AN ANALYSIS OF THE SOCIAL, ECