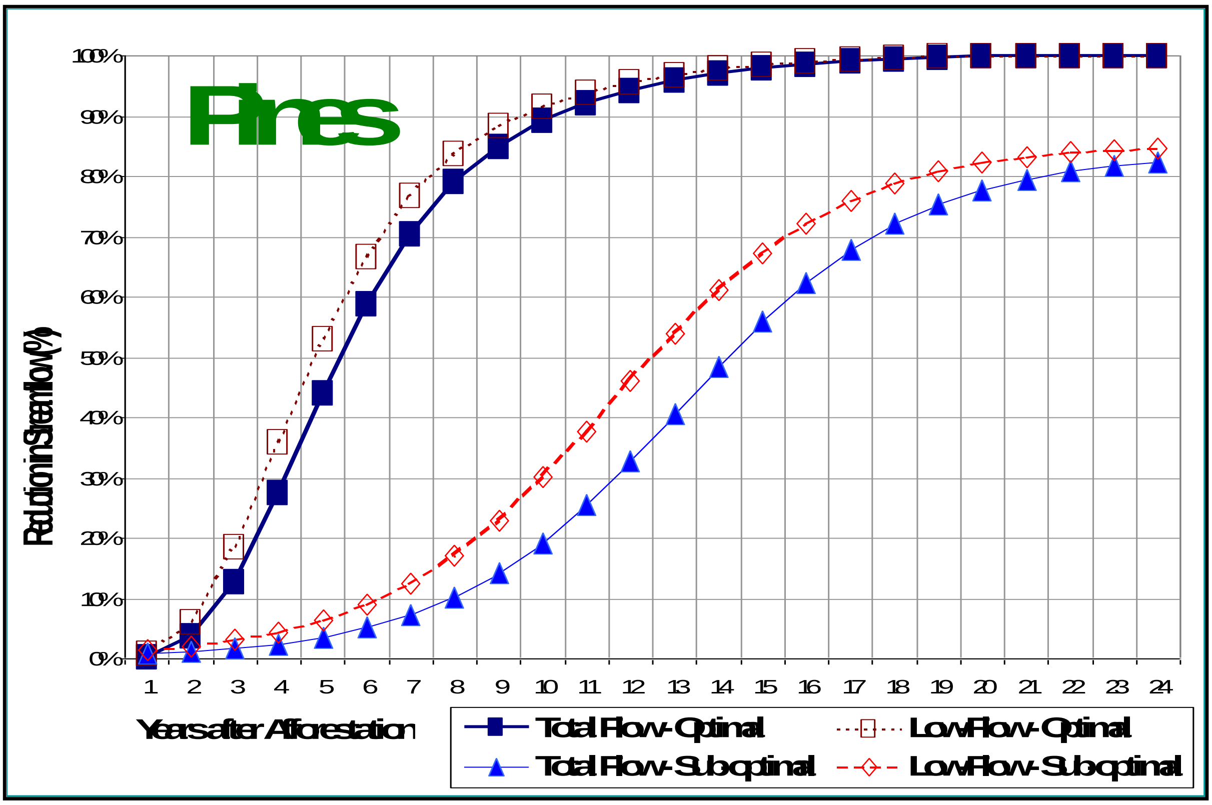

Figure 4.3: Flow Reduction Curves for *Pinus spp*. (Pines) from Scott and Smith (1997).

4.2.3 ACRU/GUSH

The shortcoming of the CSIR (or Scott) curves is that, while they were derived from actual measurements, the research was limited to only five catchments, all with high MAP. These curves are, therefore, not representative of all forestry regions in South Africa. In order to overcome these shortcomings, the Water Research Commission (WRC) in conjunction with DWAF commissioned a study using the Agricultural Catchments Research Unit (ACRU) model. The outcome of this study was streamflow reduction tables for each quaternary catchment in which forestry is grown. These are known as the Gush Tables and take into account the local conditions such as rainfall, evaporation, soil type and depth.

There are still shortcomings in this approach. The main problem is that although the methodology was developed with the view to water use licensing, on completion of the study it was concluded that *'…the estimated stream flow reductions are not appropriate for detailed on–farm decision making, but are mainly suitable for preliminary national or regional planning*' (Gush *et al*., 2002). Nevertheless, the results of this research have been accepted by DWAF and the forestry industry as being the best available, and are used as the basis for determining catchment management charges. These results are documented in the publication 'Estimation of Streamflow Reduction Resulting from Commercial Afforestation in South Africa' (Gush *et al*., 2002).

These so-called Gush tables have also been used for licensing in some DWAF Regional Offices, although this approach is not correct. However, the published Gush Tables do give the most appropriate/accurate data on the streamflow reduction, which is not the same as reduction in yield. These streamflow reductions are limited, in that they only produce a mean and low flow streamflow reduction, which cannot be readily applied within a water resource model in order to determine the impact of the streamflow reduction in yield.

At the request of various stakeholders, the CSIR and the School for Bio-resources Engineering and Environmental Hydrology (SBEEH, formerly ACRU) extended these tables to produce "families" of monthly duration curves of the reduction in streamflow for particular species. These extended tables were produced for certain exotic genuses, namely *Pinus spp.*, *Eucalyptus spp*. and *Acacia* species which enable modellers to represent streamflow reduction as a time-series for the detailed modelling required for licensing purposes. Duration curves of the assumed baseline hydrology (*i.e*. the hydrology with Acocks vegetation and no human development) were also produced. Using these, water resource modellers can produce a time series of reduction in streamflow, which is essential for any time series modelling and upon which licensing is be based.

4.2.4 Water Resource Management Platform Model (WReMP)

For the purposes of this study, a Water Resource Management Platform Model (WReMP) of Mallory *et al*. (2008) was used. The WReMP model integrates the models mentioned above and utilities that provide holistic modelling tool to deal with water resource planning and management. It is more advance to the models mentioned above and becomes a better model to use. This model has been used in assessing proposals for licensing forestry developments within the Provinces of South African, such as KwaZulu-Natal and the Eastern Cape (DWAF, 2004b). The WReMP is similar to the Water Resources Yield Model (WRYM) developed by Department of Water Affairs and Forestry to deal, *inter alia*, with the impact of afforestation on catchment yield. In both models nodes such as dams are seen as points at which inflow or outflow can occur, but also as points of interest that are connected by channels (which can be rivers, canals or pipelines).

It must be noted, however, that since this is a desktop study, the results are of low confidence. The following specific issues were addressed using WReMP model:

- Determine the available water balance for the catchment.
- Assess if forestry is an appropriate form of land use.
- Determine where forestry may be appropriate within the study area.

- Determine how much water is currently used by existing land uses.
- Make recommendations regarding the assessments of Ecological Water Requirements based on criteria from the National Water Act (Act 36 of 1998).

The Water Resources Modelling Platform (WReMP) (Mallory *et al*., 2008) was used to estimate the area of forestry which could potentially be developed, utilises a water resources model to determine the water use from all known water users as well as the Ecological and Human Reserve. The WReMP was developed by Water for Africa to primarily deal with the impact of afforestation on catchment yield. The latest methodologies to estimate streamflow reduction due to afforestation are integrated in the WReMP.

4.3 Determination of water availability in the Catchment using WReMP

A water resource assessment in terms of quantity and quality was done with a desktop assessment, using available information from existing gauging weirs, the provincial database on water use and water balance data for the catchment. This component of the study was to assess the availability of water in the study area.

According to Mallory *et al.* (2008), the first step in preparing for simulation water availability in a water resource in WReMP is to subdivide the catchment into a number of sub-catchments. The Letaba catchment, for example, has been subdivided into Tertiary catchments. Then, according to WReMP (Mallory *et al*., 2008), a typical water resources simulation would commence at the most upstream quaternary catchment and, for every time step (monthly in this case), all the inflows in the catchment are added, all the abstractions are subtracted, and whatever remains, flows into the downstream catchment (Figure 4.4).

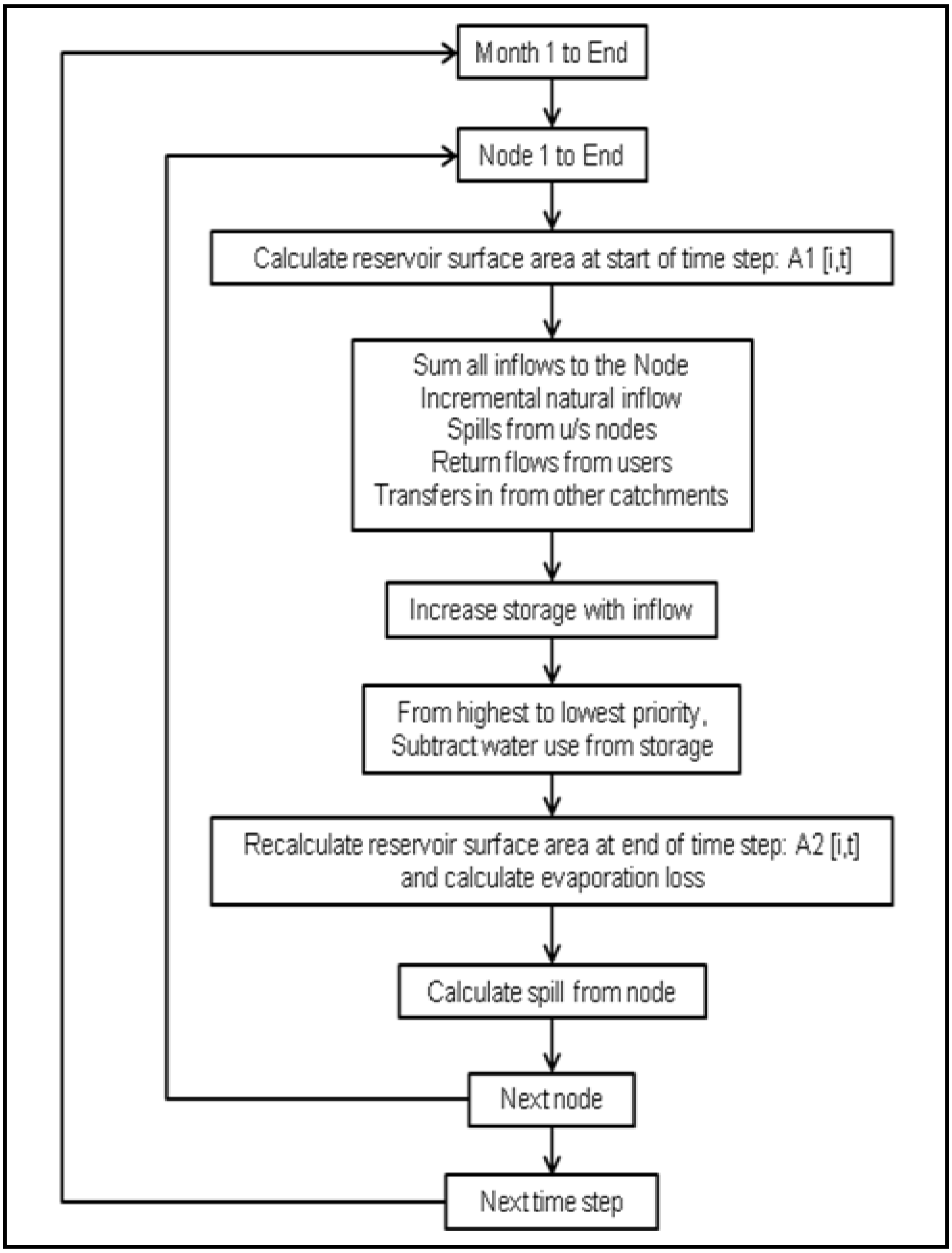

Figure 4.4: Water Resources Modelling Platform (WReMP) simulation algorithm.

Having carried out such a simulation, it was then possible to determine how much additional water is available in every quaternary catchment. Where there was additional water available, the forestry potential was determined in that catchment by increasing the area of forestry up to the point that the yield is fully utilised. However, because the addition of new forestry in upstream catchments will reduce the flow into downstream catchments, it was necessary to carry out a large number of simulations, essentially one for every quaternary catchment or sub-quaternary catchment in which forestry is possible. In each simulation, the cumulative impacts of forestry (existing and maximum additional) was taken into account as the modelling procedure progresses from upstream to downstream catchments.

4.4 Determine how much water is currently used by existing land uses

National datasets on environment were used in the environmental assessment of the Letaba catchment. A multi-criteria analysis using GIS was also used to perform an environmental scoping in order to support the assessment of afforestation potential. This was done at a scale that covered all and also used consistent data sets across the study area.

Environmental constraints categories for new afforestation (low, moderate and high) were identified taking into account biological, agricultural and social aspects. Each of these three aspects was based on a number of different considerations, and these underlying inputs were assigned different constraint categories. In cases where there were overlapping areas with different constraint ratings, the highest constraint rating was applied. The constraints categories used are described in Table 4.1 below. The methodologies applied for each of the environmental aspects assessed in this study are described in the following sub-sections below. Existing land use areas (urban development such as in much of Tzaneen and Giyani, established irrigated agriculture, areas already established for forestry) were automatically excluded as high constraint areas.

Table 4.1: Constraint categories applied in undertaking the environmental assessment (Adapted from Mallory et al., 2008).

Level of Constraint	**Description**
High	These areas are regarded as unsuitable for afforestation as a result of one or more environmental considerations, typically pristine nature, plant endemism, high value wetlands, or high potential agricultural land. Afforestation in these areas would have significant environmental impacts and applications are likely to be strongly resisted.
Moderate	These areas have moderate constraints which are less critical than the high constraints category. While some afforestation may be possible in these areas, applications are likely to require detailed environmental impact assessments on one or more of the environmental aspects. If granted, environmental authorizations are likely to stipulate stringent safeguards and mitigations to reduce the potential impacts of afforestation in these areas.
Low	These areas have low environmental constraints in all of their underlying inputs. These areas are likely to be preferred for afforestation and, although they would still require compliance with environmental authorisation requirements, they would be likely to face little opposition.

4.4.1 Biological Assessment

The biological assessment was done to check whether conservation areas and wetlands exist in a sub-catchment. Areas for conservation and wetlands were rejected as the potential areas for new afforestation. A brief description of each of the datasets used in the biological assessment is provided in Table 4.2 below.

Table 4.2: Constraints categories for new afforestation applied to maps in the biological assessment (Adapted from Mallory *et al*., 2008).

Level of Constraint	**Features**
Area of high constraints to new afforestation	• Existing protected areas • Wetlands • National protected area exclusion zones • Indigenous forests • Pristine areas
Medium	• Sensitive and threatened biomes (National Spatial Biodiversity Assessment)

4.4.2 Agricultural Assessment

Retaining land for agriculture is important in order to ensure food security, and the value of agricultural land was assessed in order to identify where applications for conversion to forestry might reasonably be expected to be resisted. A brief description of each of the datasets used in the agricultural assessment is provided in Table 4.3 below.

The first priority was to identify areas of existing agriculture. Primarily, the National Land Cover 2001 information was used but supplemented with data from a number of other datasets highlighted in Table 4.4.

The following categories of land-use data were combined to form the “existing agriculture” layer:

- Cultivated, permanent, commercial, irrigated
- Cultivated, temporary, commercial, irrigated
- Cultivated, permanent, commercial, dryland
- Cultivated, temporary, commercial, dryland

Table 4.3: Data sources used for an Agricultural Assessment (Adapted from Mallory *et al*., 2008).

Data Source	**Source**	**Date of Dataset**	**Description**
Existing agriculture			
National Land Cover 2000	CSIR	2001	This is a national map of landcover, including agricultural activity; identified by remote sensing.
Agricultural potential			
Agricultural land types	Dept. Agric	2006	This is a national map of agricultural land types.
Potential irrigated land	Derived from DWAF	2002	This is derived from a national map of rivers.
Existing afforested areas			
National Land Cover 2000	CSIR	2001	This is a national map of landcover, including plantation areas; identified by remote sensing.
Plantation Areas (DWAF)	DWAF	2009	This is a national map of plantation forestry maintained by DWAF

Areas of existing plantation and indigenous forestry were also identified, based on information received from Department of Agriculture, Forestry and Fisheries (DAFF).

The national land type information from the Department of Agriculture, Forestry and Fisheries was used to identify areas more suitable to agriculture based on their physical characteristics. Areas within 1 km of a perennial river were considered to be potentially suitable for irrigation and, together with the land types, were assigned separate constraint levels. Three constraint categories were applied to the different maps used in the agricultural assessment. Table 4.4 summarises the levels of constraint applied to these maps.

Table 4.4: Constraints categories for new afforestation applied to maps used in the agricultural assessment (Adapted from Mallory *et al*., 2008).

Level of constraint	**Features**
Areas with high constraints to new afforestation	• Areas of existing agriculture • Areas of existing plantation forestry
Areas with moderate constraints to new afforestation	• Landtype potential classes I and II
Areas with low constraints to new afforestation	• Areas within 1 km of a perennial river

4.4.3 Social Aspects Assessment

Two constraints categories were applied to the different maps used in the social assessment. Table 4.5 below describes the level of constraint applied to the map.

Table 4.5: Constraints categories for new afforestation applied to maps used in the social assessment (Adapted from Mallory *et al*., 2008).

Level of Constraint	Feature
Areas with high constraints to new afforestation	• High-density urban land-use • Places with > 300 per population/km²
Areas with moderate constraints to new afforestation	• Places with 150-299 population/km²

4.5 Determine areas where forestry may be appropriate

Three major steps were followed to assess forestry potential in the Letaba Catchment and are described below (A schematic is provided in Appendix 4):

The first step was to assess the study area against the following criteria. This answered the question, is the potential site located in any of these areas?

- Forestry areas (plantations; natural forests and woodlands)
- Protected areas (nature reserves, heritage, parks)
- Riparian areas (within a 20m-buffer from rivers)
- Wetlands areas
- Bare Rocky areas

The above areas were merged to form exclusionary zones which was dissolved and subtracted from the study area’s boundary (*i.e.* catchment). The results were then merged with the dissolved catchment, converted to a raster and reclassified into binary suitability where all the cells areas from dissolved catchment boundary was identified as suitable areas (potential areas for afforestation) while the dissolved exclusionary cells was identified as unsuitable areas for afforestation.

The second step was to identify those quaternary catchments where main factors influence an area to be a good afforestation potential. Now that there are potential areas from the steps above, the main factors that influence area to be a good afforestation potential were assessed in details in the second step. These factors are as follows:

- Climate: Rainfall
- Topography: slope and soils

- Agricultural assessment
- Household density
- Water assessment

For example, it involved checking what types of soil occur within these quaternary catchments and their suitability to afforestation, particularly for commercial purposes. The Land Type data published by the Institute of Soils, Climate and Water of the Agricultural Research Institute of the Department of Agriculture, Forestry and Fisheries was used to identify areas where the soils are suitable for commercial afforestation. The soil types that were rejected included very rocky soils, all the hydromorphic soils and those soils having melanic and vertic properties (such as black, high percentage of swell and shrink clays). Lastly, those areas within the quaternary catchments where the climate is suitable for forestry were identified.

Also with regard to soil assessment, commercial plantation species prefer deep (600 mm and deeper) and well-drained soils whereas growth is poor on wet, clayey soils. This is apparent for the *Pinus patula*, although the *Pinus elliotii* is planted in most parts of the country and is successful. *Pinus elliotii* is an excellent species for planting in poor sites where shallower soils of high, moderate and low potential occur and it can tolerate both fairly dry and fairly wet conditions (Table 4.6).

Table 4.6: Description of soil constraint categories to new afforestation (Adapted from Mallory *et al*., 2008).

Level of Constraint	**DESCRIPTION**
Soils with high constraints to new afforestation	This category encompasses soils which are in deep phase. The species prefers deeper soils of (600 – 1200 mm)
Soils with moderate constraints to new afforestation	This category encompasses soils which are in moderate phase. The species prefers deep soils of (450 – 600 mm)
Soils with low constraints to new afforestation	This category encompasses soils which prefers species low quality soils of (<450 mm) generally too dry/wet or fluctuating to a great extent between these extreme

All these factors above were reclassified into GIS and allocated a weight according to their importance. Using weight suitability where values range from good to bad with different weights for each criterion, usually a percentage of the total value for the study modelling (Table 4.7). Ranking and weighted suitability was combined to determine areas bad to good and each criterion can be expressed as a percentage of the total value. Then in the third step the data is combined using Map Algebra which is typically used to analyse raster data and combine/compare several layers of data to answer the questions above; it uses basic arithmetic to add/subtract/multiply values.

Table 4.7: Allocated percentage according to the importance of factors.

Factors	**Allocated %**	**Description**
Climate: Rainfall	25	Areas with sufficient rainfall are preferred, the higher the rainfall the more water used by trees (mean annual rainfall >650 mm)
Topography: slope and soils	25	Preferred areas with slopes ≤ 12 % and soils with low quality soils of (<450 mm) generally too dry/wet or fluctuating to a great extent between these extreme
Agricultural assessment	15	Preferred land which is not seen as falling within “agriculture” as it will remove land from food production
Household density	10	No households or 1 - 50 households per km^2
Water assessment	25	Areas with enough water for irrigation; human needs and ecological reserves
TOTAL	**100**	**Overall percentage of the above factors**

NB: Percentages can be manipulated to give different results.

Finally, binary suitability was used to identify the range of values from unsuitable to suitable, and in this study the ranking was based on the following three classes (Table 4.8):

Table 4.8: Ranking and weight areas suitable for new afforestation forestry in the Letaba Catchment

Criteria	**Description**	**Values**
Good	Grid cell where it was good for both criteria	10-7
Moderate	Grid cell where it was good for at least one criteria	7-5
Low	Grid where cells was bad for both criteria	<5

To verify areas that have the optimal potential for forestry, only those areas that ranked well (7-10) according to the model were further reclassified into three classes (Table 4.9).

Table 4.9: Ranking and weight of suitable areas for new afforestation in the Letaba Catchment.

Criteria	**Description**	**Values**
Good	Grid cell where it was good for both criteria	10
Moderate	Grid cell where it was good for at least one criteria	9-8
Low	Grid where cells was bad for both criteria	7

Therefore, only those areas that weight with a value of ten (10) were identified as highly suitable or optimal areas for new afforestation.

4.6 Determination of Ecological and Human Reserve

An additional requirement of the National Water Act (Republic of South Africa, 1998) was to take into account the requirements of the Reserve. The Reserve has two components, the Human Reserve, which is water for basic human needs, and the Ecological Reserve, which is water that must remain in the river for the sustainable functions of the river's ecology. In determining the areas in which afforestation could take place, it was important that the Reserve (both Human and Ecological) was met. In terms of the National Water Act (RSA, 1998), the Reserve has a higher priority than afforestation or any of the other water users. Ecological water requirements in the Letaba catchment have been determined by the DWAF's Resource Directed Measures (RDM) Directorate whilst desktop estimates have been made in the remaining catchments using the Hughes Desktop Model (Hughes & Munster, 1999). It was the study mentioned developed by DWAF that was used to determine Reserve in this study area.

4.7 Extracts on existing water use from other sources

Data of existing water use was also drawn from the Water Use Registering and Licensing Management System (WARMS) database. The WARMS database contains the registered areas of commercial forestry. The disadvantage with this database is that the small plantations which are called Woodlots were not included in this database as a form of water use. According to Mallory *et al.* (2008), this is an aspect that requires some additional work in future.

Hydrological data, particularly information available from DWAF's Internal Strategic Perspective (ISP) which is fore runner of Catchment Management Strategies and water balance information for the study area, was used. Internal Strategic Perspectives have been developed by the Department of Water Affairs and Forestry for all 19 Water Management Areas (WMAs) (Figure 4.5). Therefore, the ISP describes how water resources should be managed by DWAF in each WMA as an interim arrangement before Catchment Management Areas (CMAs) assume full responsibility. The objective of the ISP is to form coherence between DWAF at regional and national levels in order to manage the water resources in a consistent and predictable manner.

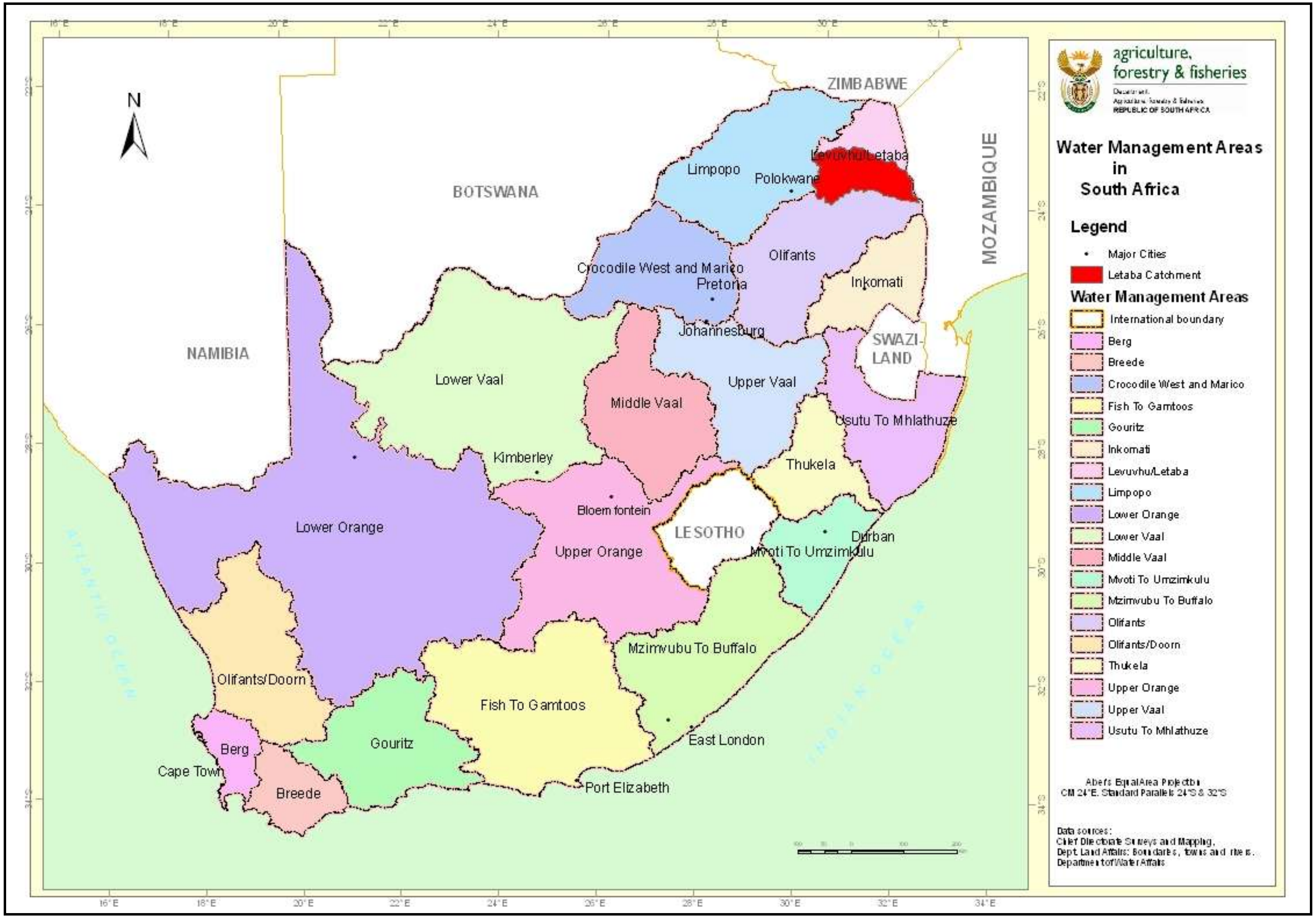

Figure 4.5: Water Management Areas in South Africa.

The data for ISPs on water resources was derived from the National Water Resources Strategy (NWRS) (DWAF, 2004), WMA Reports and other catchment studies such as Letaba Comprehensive Reserve study (DWAF, 2006). In most cases, the ISP represents the latest available estimates on the available water resources. This information, however, is still only given at sub-catchment level which is defined as Tertiary Catchments and is based on estimates of water demand and not the actual water use.

In the WReMP analysis, the WR 90 hydrological data was used. There is a newly updated hydrological data called WR 2005 which is also used in the study. The WR 2005 is an updated dataset that includes information on rainfall, natural and contemporary run-off at quaternary catchment scale in the form of a monthly time-series. The use of WR 2005 data in this study has added more confidence to the results of this study, since the results may offer more or less water. The latest version of WReMP model is still up loaded with WR 90 and restricted to the common series from 1925 to 1989 for these three major sub-catchments.

Chapter Five: Data Analysis and Results

5.1 Introduction

The main aim of this study is to get an indication of where additional forestry could possibly be considered in the Letaba Catchment. This resulted in a number of possible areas being identified based on rainfall, topography, landuse and other factors. The purpose of the analysis reported on here is to assess the impact of additional forestry in these potential quaternary catchments of the Letaba Catchment on water resources. According to ISP (DWAF, 2004) quaternary catchments are a basic unit of area used in the WR90 series of reports published by the Water Research Commission (WRC). Within the Letaba Catchment there are 23 quaternary catchments. In this study, the analyses conducted using the WReMP model was underpinned by data for these sub-catchments. The focus of the analysis was initially to assess whether or not the Ecological Reserve could be met with increased forestry. However, in many cases there are other water resource constraints which limit the potential for expansion of forestry in the Letaba Catchment. These constraints have been identified and are discussed in next chapter.

5.2 Environmental Assessment

The environmental assessment was based on the assessment of the biological (especially conservation and biodiversity) constraints to possible land use transformation. Secondly, it assessed agricultural priority and possible competitive constraints. Lastly, it was an assessment of the population and social pressures and demands which could be either a constraint or an incentive.

5.2.1 Biological Assessment

Wetlands and conservation areas are represented as biological constraints and classified in this study which as sensitive areas (Figure 5.1). Many of these sensitive areas are clustered in the central region of the Letaba catchment (around the Magoebaskloof area within quaternary catchment B81B).

Archaeological, cultural and traditional sites were also classified as areas that have high constraints for additional forestry sites. These sites are protected in terms of the National Heritage Resources Act (Act 25 of 1999).They may not be destroyed, damaged, disfigured, excavated, altered, removed from their original site or exported from the Republic of South Africa without a permit from the South African Heritage Resources Agency (SAHRA).

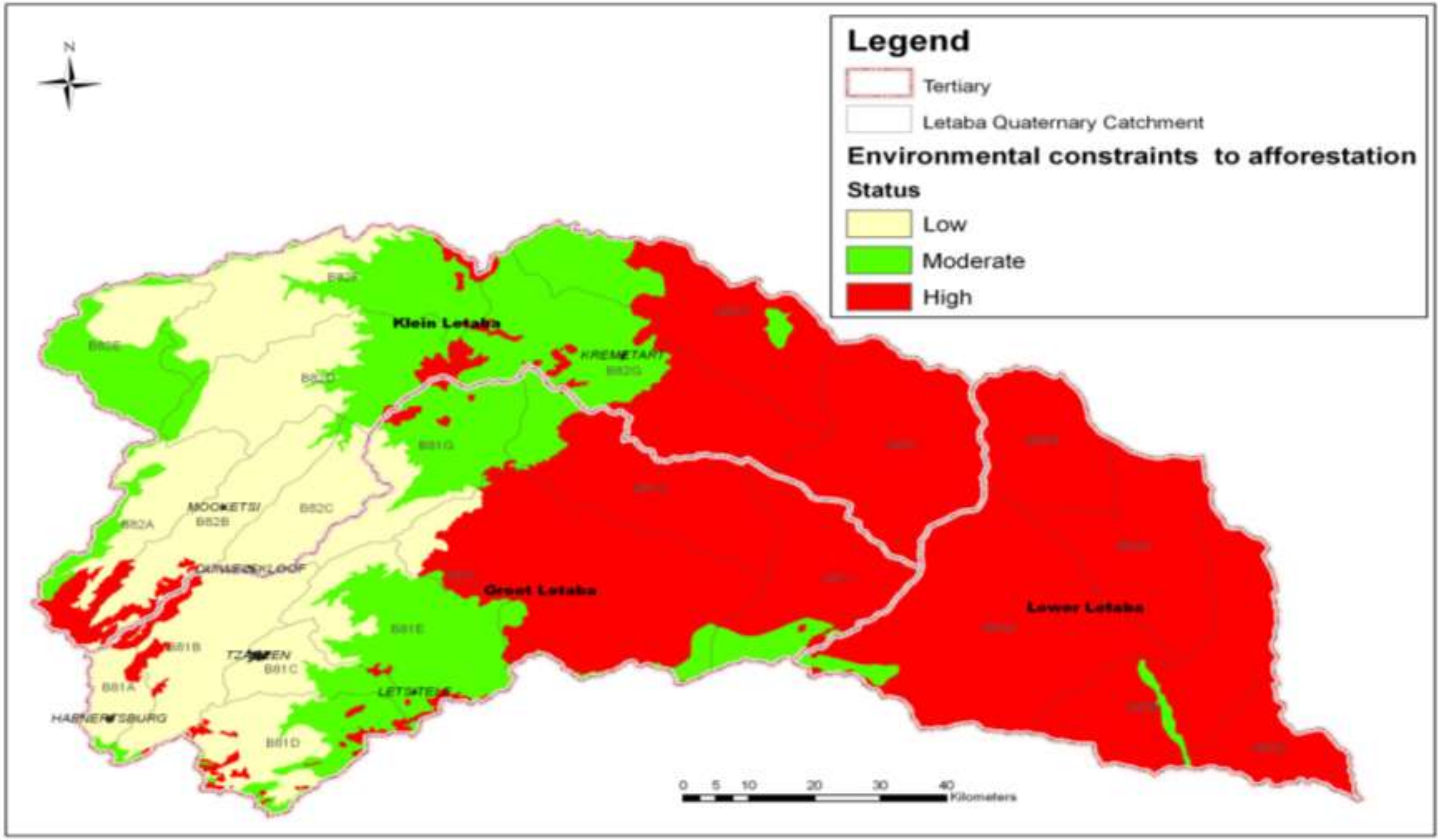

Figure 5.1: Environmental constraints to afforestation. The Lower Letaba Catchment mostly falls within the Kruger National Park and is therefore excluded as a suitable area for afforestation.

Such sites may also include grave sites, historical plantings, buildings older than 60 years, ruins, or any other signs of human habitation (*e.g*. rock paintings).

5.2.2 Agricultural Assessment

Areas of existing agriculture were identified as the most significant constraint on new afforestation, as the other constraints applied to very limited areas. There are three sets of tertiary catchments being considered within the Letaba WMAs which are Groot, Klein and Lower Letaba. As illustrated in Figure 5.2 most of the area in these catchments is categorised as having low or medium constraints to afforestation. The high constraint areas are those where pivot irrigation already exists.

The classification in Figure 5.2 also indicates more areas as having good afforestation potential which is a low constraint especially because this area is characterized by low cultivation. Most people living in the villages prefer to have their own private gardens and also small farmers are predominant in most areas. There are some areas that have been categorized as having low constraints to afforestation, but not all areas are flat and agricultural potential will be limited in areas which exhibit steep slopes. This might require further investigations as afforestation of flat areas suitable for cultivation would be discouraged by the authorities.

5.2.3 Social Assessment

The key social issues that have been identified as being of importance for the consideration of afforestation potential were human settlement densities and land ownership. In addition to the factors mentioned above, pending land claims, municipal planning and development objectives were also considered. Furthermore, human settlement in communal tenure areas is closely associated with agricultural practices such as cropping and livestock. These associated land uses would also provide constraints on the availability of land for afforestation. Population densities and household settlement patterns are, therefore, important considerations in the assessment of afforestation potential. Dense human settlement predominates in the Duiwelskloof, Tzaneen and Letsitele areas; making large parts of the Letaba Catchment unsuitable for commercial afforestation (refer to Figure 5.3).

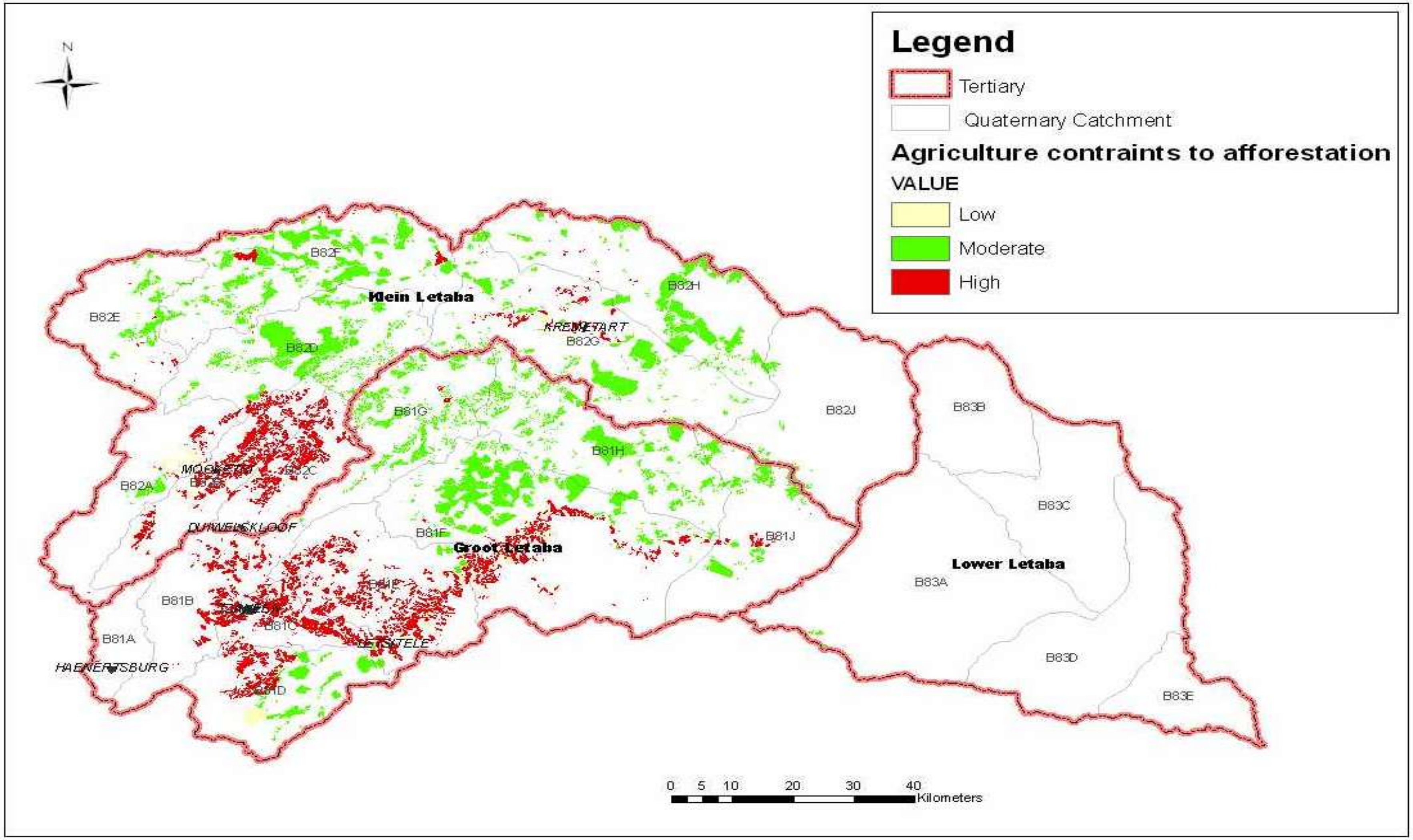

Figure 5.2: Map analyzing agriculture in the Letaba Catchment.

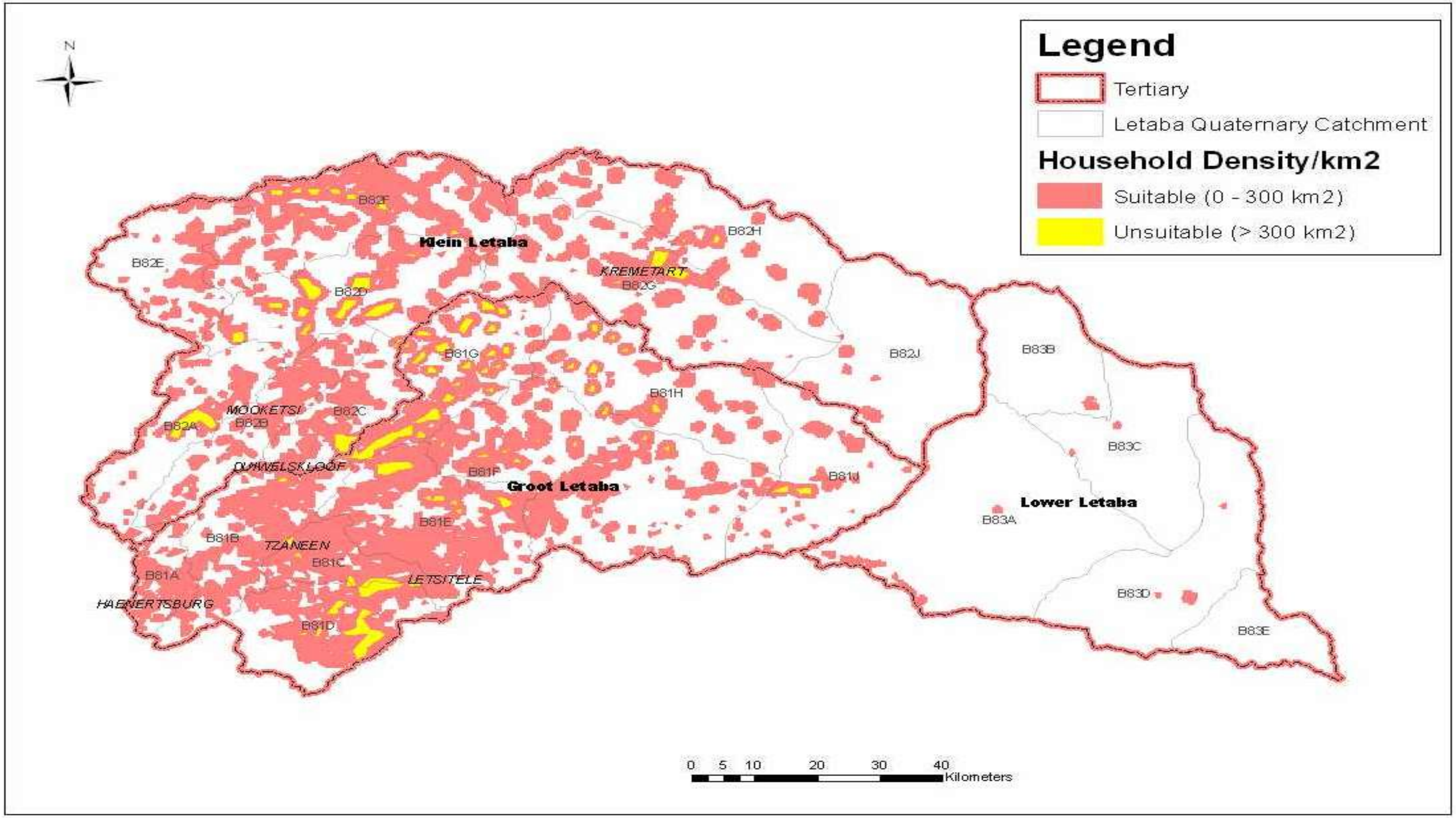

Figure 5.3: Map on the urban and rural settlement in the Letaba Catchment.

5.3 Water Resource Assessment

The second major evaluation of the official water resource availability at catchment scale and from the national DWA planning perspective for South Africa as contained in the DWAF's Internal Strategic Perspectives document. Furthermore, it was a review of actual water resource availability at local scale in areas where rainfall could support forestry. Then, computation of forestry area and calculated water use by quaternary catchment for all quaternary catchments with some forestry presence was done using the WReMP model. Lastly, a consideration of ways in which water could be made available to forestry even where all resources have seemingly been allocated was done using the WReMP model.

5.3.1 Water Availability: Current Requirements

Water use in the Livhuvhu and Letaba WMAs is dominated by irrigation sector, which represent nearly 72 % of the total requirements for water within the WMA (Table 5.1). The impact of afforestation on the yield from water resources in the WMA area represent 17 % of the total requirement and about 9 % for rural domestic supplies and for stock/game watering and the remainder for urban, industrial and mining use. As would be expected, the sectoral requirement for water is also clear a reflection of the strong rural and agricultural socio-economic nature of the WMA.

Table 5.1: Water Requirement in the Livhuvhu and Letaba WMAs

Water Uses	Tertiary Catchments			**Total per Water Uses**
	Groot Letaba	Klein Letaba	Lower Letaba	
Irrigation	126	25	0	**151**
Urban (1)	3	3	0	**6**
Rural (1)	10	8	0	**18**
Mining & bulk Industrial (2)	0	0	0	**0**
Power Generation (3)	0	0	0	**0**
Afforestation (4)	35	1	0	**36**
Total Requirements	174	37	0	**211**
Transfers out	11	0	0	**11**
Grand Total	185	37	0	**222**
Balance (1)	-26	-5	1	**-30**

1. Includes components of reserve for basic human needs at 25l/c/d.
2. Mining and bulk industrial water use which are not part of the urban area.
3. Includes water for thermal pore generation only. Water Hydropower which represents only a small portion of power generation in South Africa is generally available for other uses as well.
4. Quantities given refers to the impact on yield only

More than half of the total requirements for water within the Letaba Catachment are in the sub-catchment of the Groot Letaba River, mostly in the form of irrigation and forestry, which shows the intensity and concentration of irrigation and commercial forestry in this catchment. In the Klein Letaba sub area, irrigation is also the dominant water use by both areas. The water requirements from the WReMP database are shown in Table 5.2.

Table 5.2: Water requirements from the WReMP database (million m³/a).

Sub-Catchments (Tertiary)	**Quaternary Catchment**	**Irrigation**	**Rural**	**Urban**	**IFR**
Groot Letaba	B81A	0.39	0.17	0.05	12.7
	B81B	23.05	0.47	0	28.6
	B81C	4.6	0.37	2.53	23.9
	B81D	6.53	3.48	0.33	6.16
	B81E	18.74	2.16	0.45	32.97
	B81F	56.73	4.68	0	33.48
	B81G	0.67	6.7	0.14	0
	B81H	2.9	0	0	0.65
	B81J	0	0.52	0	30.75
Klein Letaba	B82A	3.84	0.23	0	1.14
	B82B	12.07	0.19	0	0.91
	B82C	7.23	0.59	1.33	0.49
	B82D	0.25	5.71	0.36	6.98
	B82E	0.13	1.22	0	0.53
	B82F	0.5	6.96	0	1.02
	B82G	8.54	2.49	0.89	1.51
	B82H	2.35	3.31	0	1.06
	B82J	0	0.05	0	1.25
Lower Letaba	B83A	0	0.25	0	41.21
	B83B	0	0	0	0
	B83C	0	0	0	0
	B83D	0	0	0	43.72
	B83E	0	0	0	47.91

5.3.2 Rainfall Limitation

With reference to Figure 5.4., only parts of the eastern portion of the Letaba Catchment received greater than 650 mm of rainfall *per annum* which could be considered for commercial afforestation. While much of western Letaba catchment towards Kruger National Park received less than 650 mm of rainfall *per annum* (Figure 5.4).

5.3.3 Water availability in terms of DWA's Internal Strategic Perspectives (ISP)

It is indicated in the ISPs that almost no consideration of forestry has been given in the Groot Letaba, Klein Letaba and Lower Letaba sub-catchments since they all have no surplus water available for allocation.

5.3.4 Water availability in specific sub-catchments in terms of the National Water Resource Strategy (NWRS)

The available surface water resource in the Groot Letaba sub-catchment is 133 million m^3/a. The contribution of groundwater to the available water resource in the Groot Letaba sub-catchment is estimated in the NWRS to be 12 million m^3/a (Table 5.2), while the recently completed registration of water use gives the groundwater use as 23 million m^3/a.

The gross surface water availability in the Klein Letaba sub-catchment is estimated at 27 million m^3/a (Table 5.3). There is also a relatively large groundwater resource in this sub-catchment. The contribution of groundwater to the available water in the Klein Letaba sub-catchment in Table 5.3 is estimated to be about 9 million m^3/a.

The Lower Letaba sub-catchment is situated downstream of the Groot Letaba and Klein Letaba sub-catchments and falls entirely within the Kruger National Park. This sub-area therefore receives all the water flowing out of the Groot Letaba and Klein Letaba sub-catchments. For all practical purposes, no sustainable yield is derived from runoff in the Lower Letaba sub-catchment. Water use in the catchment is negligible. The groundwater resource is given in the NWRS as zero, but this is based on actual groundwater use and is not an indication of the actual potential resource (Table 5.3).

Table 5.3: Available water in the year 2005 (million m^3/a) from NWRS

Sub-Catchment	**Natural Resources**		**Usable Return Flow**	**Total Local Yield**	**Grand Total**
	Surface Water	**Ground Water**			
Groot Letaba	133	12	14	159	159
Klein Letaba	27	9	2	38	38
Lower Letaba	0	0	0	0	0
Total	160	21	16	197	197

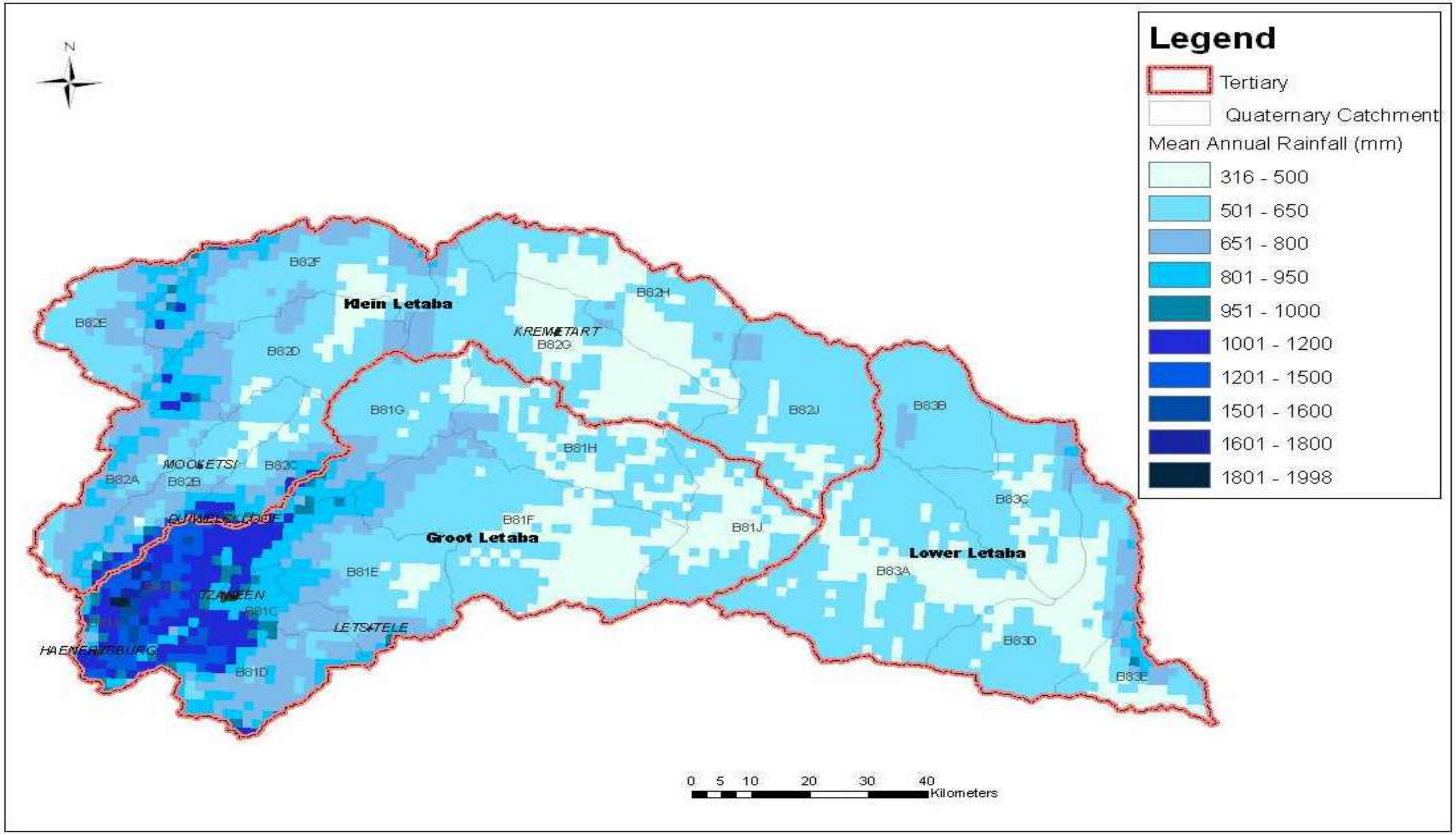

Figure 5.4: Map on rainfall analysis in the Letaba Catchment.

5.3.5 Water available in the dams of the Letaba Catchment

Mallory (2008) provided a simplified diagram of the Letaba catchment which is shown in Figure 5.5.

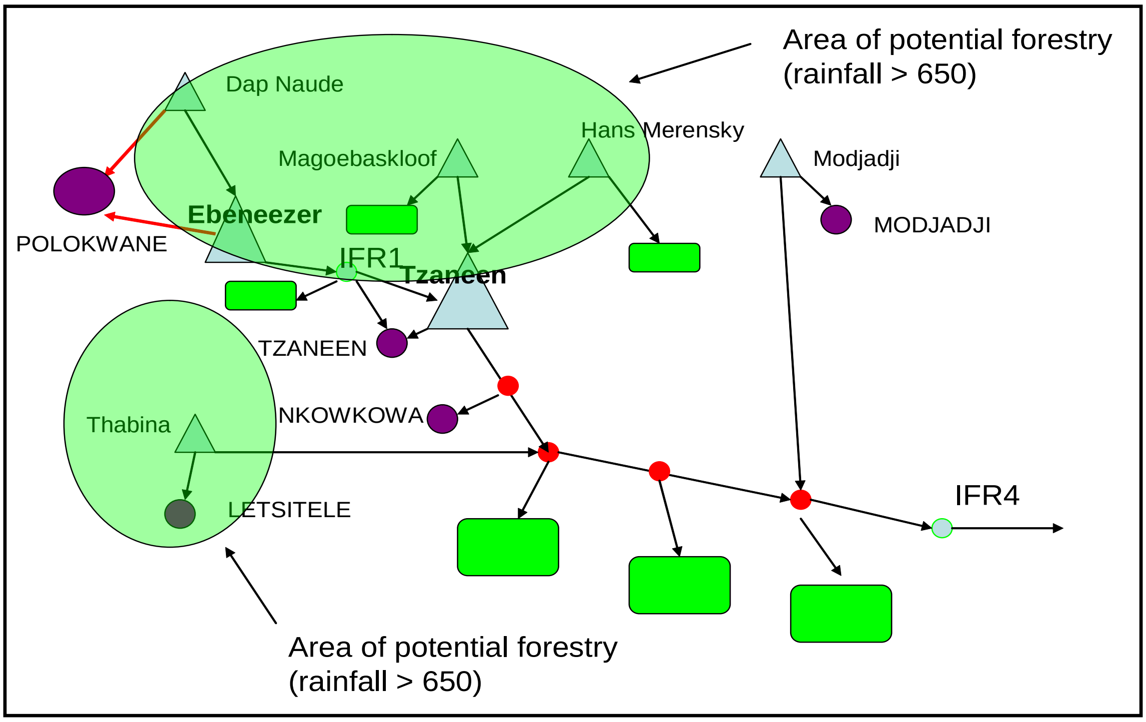

Figure 5.5: Simplified Diagram of the Letaba Catchment in the WReMP modelling (Mallory, 2008).

According to Basson *et al*. (1994), the yield from a dam (system) is defined as the volume of water which is abstracted over a specific period of time. The yield of the Groot Letaba system is best described at the major points of abstraction, namely the Dap Naude, Ebeneezer, Tzaneen, Magoebaskloof, Thabina and Modjadji Dams (Table 5.3). The WReMP model was used to check the performance of some of these dams over the years (Figure 5.6). The rule is that the dam should not be empty at any time. Based on this criteria, it became clear that the Magoebaskloof Dam is the only dam that is suitable to supply additional water for forestry (Figure 5.6). In addition, although there is significant incremental run-off-river yield downstream of the Tzaneen Dam, this area is not suitable for afforestation due to the low rainfall and limited water resources.

Table 5.4 lists the yield of the above mentioned dams as well as the allocations from these dams. A simple water balance then indicates whether or not there is water available for forestry in the catchments upstream of these dams. The Dap Naude, Ebeneezer and Thabina Dam operate independently as compared to Tzaneen Dam. The yield from the Tzaneen dam also includes the incremental flow contributions from other dams.

Table 5.4: Dams and available Yield in the System in the WReMP modelling.

Dam	Historic firm yield (million m^3/a)	Water allocation (million m^3/a)	Balance (million m^3/a)
Dap Naude	4.0	6.3	-2.3
Ebeneezer	22.0	28.0	-6.0
Tzaneen	~78*	123.4	-45.4
Magoebaskloof	10.4	13.0	-2.6
Thabina	2.9	3.0	-0.1
Modjadji	4.4	2.2	2.2

Based on Table 5.4, only the Modjadji Dam has surplus yield available. The rainfall in the Modjadji Dam catchment is too low to support afforestation. The possible increase of afforested areas upstream of Magoebaskloof Dam is addressed under the section on the recommended scenario.

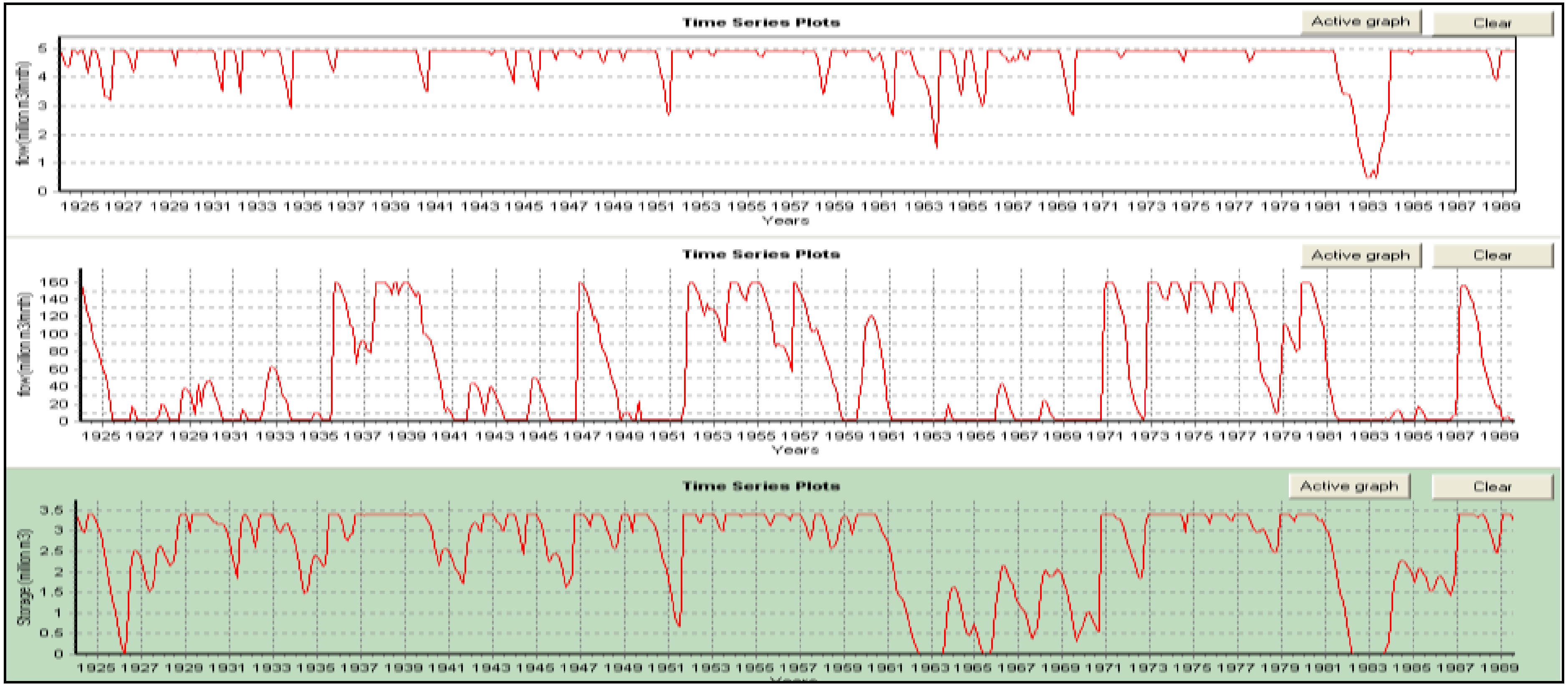

Figure 5.6: Historic flow sequence of Mogoebaskloof Dam, Tzaneen Dam and Thabina Dam respectively.

5.4.1 WARMS Data

The WARMS data was also used to determine whether any forestry was registered on the WARMS database which provided information about each tree species found in the Province and the area occupied by this species within each of the quaternary catchments (Table 5.5). WARMS should indicate all registered and licensed forestry. DWAF used this data source to estimate existing forestry in the country by breaking down forestry coverage into each species or genus (DWAF, 2004). Also DWAF have used this data to estimate how much water could be used by the existing forestry compared with other water users in the quaternary catchment (DWAF, 2004).

Table 5.5: Existing Forestry per species in the Limpopo Province from WARMS data.

QC	***Eucalyptus spp.* (ha)**	**Pinus *spp.* (ha)**	***Acacia mearnsii* (ha)**	**Total**
A71C	83	18	5	106
A71H	805			805
A80A	3151	54		3204
A80B	148	88		236
A80C	25			25
A80D	15			15
A80E	8			8
A80H	5			5
A91A	4208	184		4392
A91B	194			194
A91C	3731	527		4257
A91D	908	2328		3236
A91E	118			118
A91F	3	2		5
A91G	1674			1674
A91H	88	206		294
A92A	186			186
A92B	14			14
B81A	4868	4193	68	9129
B81B	19012	1434		20446
B81C	1228	4		1232
B81D	2505	346		2851
B81E	1630			1630
B81G	1			1
B82A	586	24		610
B82B	538	32		570
B82C	1178			1178
B82D	903			903
B82E	1892	50		1942
B82F	765			765
TOTAL	**50467**	**9489**	**73**	**60029**

Also WARM data was used to determine the number of water users that have registered. The registered water use is listed in Table 5.6 below together with the water use in the existing WReMP setup. The other source of data is the Klein and Middle Letaba Water Resources Study (DWAF, 2003), which indicates that the irrigation use upstream of the Middle Letaba is 19.5 million m³/annum of which half is estimated to be from groundwater. This report estimates the irrigation downstream of the dam to be 10.3 million m³/annum (DWAF, 2003).

Table 5.6: Registered water use in the Letaba Catchment.

Quaternary Catchments	**WARMS (million m³/a)**			**TOTAL (WARMS) (million m³/a)**	**WReMP (million m³/a)**
	Groundwater	**Dams/Lakes**	**Run of River/ Springs**		
B82A	4.9	0.7	4.3	9.9	1.7
B82B	8.1	8.0	13.2	29.3	7.2
B82C	8.0	3.6	4.0	15.6	4.5
B82D	0.7	0.7	0.5	1.9	0.1
B82E	1.6	0.7	0.0	2.3	0.7
B82F	1.1	0.0	0.1	1.2	0
B82G	0.0	9.1	1.6	10.7	4.8
B82H	0.2	2.5	0.2	2.9	0
B82J	0	0	0	0	0

5.4.2 National Water Resource Strategy

According to the NWRS (DWAF, 2004), large areas suitable for afforestation in the Limpopo Province are found in the Luvuvhu Catchment (Table 5.7).

Table 5.7: Existing forestry in the Limpopo Province from NWRS (DWAF'S WARMS Database; Midgeley *et al*, 1994; Gush *et al*, 2002).

River	**Catchment**	**Afforested Area (km^2)**	**Natural Flow (million m³ / annum)**	**Streamflow Reduction (million m³ / annum)**
Groot Letaba	B81	353	407	34.23
Klein Letaba	B82	60	114	4.17
Sand River	A70	9	72	0.90
Luvuvhu River	A91	142	519	11.34
Mutale River	A92	2	156	0.15
Nzhelele River	A80	35	113	2.90
Olifants River	B70	48	417	2.7
Total		**649**	**1 798**	**56.4**

According to NWRS, the rainfall in most of the Limpopo Province is well below the minimum 650 mm *per annum* required for commercially viable afforestation, (DWAF, 2004). Not surprisingly therefore, both existing forestry within the Province, and future potential, are limited. Table 5.7 above provides a summary of the afforested areas in each of the major catchments in the Luvuvhu and Letaba Water Management Area, together with the resultant reduction in streamflow.

5.4.3 Invasive Plants

Currently, approximately fifty (50) invasive species can be found in the Letaba Catchment (Appendix 1) .According to Versveld *et al.* (1998), the total area of invasive plants in the Limpopo Province is estimated at 794 km^2 or 79 400 ha (0.6 % of the total area of the Limpopo Province), much of this is located in riparian areas (Table 5.8). This is the only national data source on alien vegetation which was used in the WReMP model as a reference data set. Based on the WReMP model, the volume of water use attributed to the above mentioned invasive alien plants across the entire Province is 61.6 million m^3/annum (Table 5.8). This is equivalent to the water use that would be attributed to approximately 60 000 ha of forestry. It is important to note that the actual use by catchment varies significantly with climate and availability of these invasive plants in the catchment. Table 5.8 describes the breakdown of estimated area of invasion and associated water use by catchment in the Limpopo Province. See Appendix 2 for a breakdown of estimated area of invasion and associated water use by quaternary catchment.

Table 5.8: Stream Flow Reduction Due to Alien Vegetation in the Limpopo Province.

River	Catchment	Area of alien vegetation (km^2)	Streamflow reduction (million m^3/annum)
Sand River	A70	279	3.1
Nzhelele River	A80	12	2.0
Mutale River	A92	5	0.4
Luvuvhu River	A91	183	24.7
Groot Letaba	B81	81	14.0
Klein and Middle Letaba	B82	16	0.80
Olifants	B70	218	16.2
Total		**794**	**61.6**

Table 5.8 highlights that if the invasive alien plants were to be eradicated from Groot, Klein and Middle Letaba and then a volume of approximately 14.80 million m^3 *per annum* of water could be released. This water could then be used to meet the needs of the Reserve; be taken up by forestry activity and other water using activities such as mining or agriculture or held to meet future demands.

5.4.4 Woodlots in the Letaba Catchment

In the entire Letaba Catchment only 23.6 ha registered in the WARMS database as a Stream Flow Reduction Activity which is classified as 'Woodlots' (Table 5.9). Woodlots are Small-scale subsistence forestry which is often in the 0.5 ha – 10 ha category, and most of this still falls completely below the radar, although cumulatively the impacts can be very significant. Woodlots are an important component of the forestry environment. Forest products from woodlots - such as firewood, fodder, and building material, are often under-valued in economic terms. It is recommended that these be seen as part of the overall forestry portfolio.

Table 5.9: Registered Woodlots in Limpopo Province from WARMS DATA 2008

Quaternary Catchment	**Area (ha)**	**Species**
A91F	3.4	*Eucalyptus spp.*
A91F	1.7	*Pinus spp.*
A91H	206.2	*Pinus spp.*
A91H	77.8	*Eucalyptus spp.*
B82F	23.6	*Eucalyptus spp.*

5.5 Assessment of Forestry Potential

A simulation has been carried out on a few selected catchments to determine which catchment could allow additional forestry. In order to streamline the process and limit the number of simulations, a low-flow analysis was carried out to determine where forestry is possible given the limitations imposed by existing development and the ecological. This low-flow analysis determines, in each quaternary catchment, the natural low flow, the current-day low-flow. Having identified the catchments in which forestry is possible, the intention was to estimate the maximum possible area through trial and error, commencing at upstream catchments, to meet the 20 % low-flow reduction criteria. The flow duration curves in all the areas was done to check which areas could have a potential and what will be the maximum hectares of potential to make sure that the assumptions made were not against the ecological requirements. Two samples are shown in Table 5.10. Sample 1 represents the B81B catchment and shows that plantations on the potential areas for afforestation, forestry could go to a maximum of approximately 55 km² (5 500 ha). It means that no more afforestation should be allowed in this quaternary catchment.

Table 5.10: Samples of Quaternary catchment that could have potential of forestry

	Sample 1: B81B Catchment (Magoebaskloof Dam)	**Sample 2: B81E Catchment (Dummy Dam E23)**

Catchment Area (CA)	61.4 km²	58 km²
Existing forestry	24.9 km^2	42 km^2
Additional:	**30.1 km^2**	0.00 km^2
New total area:	55 km^2	1.42 km^2
Natural low flow	0.21 million m^3 (October)	0.0 million m^3 (October)
New low flow	**0.15 million m^3 (October)**	0.0 million m^3 (October)

The duration curve of Sample 1 can be seen in Figure 5.6 when an additional forestry could be planted in this quaternary catchment.

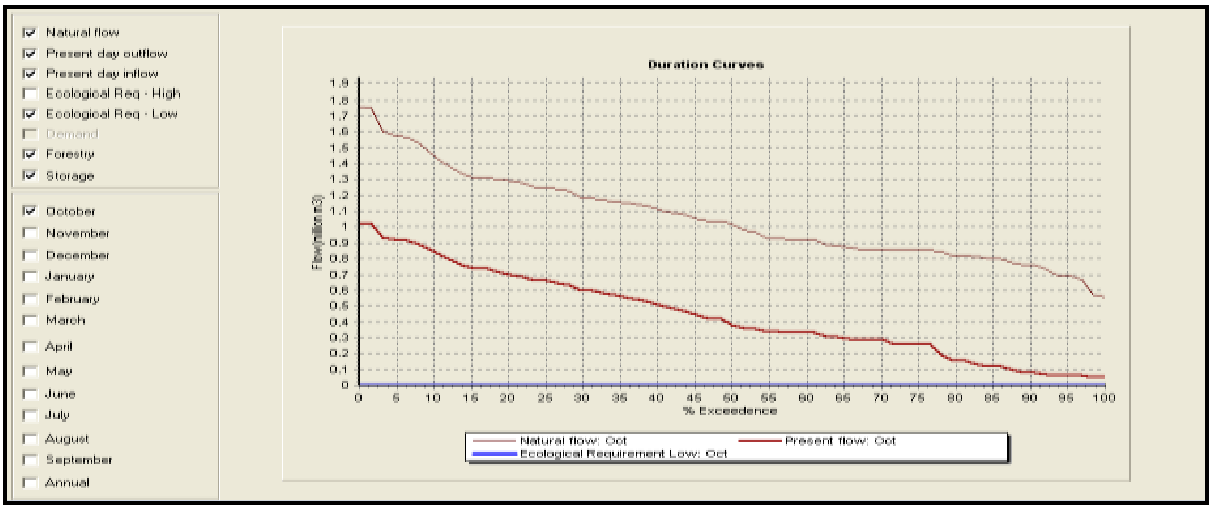

Figure 5.6: Duration Curve of Mogoebaskloof after additional forestry.

Graph of Sample 2 shows very clearly that the addition of forestry would affect the ecological requirements (Figure 5.7). This is clearly contradictory to the National Water Act, which sets the ecological reserve as the highest priority. Notwithstanding the above reasoning and assumptions, development should never be allowed which could change a river from being naturally perennial to non-perennial as a result of the development.

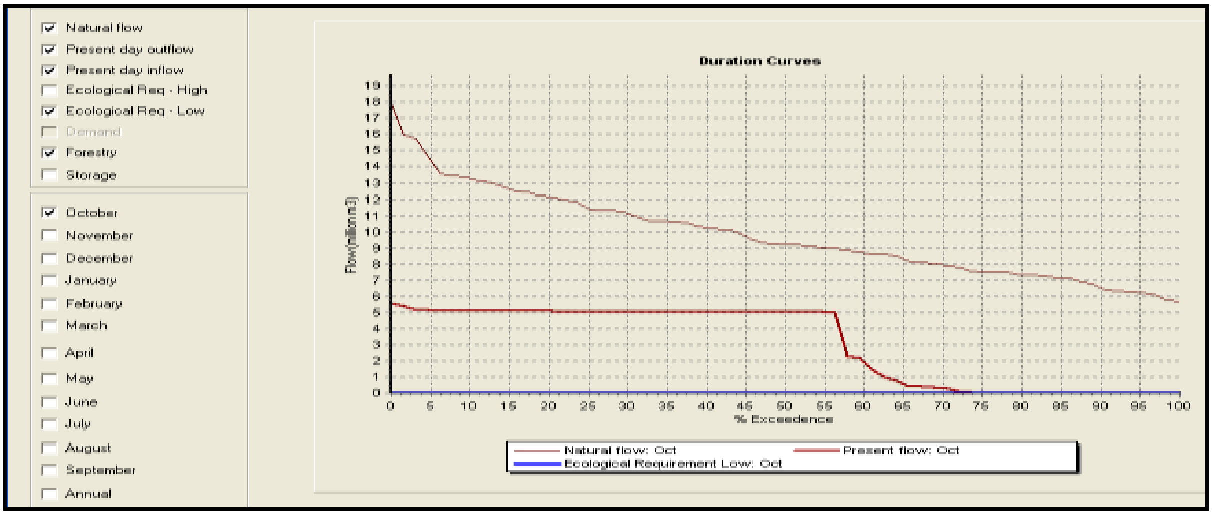

Figure 5.7: Duration Curve of Dummy Dam at B81E Catchment.

5.5.1 Soil Assessment in the Letaba Catchment

Generally, the production of saw-timber requires very good sites that give rise to rapid growth rates, while wattle bark and pulpwood can be produced in an economically viable manner; even on poorer sites. There is a wide range of *Eucalyptus spp*. species planted, with each species having its site preferences, in terms of the ability of the species to tolerate cold and drought conditions. Provided that there is sufficient rainfall and depth of soil, it is always possible to find a commercial forestry species that will do well on a particular site – but it is critically important to carefully match species to site characteristics (Esterhuyse, 1999). Figure 5.8. depicts soil characteristics of the Letaba Catchment. The areas indicated by green represent soils which are moderately drained, whereas the areas indicated yellow soils are subjected to water logging. Rocky outcrops in the form of stony koppies are also common in the study area (Wessels, 1978). From the results of the suitable areas (Figure 5.9) it becomes clear that areas of high rainfall are having very high potential for afforestation. Most of the sub-catchment is in the B81 which are suitable areas.

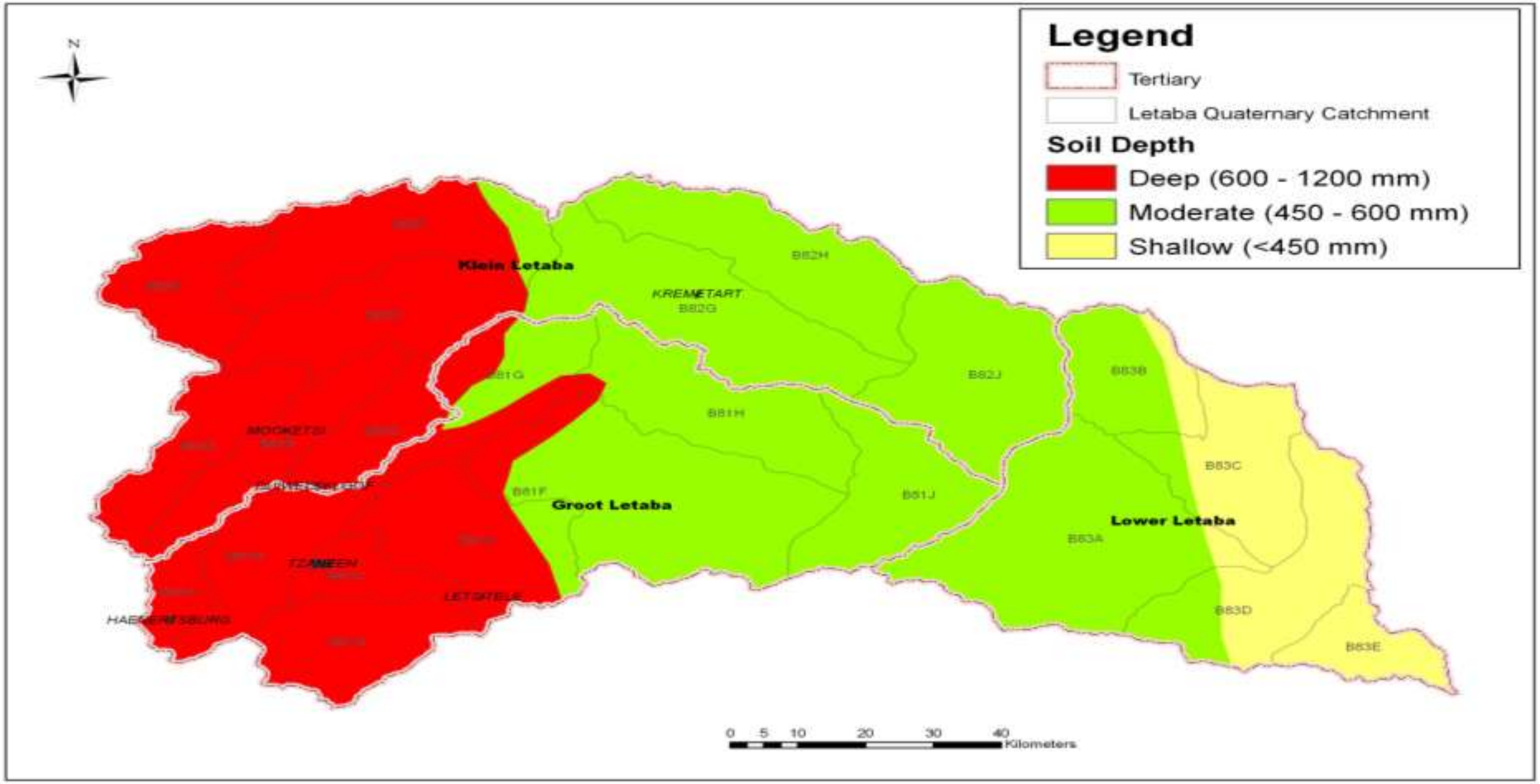

Figure 5.8: Map showing soil depth in the Letaba Catchment.

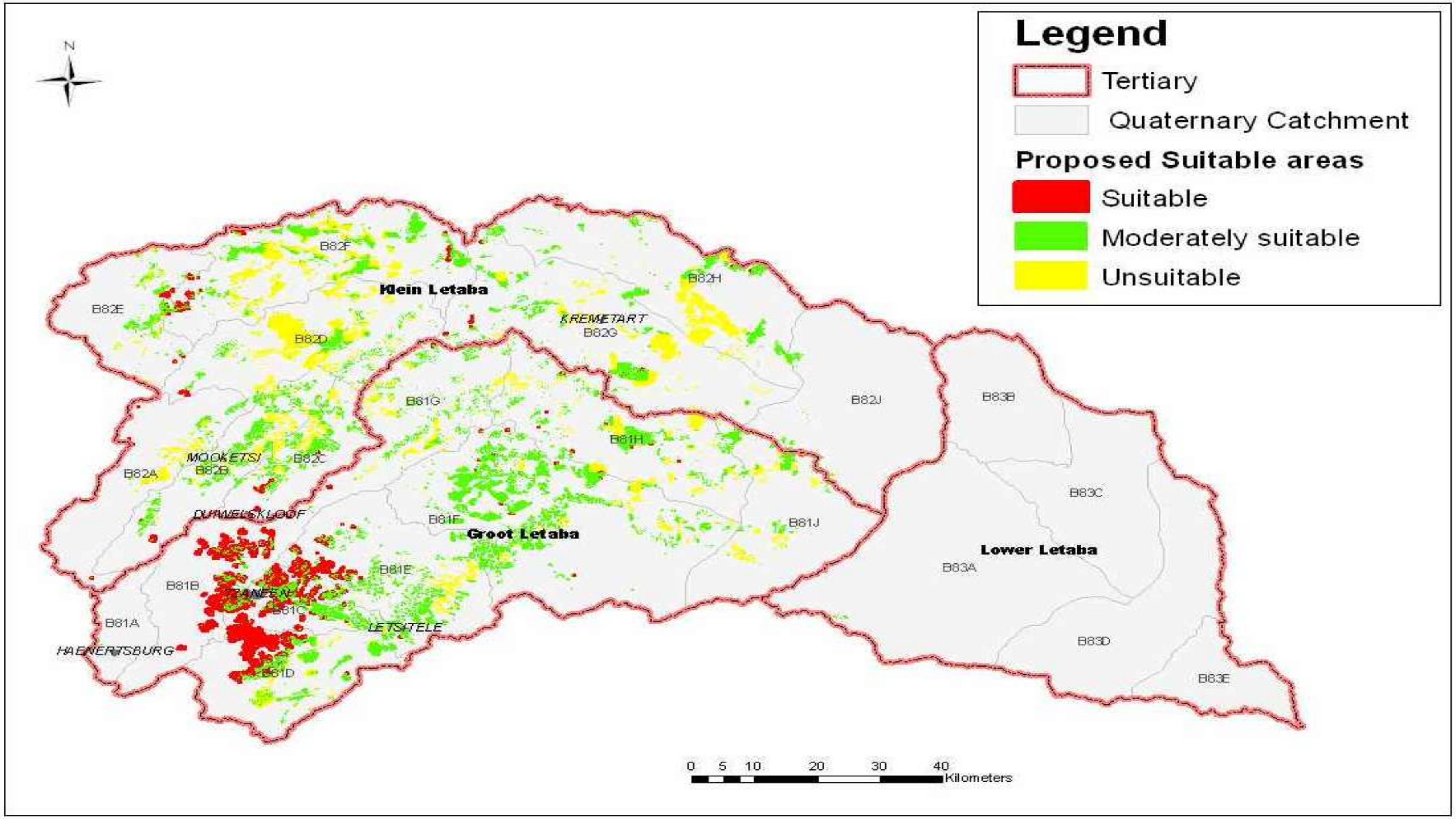

Figure 5.9: Map showing suitable areas for afforestation within the study area.

5.6 Reserve Determination

An integrated approach for considering a range of ecological categories, and their consequences, was adopted based on the Ecological Importance and Sensitivity (EIS), Social and Cultural Importance (SI) and the Economic importance (*i.e*. value of in-river and out-of-river use of the resource) so as to better inform decision-making regarding the Reserve. This approach included the innovative use of a scenario analysis which is consistent with a basic principle of Integrated Water Resource Management (IWRM), *i.e*. consideration of all realistic alternatives to a specific proposal.

According to Comprehensive Reserve Determination Study (DWAF, 2006), ecologically, the upper catchment (above Ebeneezer Dam) of the Letaba Catchment River is considered to be natural and has a high ecological importance (Appendix 3). The relatively natural condition is attributed to limited disturbance by human activities. But there are ecological modified sections of Letaba Catchment River. These are between the Tzaneen Dam and the border with the Kruger National Park. This is due to the reduction in flow as a result of upstream impoundments (*e.g*. Tzaneen and Ebeneezer Dams), large weirs (*e.g*. Junction, Yamarno, Prieska and Jasi) as well as direct abstraction for irrigation (Table 5.11).

Table 5.11: Summary of the Present Ecological Status (PES), Ecological Importance and Sensitivity (EIS) and Socio-cultural Importance (SI) of each Site in the Letaba River Catchment, the Recommended Ecological Category (REC) suggested by the specialists and used to determine the EWR, and the most likely alternative ECs, where applicable.

Site	AREA	PES	Importance		Ecological Category		
			EIS	SI	REC	Alternatives	
1	Groot Letaba (Appel)	C	Mod	Low	C	N/A	D
2	Leststitele	D	Mod	Low	D	N/A	N/A
3	Hansmeresky	C/D	High	Mod	C/D	C	D
4	Letaba Ranch	C/D	High	High	C/D	N/A	D
5	Klein Letaba (Prieska)	C	Mod	Mod	C	D	N/A
6	Lonely Bull	C	High	Low	C	D	B
7	Letaba Bridge	C	High	Low	C	D	B

Table 5.11 shows that the Klein Letaba is in moderately modified to modified state in terms of Ecological Importance and Sensitivity (EIS) and Socio-Cultural Importance (SI). This is mostly due to dense settlements and agriculture above the Middle Letaba Dam and upper Klein Letaba River. The Letaba bridge is in the Lower Letaba catchment which is situated downstream of the Groot Letaba and Klein Letaba sub-area and falls entirely within the Kruger National Park. For this reason, its ecological category looks better than Letaba Ranch (Table 5.11). It receives all the water flowing out of the Groot Letaba and Klein Letaba and there are no transfers into or out of the Lower Letaba Catchment.

5.7 Results of Optimal Areas Overlay on Image

The overlay map (Figure 5.10) showed that most suitable areas are in the quaternary catchments of B82F, B82G, B81F and B81H as highlighted in the green circle. The results are very interesting as rainfall was allocated the highest weight yet the results indicate potential areas in the low rainfall areas. This also shows how factors influenced each other when they were overlaid and integrated using a GIS. While these areas can have low rainfall, they were identified as suitable since the other factors such as soil, slope, and household density had low constraint levels and were thus not environmentally sensitive.

From the water reconciliation conducted in this study, it should be clear that it will pose a much bigger challenge to persuade the DWA to issue additional waters license in this study area because of the current water constraints experienced and reserve required in the catchments. Although, if some alien invasive species can be removed that can release a significant amount of water, could water licenses be issued. Any water available might be contested by irrigators in the surrounding areas, as they might have to cut down on their agricultural activities in order to maintain the reserve. However, considering water (in)availability and climate change, it is unlikely that forestry will be granted permission to expand since one of the goals of the South African government is to maintain and increase food security.

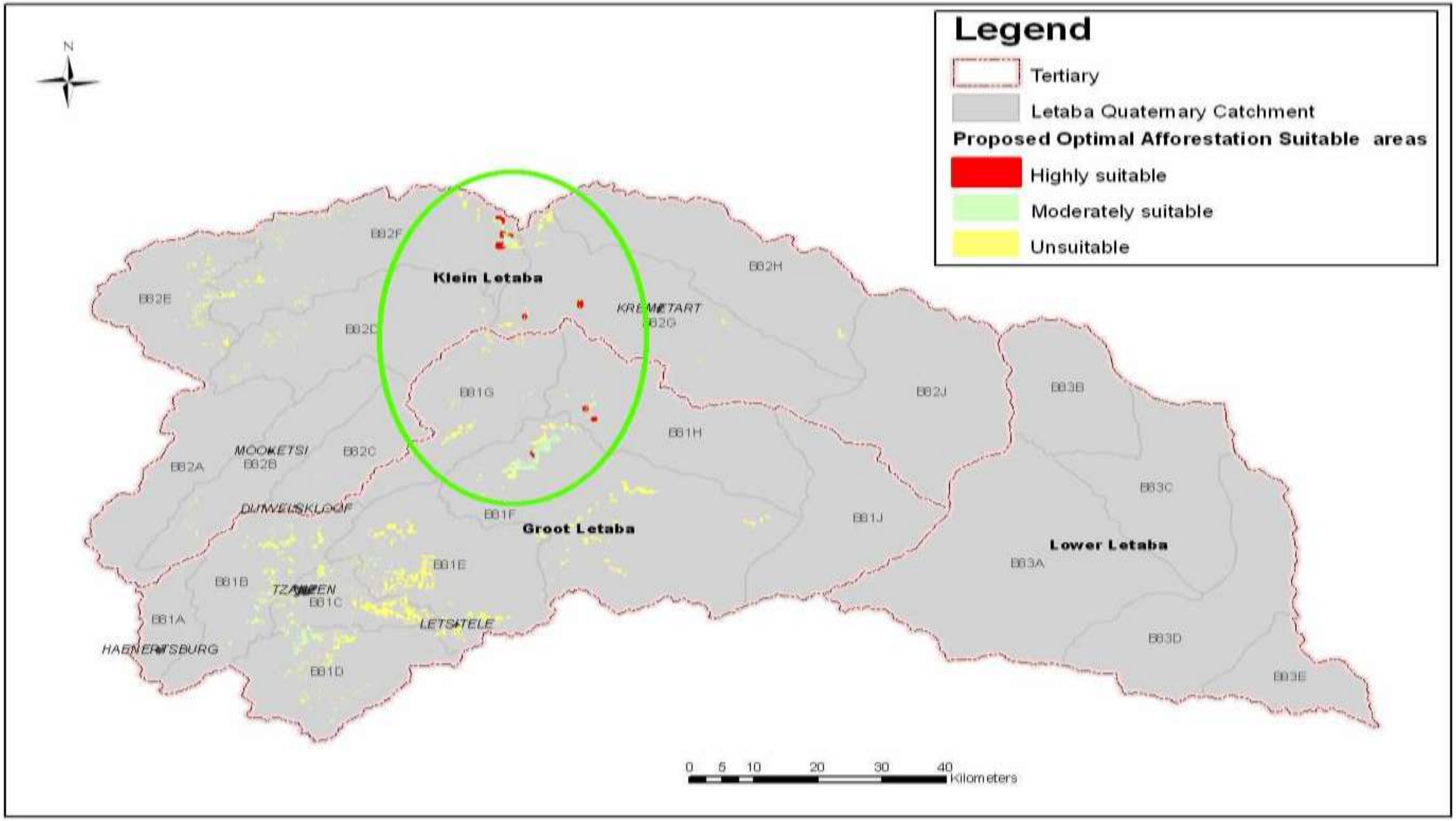

Figure 5.10: Map showing optimal areas for afforestation.

5.8 Chapter Summary

It is clear from the analysis in this chapter that additional forestry plantation in the Letaba Catchment would exert such a demand on the base flow that would conflict with the objectives of water resource protection to sustain ecological functioning of goods and services from the rivers within the study area. The streamflow reduction, which is the effective water use attributed to existing forestry, is already high when viewed in the context of the natural flows of the quaternary catchments of this study area. The expansion of forestry will, therefore, result in a reduction in runoff and the impacts thereof on the ecological and human reserve as well as run-off-river users will be unsustainable. Thus, additional forestry is not feasible in this catchment, particularly when the existing high use and demands of water in the system are taken into consideration.

Chapter Six: Conclusion and Recommendations

6.1 Conclusion

Water is a scarce resource in South Africa, and therefore requires that it is effectively managed to meet with the growing demand. Surface and groundwater resources in many catchments are however extensively used and mismanaged, and the yield of water in those catchments is modified by agricultural and human related activities. The potential impact of exotic plants on water resources was known to be serious, but there is inadequate information available to evaluate the significance of these water losses across the whole country (Le Maitre *et al*., 2000), and where information is available, it differs in terms of methodology used to estimated water use. This provides big debates on the comparison of the effects of exotic and indigenous plant species on water resources.

Forestry is an industry which is traditionally based in rural areas. As a rural based industry, forestry can play a very significant role in sustaining the lives of rural people. Thus, the South African government plays a leading role in the forestry sector, in the form of the White Paper on Sustainable Forestry Development in South Africa (1996), by creating an enabling environment for economic and social development through sustainable commercial forestry. The plantation of forest is also one of the few ways to make productive use of land that is not suitable for farming. It also contributes to the infrastructure and social developments.

Forestry already contributes directly and indirectly to the alleviation of poverty in South Africa, but it has the potential to do even more as a significant employer in rural areas. The forestry sector also offers poor rural people the opportunity to become involved in economic activities through initiatives such as DWAF's Participatory Forest Management (PFM) programme and the Forest Transformation Charter. The forestry sector employs more 170 000 and exports products of a great value.

On the other hand, forestry plantations have negative impacts on water resources whereby it consumes or decreases surface runoff and this may cause conflict between forestry industry and downstream demands for irrigation, industrial, domestic use and natural ecosystem functioning. The concern about forestry as a water user is not its total water use, but rather where and when forests use water. Understanding, or quantifying, this impact on quaternary catchment is useful for both sustaining surface water and timber yield. This is also fundamental information for optimal water resource allocations and can be used for planning purpose.

The current effect of afforestation in the study area is already severe as indicated by the WReMP model that the criteria of 20 % low-flow reduction has not been met. In the study area the criteria mentioned above has not been met; as the percentage of the afforested area is most obviously source of reduction as result of afforestation.

The reduction of water by forests is limited by availability of water. During the rainy season the consumption of water is high because of the availability of water and rate of evapotranspiration due to plant growth, whereas during the dry season the consumption is less, but the general impact on runoff is relatively more severe. This applies to both wet and dry catchments. Streams may be dry up during low flows, especially when the whole quaternary catchment is afforested, which will have negative implications to downstream water users.

The stream flow reductions are sensitive to rotational length or period. The longer the rotation the greater would be the mean impact of the crop and the lower the frequency of recharge opportunities (periods after clearfelling when evapotranspiration losses would be low). The rotational period increases the reduction of flow. The rotational period on which timber is grown is principally determined by the intended end product. For example, *Eucalyptus* grown for pulp or mining timber are cut on eight to ten year cycle and *Pinus* grown for pulping are usually cut at around 18 to 30 years. At the early years of plantation the reduction in flows is higher. As plantations mature, the reduction in flow tends to be constant. That is to say mature plantations have a lower hydrological impact than earlier in the rotation sequence.

6.1.1 Challenges experienced by Forestry Sector in South Africa

The Department of Water Affairs is the custodian of the Nation's water resources. Guided by its duty to promote the public trust, has ultimate responsibility for, and authority over, water resource management, the equitable allocation and usage of water. Discriminatory actions of the past caused an inequitable allocation of water resulting in poor financial development in sectors of society. It is the Department's responsibility to address these inequities. One such attempt is the provision of water to small growers / community woodlots for financial gain through the provision of timber to sawmills or for "domestic use" by providing poles and firewood for a community. Depending on the impact of the use, these developments are allowed in stressed catchments but specific measures should be taken to identify and map areas where the biological and water impact is not regarded as significant. Afforestation for community benefit is then promoted in the areas identified.

Areas with climatic potential for forestry are often already under water stress. The limited areas of South Africa with climatic and soil conditions suitable for crop production under dryland conditions overlap with those suitable for commercial forestry. Historically and inevitably, there has, and still is conflict between forestry and agriculture for land and water resources. In the inland areas such as Letaba Catchment, forestry has developed in land used for many forms of agriculture, including crop production and livestock grazing. In Limpopo Province, there is competition with fruit plantations (such as Banana), with some exchange of land between the two, in particular from banana plantation to forestry.

Threats to water resources and the authorisation process are the spread of uncontrolled alien species jungles and unlawful development. The Department of Water Affairs is constantly addressing these matters and is currently considering an incentive to land users to eradicate spreading jungle from their properties in exchange for a smaller water allocation. Another initiative is the Kwa-Zulu Natal Legal committee, which has been established to address unlawful development specifically. The Department (DWA) is busy with legal action on alleged unlawful development in all regions and a guideline to address unlawful development consistently, is currently being developed. The legal guideline and a regional forum as developed in Kwa-Zulu Natal combined with the alien jungle species (wattle jungle) exchange will hopefully be the tools to improve the water /ecological resources impact of alien trees on the environment.

The South African Forestry Sector contributes meaningfully to economic development in South Africa. By its very nature it is an industry that focuses on development and job creation in the rural areas of the country, where other forms of economic development are often sadly lacking. For example, it has been estimated that there are 170,000 people directly employed in the Forestry Sector and that an estimated 1.8 million livelihoods depend on this Sector in 2009.

While the Forestry Sector contributes meaningfully to economic development, it is not without problems. There are number of challenges and problems that the sector faced with. Some of them are that new afforestation has diminished over the years as a result of a shortage of suitable land, where expansion is allowed within the parameters of environmental and water policies. Timber losses due to fires, pests and diseases and other factors have also reduced the availability of raw material from existing plantations. The increased demand for sawn timber experienced in the pre-2008-recession period, driven mostly by the Construction Industry, encouraged over-harvesting of sawlogs and a reduction of rotation ages (DAFF, 2010).

The sustainable growth of its downstream processing industries can only be achieved through the reliable supply of raw material. Because of the various reasons mentioned above, critical timber shortages are forecast in the medium to long term. This raw material shortage is especially acute in the Sawmilling Industry where a shortage of sawlogs exists. Although demand is currently tempered by the global economic recession, it is predicted that the industry will not be able to produce enough sawn timber, if the current sawlog supply situation is maintained, within the next ten years. Smaller mills are already struggling to procure timber and several sawmills have already closed down, resulting in significant job losses in rural areas, where economic development is critical (DAFF, 2010).

The only way that forestry water use can be controlled is through restricting the area, extent and parts of the catchment in which it is planted. The *Eucalyptus*, *Pinus* and *Acacia* species in South Africa are regarded as invasive alien plants. When these species are not properly managed, they become forests which lead to the spread of alien invasive plants creating "forest jungles" that effectively remain "water users". There is a perspective that the water use of Invasive Alien Plant Species (IAPS) should be included with that of the forestry sector due to the impact of abandoned forests. In 1995, the former Department of Water Affairs and Forestry established 'Working for Water" Programme which is a multi-departmental initiative. Working for Water is an initiative aiming to control invasive species, due to variety of reasons. One of those reasons is to clear invasive plant species because of their effect on water security (DWAF, 2006). This was proven to be true because the clearing of exotic species such as *Pinus patula*, *Eucalyptus* and *Acacia mearnsii* along the riparian areas was found to have a substantial increase in streamflow. The results showed that streamflow increased by 9 - 12 m^3/ha/day immediately after clearing (Dye and Poulter, 1995; Prinsloo and Scott, 1999). Also Working for Water has been associated with 34 national and international awards, due to its positive success on the control of invading alien plants and job creation.

The best means of reducing the impacts of afforestation would appear to be to reduce the sub aerial proportion of a single catchment on which forestry is planted. That means afforestation in any quaternary catchment must cover less than 20 % of the sub aerial area of a quaternary catchment. The riparian zone or wetland areas must also be kept free of trees, as stated in National Water Act as this will hopefully allow other users downstream including the environment to have access to water.

The results of this study clearly indicate that any additional forestry in the catchment will poses a threat to the water resource. It should be clear that it will pose a much bigger challenge to persuade DWA to issue a water license in the Letaba Catchment because of the current water constraints experienced and reserve required in the sub-catchments. Although, if some alien invasive species can be removed that can release a significant amount of excess water, water licenses could then be issued. Any water available because of the removal of alien invasive species might be contested by irrigators in the surrounding areas, as they might have to cut down on their agricultural activities in order to maintain the reserve. However, considering water availability and climate change, it is unlikely that forestry will be granted permission to expand since one of the goals of the South African government is to maintain and increase food security and ensure equity in water allocation.

6.1.2 Discussion with people who have knowledge about the area

The minister of Department of Water Affairs and Forestry made a call that significant area of additional land be made available national for forestry. The decision-making model for afforestation is defined by the severe water constraints experienced across the Limpopo Province. There is the need to provide water to fast growing towns and settlements; to meet the requirements of the ecological Reserve (which is, for the most part, not being met); to guarantee the health of rivers in the Kruger National Park; and to maintain the state of the Limpopo River, an international system. Further to this there is a highly developed and high water-using agricultural sector, which is reliant on both surface and groundwater, and growth in mining, which can be of high value but may bring little to local communities and the rural poor. Forestry water use is significant but it should be allowed to “fight its corner” in terms of cost and benefit, at least against agricultural and mining development needs. Unfortunately the forest sector does not have the liberty of providing groundwater to meet it own needs, although the provision of compensatory yield (for example through the construction of a dam, or even the provision of a borehole) to make up for plantation water use, is an option that could be explored.

According to Luvuvhu/ Letaba ISP (DWAF, 2004), in the Letaba Catchment some of the catchments water is in the deficit. It means that there is no water for supply and new development. The water shortages experienced in the Letaba catchment area have led to intense competition for the available water resources between different sectors. The Kruger National Park (KNP) is located at the lower end of the catchment, is internationally renowned as a conservation resource, and is responsible for significant tourism and contribution to South Africa’s GDP. In order to sustain the flow of the Letaba River in the KNP and protect aquatic biota, riparian vegetation and terrestrial animal life, water has to be released from the series of dams and weirs starting at the headwaters of the catchment.

The researcher had discussions with some stakeholders; these discussions were held to determine if there was any land that they perceived to be suitable for the expansion of forestry; considering the availability of water resource. The researcher based his discussion more on the Magoebaskloof area, since it was the area highlighted by the WReMP model having potential to be planted with forestry. The Magoebaskloof area is associated with the high-lying land in the Haenertsburg area and stretching north-eastwards to Modjadjiskloof (Duiwelskloof). There is a tea plantation called the Sapekoe Tea Estate seemed to be abandoned which is situated along the road linking Haenertsburg to Tzaneen. The questions of the researcher were more based to this tea plantation. One opportunity for forestry in the Letaba is the prospect of returning the Sapekoe Tea Estate land to the plantation forestry it once was, using the water that is currently allocated to tea. This is not a direct threat to biodiversity, provided only previously farmed lands are planted. Expansion of forestry beyond previously ploughed and planted land is therefore out of the question.

The researcher visited Brandon Mashabane and Jacob Mahlangu to assess their views on the expansion of forestry in the Letaba Catchment. Brandon Mashabane his is a regional manager for Working for Water Programme. The researcher found out that in recent years the global tea market has deteriorated, and only the most competitive companies appear to have remained in full operation was Sapekoe (Pty) Ltd. The land is State-owned and was leased to Sapekoe (Pty) Ltd, a British-owned company. Before the planting of tea in the 1960’s, the land was under commercial timber plantations. The land has been claimed by the Makgoba’s community (Appendix 4) and is apparently under the management of a contractor who has been contracted by the community to manage the tea estate as a joint venture with them. It is unclear what the current state of affairs is, but the tea estate is not in operation and appears to be abandoned. Figure 6.1 shows the tea bushes that have gone un-harvested for many years that have now reached heights of maximum of 5 m with bugweeds. Figure 6.2 gives a picture how well managed tea plantation should look like.

Figure 6.1: The abandoned Sapokoe Tea plantation with bugweeds with height between 3-5 meters.

According to Mr Mahlangu and Mr Mashabane (*pers comm*., 2010), the tea plantation is in the region of high rainfall area, which is between 900 to 1 200 mm *per annum*. The area is characterized by misty all the time, which are good sign for growing forestry. The catchment is over-allocated, according to Mr Mahlangu (*pers comm*., 2010) and there are no possible new application for forestry could be accepted in the area. He suggested that trading with existing water users will be only option since the tea plantation is abandoned. Therefore there is this water which was allocated for irrigation of tea plantation that is no longer in use. Whatever amount it was can be allocated to the forestry as the trading with water license.

Figure 6.2: Tea plantation at Middlekop which is better managed (Source: Kruger Canyon)

Mr Maswemi (Assistant Director: Forestry Support at National Office), he used to work with Hansmeresky in the Letaba area. He was concern about the risk of fire in Mogoebaskloof. He mentioned that fire could occur at anytime and that tea can burn when it's green. He believes that it will be very difficult to put off fire once it has started especially in an area like this where there are a lot of invasive plants. Invasive plants that were supposed to be at the knee level but there are five meters tall. He further mentioned that there are no fire belts around the tea plantation, and to construct a fire belts will cost the Makgoba Community a fortune (*pers comm*., 2010).

Mr Maswemi (*pers comm*., 2010) also cautioned that Provincial Department of Agriculture might want the land back, but for them to take the land back for agriculture will be very costly. But when comes to planting of forest it would not cost that much. It would be just to bulldoze the area and have a tree plantation. It would be to collect tea trees to one place and burn them and no chemical control will be required.

6.1.3 Climate Change and Afforestation

Climate Change it's a new challenge facing the globe. It is anticipated that Climate Change will have significant impacts on forestry, at the same time could offer meaningful mitigation possibilities. Climate Change is emerging as perhaps the greatest environmental challenge of the twenty-first century and forests are important in terms of their potential to absorb carbon emissions. The growth of trees is a carbon sink and therefore important as one mitigation of global climate change. This creates opportunities to develop international funding and technology partnerships, including carbon trading, through afforestation. Carbon offset investments/carbon emission trading is not a well developed practice in South Africa and a special initiative would be required to expose the forest sector to these opportunities. Such an initiative should be undertaken because this can help a great deal in enabling communities to reap financial benefits from growing trees while waiting the harvesting of timber at the end of the rotation period.

Forestry plantations are, however, also sensitive to climate change and therefore the forestry sector should focus on maximising mitigation potential. In addition, it must be stressed that the forest resource base is small and adaptation options should be developed to enable the sector to respond to climate change.

6.2 Recommendations

6.2.1 Use of other Indigenous species

Commercial forestry plantations in South Africa are limited almost exclusively to the production of *Pinus*, *Eucalyptus* and *Acacia* trees. These are all fast growing species which can, under favourable circumstances, offer returns on investment in as little as seven to ten years. Slower growing trees use significantly less water for each year of growth and, if properly marketed, should offer a far higher product value, thus compensating for their lower production rate. For instance, although *Pinus* species takes on a longer rotation which is typically more than twenty five years when compare with other species, timber from these trees typically fetch a higher price. Examples of timber-related products include wood chips for export, pulp (all species), mining timber, poles, tannin (from wattle bark), furniture, and building and construction material.

The current study shows that there is insufficient water for the plantation of additional forestry in the study area. Moreover, additional forestry plantations would have extremely negative impacts on the current water resources, and the natural environment. Many quaternary catchments are already water stressed with most of them containing forest plantations on both privately–owned and communal land. There is widespread belief that indigenous trees use less water than exotic plant species, but attempts to prove or disprove this assumption are still limited and challenging. For instance, Gush & Dye (2006) highlighted that there is insufficient data and information on water use by indigenous species. However, Gush & Dye (2006) also indicate that water use by indigenous trees is seasonal and closely correlated to moisture availability. Water use efficiency and transpiration of indigenous species appear to be lower than exotic species. The low transpiration rate of indigenous species was proved to be particularly true when compared with *Eucalyptus grandis* (Dye *et al*., 2008). According to Gush & Dye (2006), the reason could be due to the fact that transpiration of indigenous species ceases during dry winter months due to loss of leaves. When transpiration ceases, it prevents the loss of water during that period. Recent study by Dye *et al*. (2008) confirmed the belief that indigenous species in general appear to possess an advantage over exotic species in productive sites through their lower water use and lower impact on streamflow reduction.

Therefore, where further expansion of commercial fast-growing plantations might be refused on the grounds of water conservation, it might be possible that to plant indigenous trees that use less water. An additional benefit of this would be that although these trees may have a longer rotation period they may provide equitable returns in the long run due to their higher value. Establishing productive stands of slow-growing (low water using species) high-value trees could well be a desirable alternative. Also where catchments are water stressed, as is the case in the Letaba Catchment, and reductions in afforested areas are proposed as a means of increasing supply, a phased conversion to species using less water may provide an acceptable water demand management strategy. This is an alternative land-use option which needs to be explored by the forestry industry, by rural communities in search of development opportunities, and by water managers seeking to bring water in meaningful ways to areas previously disadvantaged in their allocation and use of resources.

The choice and silviculture of species will need to be backed by research into species and site characteristics marketing and profitability. Candidate species could include indigenous trees such as *Millettia grandis* (Umzimbeet), *Ptaeroxylon obliquum* (Sneezewood), *Acacia xanthophloea* (the Fever tree), *Podocarpus spp*. (the Yellowwoods), and *Khaya nyasica* (Red mahogany). Also the research should not the limited to the above mentioned indigenous species; it could include exotics such as *Azadirachta indica* (Neem). This species comes from countries like Burma and India, where it is used as an insecticide amongst other things. Other invasive species that can replace fast growing species are species such as

Jacaranda mimosifolia, which is used as a decorative hardwood; *Pseudotsuga menzisii* (Douglas fir) which is from North American, and *Quercus acutissima* (saw-toothed oak).

The most common counter-argument with the planting of the indigenous trees for commercial purposes is that it takes too long to get a return on investment, but there are prospects for intermediate and multiple-use benefits which could surely compensate for this. But even trees grown for saw-timber takes too long to get a return on investment for example *Pinus* species now rarely stand for more than 25 years. This quick return on investment is seen as particularly important when it comes to encouraging poor rural communities to grow trees.

6.2.2 Licensing

The original Afforestation Permit System has been changed to a Stream Flow Reduction Activity (SFRA) Water-use Licensing System, brought about by the NWA (DWAF, 1998). This is not just a convenient name change, but incorporates a number of requirements that applies to any declared SFRA which at present its only forestry. To mention a few of those changes were as follows:

- Conversion of the Afforestation Permit Review Panels to SFRA Licensing Assessment Advisory Committees, applicable from 1 October 1999, with the requirement to establishment of these Advisory Committees captured in a final draft Terms of Reference (ToR) for SFRA LAACs.
- The Reserve, incorporating water for basic human needs and the aquatic environment, has to be (legally) complied with before any water-use license is issued.
- Development of Combined licensing which include a co-operative governance approach (involving the DWA, Department of Agriculture, Forestry and Fisheries (DAFF) and DEA), also applicable from 1 October 1999.
- Development of Water-use Licensing Policy and Procedure for Licensing SFRAs, which were applicable from 1 October 1999.
- New licensing and registration forms for SFRAs.
- Section 27(i) of the NWA.

There is a competition between the need to develop, and the encouragement of development strategies and the Legislation in place to control development. There is growing pressure to develop and there is growing pressure to preserve! On the other hand the growers are feeling the pressure from the new legislation. Licensing is mandatory according to National Water Act (DWAF, 1998), but growers feel pressure in the slow process of issuing license for afforestation. The authorisation process is slow and adds cost to forestry development. The authorisation process is legislatively intense as it must consider NEMA, CARA and other legislation in addition to the NWA. It involvement of other Sectors through Licensing Assessment Advisory Committees (LAACs) slows process. The growers feel this is all very well as long as the government, specifically the DWA can help in the application and issuing processes. The main concern was attributed to the delays in issuing licensing, which led to people planting before license was issued.

Some rural communities are not even interested in the legislation at all. They usually say “Don’t tell us what to do on our land”. Legislation is, therefore, seen to be imposed in these communities. Thus there is a need to educate and to work with the tribal Chief (Amakhosi) or the regional authority, and from there with the community.

6.2.3 Water Trading

The WReMP model indicated that the water resource is already fully utilised in the Letaba catchment. The abandonment of tea plantation in the Magoebaskloof area gives an opportunity for water trading in this catchment. Water trading is when a user relinquishes its water use licence, the water that becomes available can then be issued to another user, or to the same user but for another use. Trading with existing water users will be the only option since the tea plantation is abandoned. Therefore, water which was allocated for irrigation of tea plantation that is no longer in use. Whatever amount it was can be allocated to the forestry as the trading with water license.

6.2.4 Educating rural communities

Deforestation, fire, pollution, habitat fragmentation and invasive organisms are major problems affecting the biological diversity in the Limpopo Province (LEMA, 2003; DEDET, 2006). Ignorance of the license procedure by local people is influenced by lack of information about the NWA, which has also increased illegal planting of forestry in this Province. Therefore, raising awareness of the National Water Act and related environmental acts within the general public, particularly at community level, before the implementation of the act, can lessen law infringements. However, access to environmental information is a major challenge in rural areas (DST, 2005). This would give the assurance that communities are not trespassing on any environmentally sensitive areas. It will also help to ensure that regulators and stakeholders work toward a common good.

6.2.5 Consideration of Small Scale woodlots as Schedule 1

Provision for water use by subsistence and homestead woodlots should be made by providing for the allocation of a Schedule 1 provision and/or General Authorization (GA) for such small-scale woodlots. The current regulations do not allow for any form of forestry without licensing. This includes even very small “homestead” woodlots and the assumption is that all planted forestry is commercial. This effectively precludes even the smallest scale of grower, who may be growing trees only for homestead or extremely local use (farm fence poles *etc*.), from any form of forestry. The DWA would probably not have a problem offering a GA for this type of development from a water use perspective, but the planting of trees would still be subject to the provisions of other Departments. The DWA could therefore issue a Forestry Water Use GA, but not a Forestry GA. Other Departments might be more willing to offer a general provision towards very small-scale tree planting for homestead use, provided the species planted were not invasive.

6.2.6 Enforcement

Forest laws and policies such as the National Forest Act (84 of 1998) were passed to regulate the use of forests and woodlands in South Africa. Most importantly, the National Water Act (No.36 of 1998) was also passed to serve as the general framework for protection, use, control and management of water resources (DWAF, 1998). Contravention of these Acts is an offence and the perpetrator can be fined (not stated) or sentenced for one to two years, or both. Some of the plantations are planted in the riparian zone in the Letaba Catchment, which is against the Acts mentioned above. The enforcement of the Law and Regulation should be strengthened by the Departments administrating the Acts mentioned above.

6.2.7 Construction of dams to mitigate possible impacts on low flows

The impacts of forestry on water resources are most critical with regard to low flows. Many streams especially in undeveloped areas, where there are no large regulated dams, would not meet the estimated low flow Reserve requirements for a short critical period in the dry season if there were to be any significant forestry development. Whilst these low flow Reserve requirements and the actual extent of impact of forestry are currently subject to investigation, this is one area where government and / or industry intervention could be implemented to bring about mitigation. Actions could include:

- A specific allocation for release from existing dams of schemes to compensate for low flow water use;

- The trading or purchase of water allocations within the same catchment (as with the case with Sapokoe Tea plantation at the Magoebaskloof area), which can be used for mitigation; or even;
- The construction of storage facilities (*e.g*. dam) which can capture excess wet season flows to be released these during the critical dry season.

6.2.8 Clearing and Conversion of "Jungle Plantations"

The water balance calculation for all South African catchments includes a component for the impact of Invasive Alien Plants (IAPs) on the available yield. This impact is assessed against the *status quo* had the vegetation been in natural condition. Many sub-catchments in the study area are in deficit and the impact of IAPs is a part of that deficit. The catchment is in deficit when in a catchment Reserve cannot be met, and there is a danger of the State failing to meet its equity obligations.

The Invasive Alien Plants are not water users in terms of the NWA (DWAF, 1998), but IAPs do have an impact on the water resource, as does any vegetation. The IAPs have the effect of increasing the 'baseline' water requirement (that is established as the water use in the Acocks vegetation cover) to some new baseline. It is this baseline, which is used in determining how much water is available from a catchment. Therefore clearing of IAPs could have a positive effect in restoring the old baseline vegetation and baseline water requirement, thereby releasing the balance into the system which in turn means bringing water back into the water balance for productive use.

The task of clearing all invasive plants in South Africa, thus bringing this water back into the common pool, is more than Working for Water can achieve on its own. According to the National Water Act (NWA, Act 36 of 1998), no further water use licenses may be issued in catchments, which are in balance or in deficit, because this would mean reducing the viability of existing lawful users (DWAF, 1998). However, if the available yield can be increased by, for example, reducing the impact of IAPs, then a new allocation could be considered even if the catchment is still in deficit. This suggests the incentive whereby the water released through the clearing of IAPs could, in some instances, be made available to the landholder or to any other body responsible for that clearing.

An invasive wattle jungle is defined as an area of invasive trees where the density, extent, and age of invasion are such that the natural biodiversity of the landscape has been permanently transformed. Jungle wattle has taken hold of the landscape in many parts of South Africa. Riparian zones are most readily invaded and there is no doubt that all of these need to be cleared. This is evident in the study area, particularly in the Haenertsburg area. However, jungle wattle also covers large areas of grassland, woodland, farmland and grazing veld, sometimes providing a valuable resource, especially in the form of fuelwood. This is also putting strain on the natural forests and vegetation which are perforce being harvested as alternative sources of fuel and timber. Areas which have been densely invaded by jungle wattle have lost their ecological integrity, and are no longer of value for biodiversity conservation. Biodiversity loss is often one of the major constraints to new afforestation and thus needs to be addressed.

In other areas commercial farmers cannot afford to clear the jungle wattle off their farms. But provision of an incentive for those that are removing juggle wattle by giving them a forestry license, could bring these areas under control and convert them to well managed stands. The granting of forestry licenses on land already invaded allows some expansion of the forestry estate without any reduction in the remaining biodiversity capital. The benefits therefore could include meeting the social needs, protection of the natural environment, reduction of areas under invasive species, and controlling the further spread of invasive species. Licensing should be conditional on the availability of water, and particularly the needs of the environmental and human reserves. Although the licensing of areas covered with invasive species is argued on the basis of improved water production through better management, this will not equal the amount of water which would be produced if all invasive were eradicated. The main aim of this process will be to clear unwanted wattle and other invasive species and this can bring about an increase in water yield over and above the *status quo* of the catchment.

To conclude, control of invasive alien plants is required because infestation in the study area is already significant and will worsen if no action is taken. Secondly, Invasive Alien Plants can cause significant reductions in runoff in catchments if allowed to spread uncontrolled. Clearing these plants is generally also a cost-effective augmentation option and has many other benefits such as conserving biodiversity, job-creation and limiting the risk of fires in both rural and urban catchments.

The study confirms that invasive plant species contribute significantly to the loss of water through evapotranspiration, use of more water, and reduces streamflow. There are also uncertainties and technical difficulties when estimating water use by indigenous and exotic plant species. Those uncertainties and challenges relate to:

- Limited database of water use of different species (indigenous versus exotic);
- Challenges when extrapolating water use model in different ecosystems;

- Lack of standardized or universal methodology for estimating water use;
- Challenges when scaling-up of species water use measurement to be representative of tree water use in the whole vegetation type or ecosystem; and
- Limited budget for forestry research.

Based on these challenges, there is still a need for further investigation on water use by indigenous and invasive plant species, and to attract more funding for forestry research.

The equitable and efficient allocation of water to Stream flow Reductions Activities depends on the accurate information or calculations of their likely effects on the allocatable water. This requires consistent and sufficiently accurate estimates of the reductions in stream flow and changes in flow regime that will arise from each activity. These include estimates of reduction in different seasons and during periods of low flow, as well as high, low and normal annual flow. The estimated reductions will have to be assessed relative to an agreed baseline for the water resource in that catchment. Substantial work has been done in trying to quantify the impacts of forest plantation using WReMP model. The model was used in simulating the effects of afforestation on the water and areas that could have a potential for forestry in the study area. The hydrological effect of afforestation on flow depends on the percentage of afforested area in a catchment, the rotational period, the *genera*, and water availability. The disadvantage with the use of models is that the degree of accuracy in models is not well known. The results shown in this study indicate that the stream flow will be significantly affected by the addition of forestry in many of the quaternary catchments in the study area and is thus, at present, it’s not an option to plant additional forest.

Therefore, it implies that there will be no enough water to support growth of forestry to meet current and future demands for timber, as well as the transformation targets in the catchment. Since, there will be no water available for new afforestation in developed catchments such the Letaba Catchment. The additional forestry will make difficult to manage or mitigate for low flow impacts. Also the uncertainty around the Reserve could be one of the major bottle necks in the process.

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Appendixes

Appendix 1: Top fifty Invasive Species found in the Letaba Catchment

Genus	Species	Common Name
Pasiflora	spp	Granadilla
Salix	babylonica	Weeping Willow
Acacia	mearnsii	Black Wattle
Acacia	dealbata	Silver Wattle
Delonix	regia	Flamboyant
Eichornia	crassipes	Water hyacinth
Ligustrum	japonicum	Japanese Privet
Mimosa	pigra	Sensitive Plant
Morus	alba	White Mulberry
Toona	cilliata	Toon Tree
Senna	occidentalis	Cassia
Cereus	jamacaru (C. peruvianus)	Queen-of-the-Night
Agave	sisalana	Sisal
Arundo	donax	Giant Reed
Senna	didymobotria	Peanut-butter Cassia
Cestrum	laevigatum	Inkberry
Chromolaena	odorata	Praffin/Triffid Weed
Cortaderia	spp	Pampas Grass
Lantana	camara	Lantana
Leucaena	leucocephala	Giant Wattle
Macfadyena	unguiscati	Cat's Claw Creeper
Opuntia	ficus-indica	Sweet Prickly Pear
Opuntia	fulgida	Rosea Cactus
Pinus	spp	Pines
Psidium	guajava	Guava
Rubus	cuneifolius	Brambles
Acacia	terminalis	Peppertree Wattle
Aristolochia	elegans	Dutchmans pIpe
Cardiospermum	grandiflorum	Balloon Vine
Sesbania	punicea	Red Sesbania

Genus	Species	Common Name
Solanum	mauritianum	Bugweed
Solanum	seaforthianum	Potato Creeper
Tecoma	stans	Yellow Bells
Tithonia	diversifolia	Mexican Sunflower
Tithonia	rotundifolia	Red Sunflower
Pistia	stratiotes	Water lettuce
Acacia	decurrens	Green Wattle
Acacia	melanoxylon	Blackwood
Azolla	filiculoides	Water fern
Bambusa	fulgaris	Bamboo
Bauhinia	variegata	Orchid tree
Caesalpinia	decapetala	Mauritius Thorn
Ricinus	communis	Castor-oil Plant
Myriophyllum	aquaticum	Parrots feather
Nicotiniana	glauca	Wild Tobacco
Populus	canescens	Grey Poplar
Eucalyptus	spp	Eucalypts
Jacaranda	mimosifolia	Jacaranda
Melia	azederach	Syringa
Grevillea	robusta	Silkey Oak
Ipomoea	alba	White Morning Glory
Opuntia	spp	Prickly Pears
Populus	deltoides	Match Poplar
Syncarpia	glomulifera	Terpentine Tree
Quercus	accutisima	Bristle Oak
Ageratina	adenophora	Crofton Weed
Gmelina	orborea	White Teak
Khaya	anthotheca	East African Mahogany
Chukrasia	tabubularis	Indian Mahogany

SPECIES (blue) BIOLOGICAL CONTROL ONLY

SPECIES (red) CHEMICAL, MECHANCAL AND BILOGICAL CONTROL

Appendix 2: Streamflow reduction due to alien vegetation in the Limpopo Province.

QC	Area Alien Vegetation (km²)	Unit SFR (mm)	SFR (Mm³/a)
A71A	118.6	65.5	1.409
A71B	100.8	62.0	1.098
A71C	17.3	63.8	0.171
A71D	1.5	91.1	0.017
A71E	23.6	61.2	0.241
A71F	15.9	59.0	0.147
A71G	0.0	0.0	0.000
A71H	1.3	107.8	0.024
A71J	0.3	82.4	0.004
A71K	0.0	0.0	0.000
A71L	0.0	0.0	0.000
A72A	0.0	0.0	0.000
A72B	0.0	0.0	0.000
A80A	11.3	257.5	1.901
A80B	0.3	423.1	0.022
A80C	0.0	0.0	0.000
A80D	0.1	272.7	0.007
A80E	0.5	244.4	0.027
A80F	0.0	0.0	0.000
A80G	0.0	0.0	0.000
A80H	0.0	0.0	0.000
A80J	0.0	0.0	0.000
A91A	54.7	265.7	4.714
A91B	14.5	265.5	0.953
A91C	77.1	264.1	11.690
A91D	21.4	262.3	5.621
A91E	2.9	153.9	0.440
A91F	2.0	155.0	0.093
A91G	7.4	150.6	1.110
A91H	1.1	100.9	0.069
A91J	0.5	5.3	0.002
A91K	1.0	2.0	0.002
A92A	2.4	139.2	0.330
A92B	1.6	98.8	0.098
A92C	0.1	88.0	0.001
A92D	0.7	35.5	0.005
B71A	19.5	125.5	1.054
B71B	9.6	106.0	0.332
B71C	19.8	200.1	3.069
B71D	13.5	192.7	1.063

QC	Area Alien Vegetation (km²)	Unit SFR (mm)	SFR (Mm³/a)
B71E	77.6	91.5	2.746
B71F	22.1	144.7	2.329
B71G	20.0	144.6	2.839
B71H	1.3	54.2	0.052
B71J	0.2	35.0	0.002
B72A	0.0	0.0	0.000
B72B	0.0	0.0	0.000
B72C	0.1	48.2	0.002
B72D	0.6	46.7	0.006
B72E	2.0	201.0	0.216
B72F	0.8	216.9	0.144
B72G	0.4	85.1	0.016
B72H	0.6	75.3	0.024
B72J	0.0	0.0	0.000
B72K	1.2	48.4	0.015
B73A	11.2	194.6	2.170
B73B	0.9	45.5	0.010
B73C	15.6	7.6	0.119
B73D	0.1	85.7	0.001
B73E	0.1	80.0	0.001
B73F	0.1	116.7	0.001
B73G	1.1	2.7	0.003
B73H	0.0	0.0	0.000
B73J	0.0	0.0	0.000
B81A	14.4	212.9	3.070
B81B	38.2	207.9	7.940
B81C	7.6	235.6	0.736
B81D	16.5	217.7	2.069
B81E	1.4	123.7	0.074
B81F	1.1	74.9	0.023
B81G	0.8	39.1	0.027
B81H	0.7	24.4	0.009
B81J	0.4	21.0	0.004
B82A	2.8	144.4	0.163
B82B	2.6	183.6	0.149
B82C	4.6	185.8	0.280
B82D	2.7	158.1	0.107
B82E	0.0	0.0	0.000
B82F	0.4	139.5	0.020
B82G	1.0	35.3	0.018
B82H	0.7	22.4	0.010
B82J	0.7	33.7	0.014
TOTAL	**793.5**		**61.1**

Appendix 3: Reserve Determination (Surface Water Reserve Determination for Water Management Area 2: Luvuvhu and Letaba)

Quaternary Catchment	Water Body	EWR site name	EWR Site Co-ordinates		Reserve calculated using Incremental (I) or Cumulative (c) Flows	PES	EIS	REC	Ql/ Qt	MAR	MAR %	Level	NWA	Date Approved	Notes
			Lat (S)	Long (E)											
A91A	Tshikali River				c	D	M	D	Qt	66.7	13.7	D	21(a)	15/11/07	
A91B	Luvuvhu River				c	D	L	D	Qt	26.7	16.4	D	25(2)(b)	08/05/01	
A91C	Mudziriti River				c	D	M	D	Ql & Qt	61.2	15.4	D(Qt) D(Ql)	21(b),(f), (g)	04/07/03	
A91F	Luvuvhu River				c	D	M	D	Qt	190.6	15.6	D	21(a)	14/06/07	1*
A91G	Mutshindudi River	Mutshindudi River	22º54´52.9"	30º29'18.2"	I	C	H	C	Qt & Ql	47.5	29.9	R	21(a),(b), (c),(i)	19/03/02	
A91H	Luvuvhu River				c	C	H	B/ C	Qt	352.1	29.5	D	21(a),(b), (c),(i)	13/03/03	
A91J	Luvuvhu River				c	C	H	C	Qt	371.6	13.2	D	21(a)	07/03/01	2*
A92D	Mutale River				c	C	H	C	Qt	155.9	22.7	D	21(c),(i)	22/02/07	
B81A	Groot Letaba River				I	C	M	C	Qt	69.0	27.8	D	25(2)(b)	08/05/01	
B81B	Politsi River	Magoebaskloof Dam	23º48'59.7"	30º03'23.8"	I	C	H	C	Qt	21.3	27.4	D	25(2)(b)	08/05/01	
B81B	Tributary of Politsi River	Vergelegen Dam	23º46'17.6"	30º04'59.1"	I	C	H	C	Qt	0.3	27.4	D	25(2)(b)	08/05/01	
B81B	Groot Letaba River	Appel (Groot Letaba)	23º55'03.7"	30º03'03"	c	C	M	C	Ql & Qt	71.3	27.7	C	21(a),(b), (c),(d),(f), (g),(i),(k)	27/12/06	3*
B81C	Letsitele River				c	D	M	D	Qt	16.8	16.3	D	21(a)	15/02/02	
B81D	Thabina River				c	C	M	C	Qt & Ql	55.2	25.9	D	21(a),(c), (d),(f),(g), (i)	02/07/03	

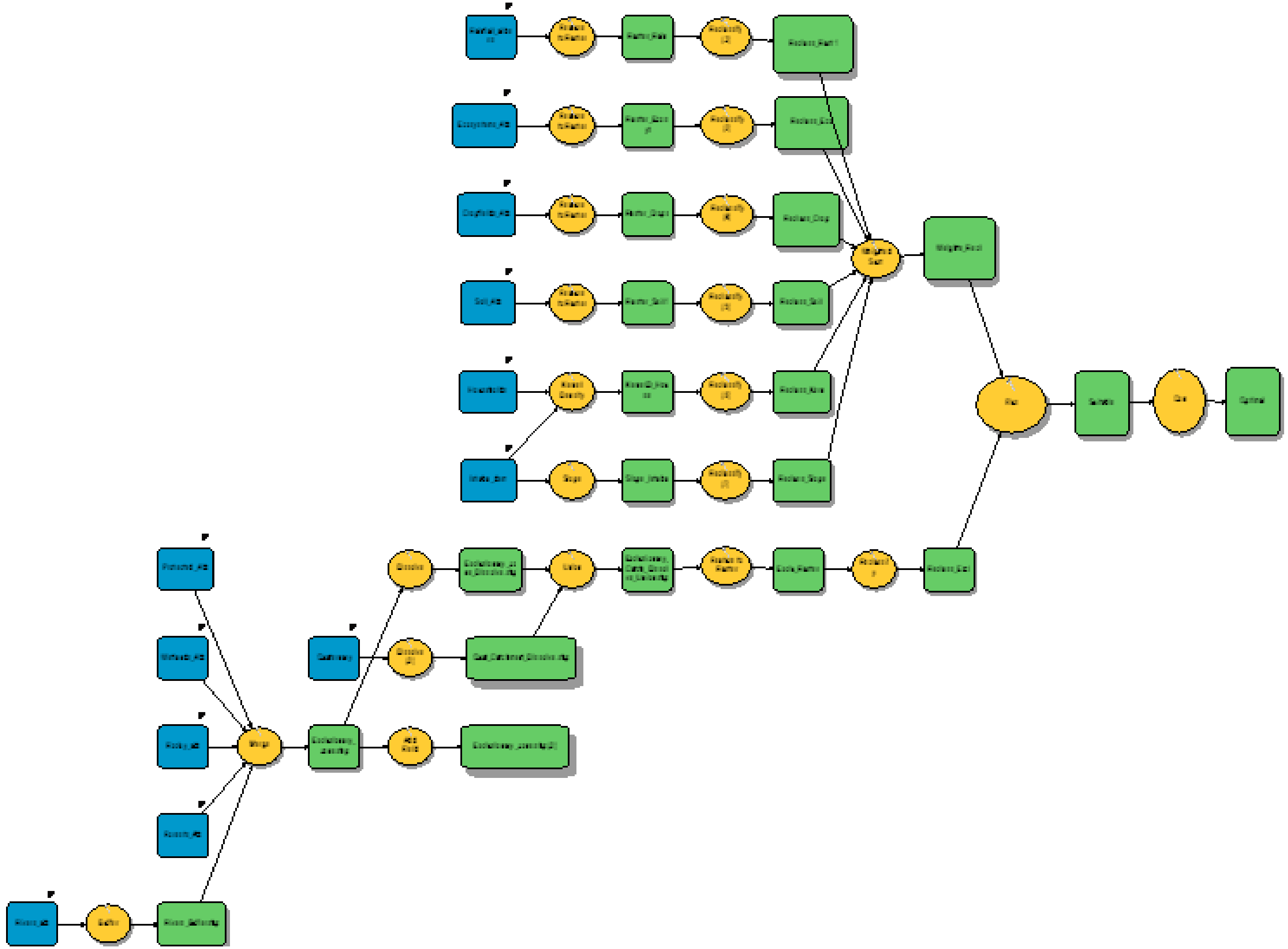
Quaternary Catchment	Water Body	EWR site name	EWR Site Co-ordinates		Reserve calculated using Incremental (I) or Cumulative (c) Flows	PES	EIS	REC	Ql/ Qt	MAR	MAR %	Level	NWA	Date Approved	Notes
			Lat (S)	Long (E)											
B81E	Letsitele River	Letsitele River	23º53'17"	30º21'40.5"	c	D	M	D	Qt & Ql	86.1	36.9	C	21(a),(b), (c),(d),(f), (g),(i),(k)	27/12/06	
B81F	Groot Letaba River	Hans Merensky	23º38'57.8"	30º39'38.3"	c	C/D	H	C/D	Qt & Ql	364.5	11.7	C	21(a),(b), (c),(d),(f), (g),(i),(k)	27/12/06	
B81G	Mololotsi River				c	C	L	C	Qt	16.1	27.5	D	21(a)	25/02/02	
B81J	Groot Letaba River	Letaba Ranch	23º40'39.1"	31º05'55.1"	c	C/D	H	C/D	Qt & Ql	402.3	17.4	C	21(a),(b), (c),(d),(f), (g),(i),(k)	27/12/06	
B83A	Groot Letaba River	Lonely Bull	23º45'9.5"	31º24'26.3"	c	C	H	C	Qt & Ql	546.6	8.6	C	21(a),(b), (c),(d),(f), (g),(i),(k)	27/12/06	
B83D	Groot Letaba River	Letaba Bridge	23º48'35.4"	31º35'26.9"	c	C	H	C	Qt & Ql	561.7	9.2	C	21(a),(b), (c),(d),(f), (g),(i),(k)	27/12/06	
B83G	Klein Letaba River	Klein Letaba River	23º15'2.9"	30º29'44.6"	c	C	M	C	Qt & Ql	95.0	18	C	21(a),(b), (c),(d),(f), (g),(i),(k)	27/12/06	
B82C	Brandboontjies River					D	L	D	Qt & Ql	13.9	14.4	D	21(a),(c), (d),(f),(g), (i)	02/07/03	
B82H	Nsami River					C	M	C	Qt & Ql	10.8	21.8	D	21(a),(c), (d),(f),(g), (i)	02/07/03	

KEY NOTES: 1*= Supersedes the previous Desktop Reserve for A91F, approved on the 21/02/02

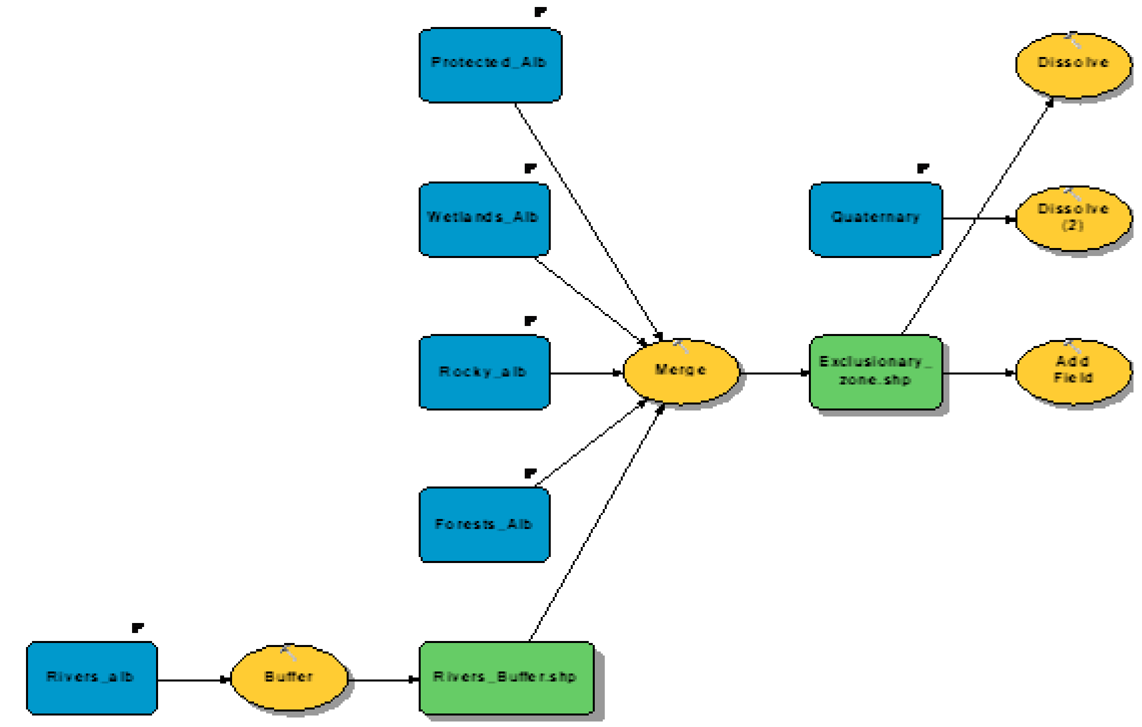
2*= Water quality component determined using 1998 IFR Refinement Study at 22º29'40"S, 31º03'30"E

3*= Supersedes the previous Desktop Reserve for the Letaba River in B81B, approved on the 15/01/01

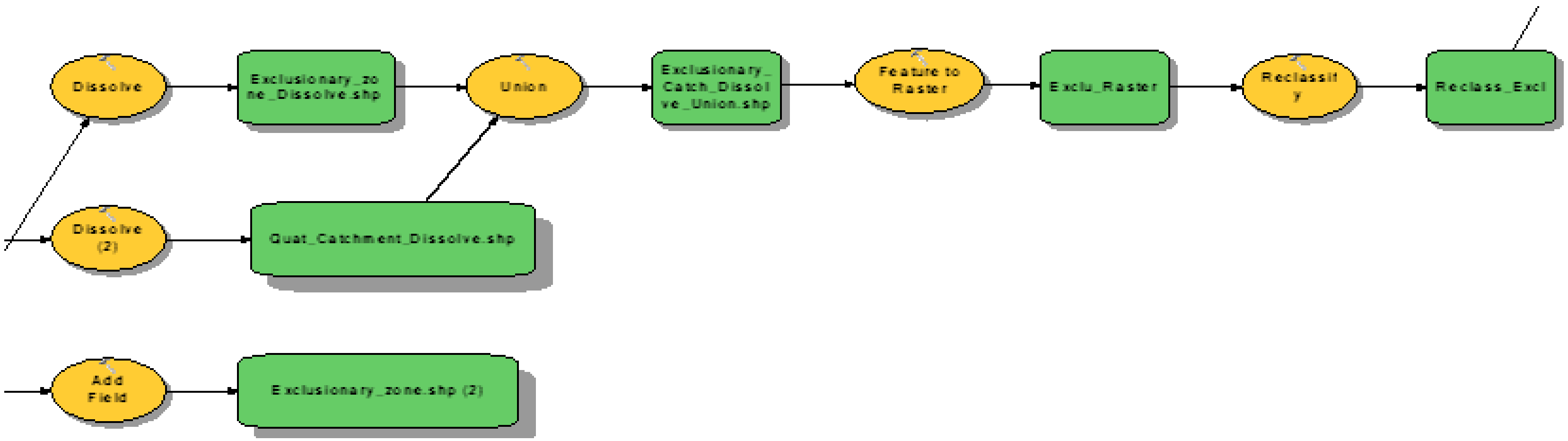
Appendix 4: Afforestation Model Schematic



PHASE 1



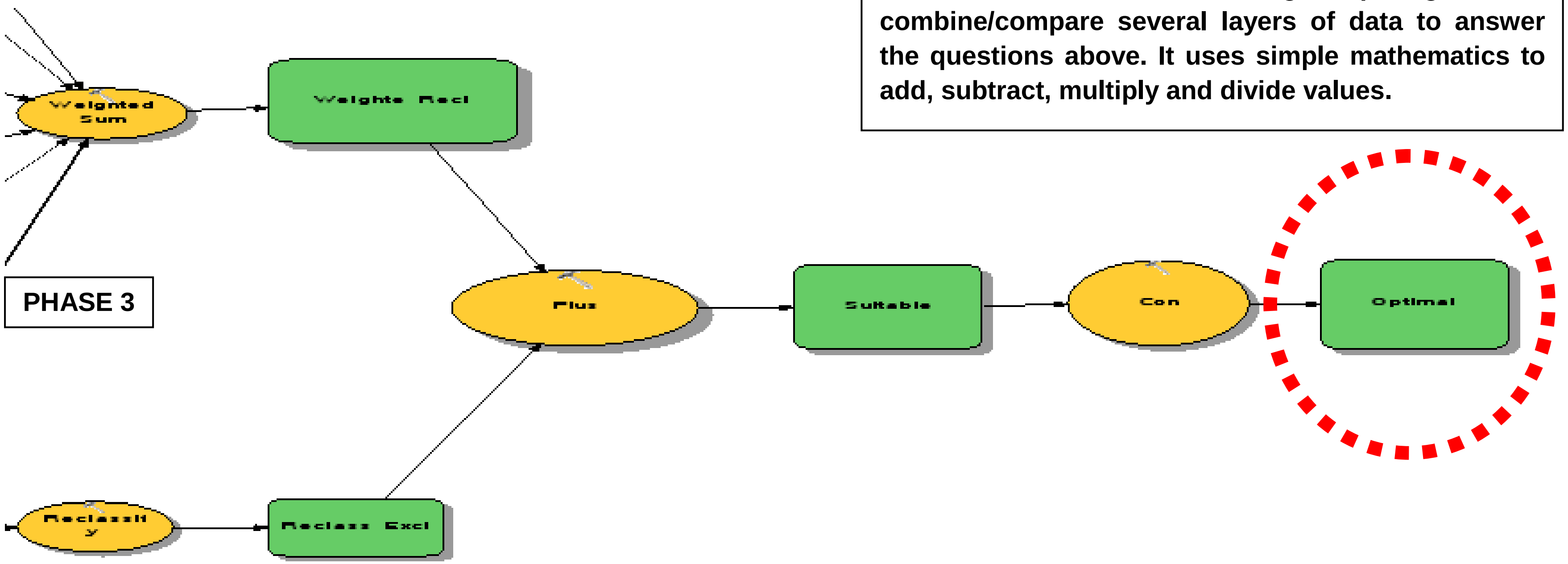
The above areas will be merged to form exclusionary zones which will be dissolved and subtracted from the study area's boundary (i.e. catchment). The results will then be merged with the dissolved catchment, converted to a raster and reclassified into binary suitability where all the cells areas from dissolved catchment boundary will be identified as suitable areas (potential areas for afforestation) while the dissolved exclusionary cells will be identified as unsuitable areas for afforestation.



The above factors are those that were considered to influence afforestation potential. These factors are: Climate: Rainfall; Topography: Slope and soils; Agricultural assessment; Household density; Water assessment. All these factors above were reclassified using GIS and allocated weight using Weight suitability where ranges of value from good to bad with different weights for each criterion; usually as a percentage of the total value for the study modelling the two models ranking and weighted

Suitability will be combined to identify areas that are suitable and unsuitable in terms of each criterion can be expressed as a percentage of the total value.

The data is combined using Map algebra to combine/compare several layers of data to answer the questions above. It uses simple mathematics to add, subtract, multiply and divide values.



Finally, binary suitability can be used to highlight the range of values from unsuitable to suitable, and in this study the ranking was based on the following three classes:
When the grids are added:
10-7 = (Suitable) grid cell where it was good for both criteria
7-5 = (Moderate) grid cell where it was good for at least one criteria
<5 = (Unsuitable) grid where cells was bad for both criteria

Appendix 5: Limpopo forges ahead with land claims

January 9, 2005

By Wiseman Khuzwayo

Johannesburg - The Limpopo regional land claims commission (LCC) is forging ahead in effecting the land claims against one of South Africa's most fertile regions, which includes a farm belonging to SA Reserve Bank governor Tito Mboweni.

The farms are thought to be worth about R3 billion and there is another R3 billion of forestry.

Mashile Mokono, the regional commissioner, has found that the land claims by the Makgoba community for the Magoebaskloof were prima facie valid. These claims are against 168 prime agricultural farms, comprising almost 200 000ha, in the Hoedspruit and Blydepoort areas of Tzaneen, about 70 km from Polokwane (formerly Pietersburg).

A number of land owners in the region contend that the claims are invalid.

On the other hand, Charles Molifi, a spokesperson for the Limpopo LCC, said there were many willing sellers who had come forward. Their farms were being valued by the national department of agriculture.

He said those not willing to sell would be referred to the legal unit of the LCC. From there they could take the LCC to the land claims court. Expropriation would be a last resort.

According to a report by the committee representing the land owners, preliminary indications are that as much as 40 percent of the land could be available on a willing seller basis.

Two Government Gazette notices were issued by Mokono last year, in which he identified the farms. One of these is the large Sapekoe Tea Estate, formerly South Africa's foremost tea producer and exporter.

The first Government Gazette notice omitted Mboweni's 2 231ha farm and two farms belonging to Bishop Joseph Lekganyane of the St Egenas Zion Church, whose headquarters are in Limpopo.

A subsequent notice included the three farms. A source in the regional LCC said these farms could not be included in the first gazette because research into them had not been completed.

Cathy Powers, a spokesperson for Mboweni, said he was on record as saying that he was willing to co-operate with the process.

Former Limpopo premier Ngoako Ramatlhodi also owns a plot in the region, where he has built a huge home known as Pumpkin Palace because it is on a former pumpkin producing farm.

Ramatlhodi said: "I have told the government that I am willing to sell. I can't stand in the way of the land claims. I could not sleep well with that."

Two claims on the farms were lodged in 1998 on behalf of the Makgoba community. These were made under the Land Restitution Act of 1994, which applies to the land from which black people were forcibly removed from 1913.

In his report, Mokono said the land dispossession of the Makgoba community took place after June 19 1913, and the community was forced to scatter.

He said the Makgoba people were dispossessed when the department of forestry established plantations of blue gum and pine.

He described it as "a subtle and indirect act of racial discrimination, which ... cannot be said to have been for the public interest but to divest [the] Makgoba people of their unregistered rights on the fertile land, thereby implementing the racial law that prevented black people from owning or leasing land in South Africa".

The land owners commissioned research by a University of the North history academic, Louis Changuion. His report concludes that the Makgoba community has no claim to the farms in Magoebaskloof.

"The Makgoba tribe occupied the area constituting these farms until the war with the ZAR [Zuid-Afrikaansche Republiek] in 1894/95. This war ended on June 11 1895, when Chief Makgoba was beheaded by Swazi warriors.

"The Boer War Council took a decision to remove the Makgoba tribe, as well as their associates - the Tsolobo, the Mmamathola and Mosote tribes, and to resettle them near Pretoria. As a result, all the Makgoba tribe was removed from the area in 1895.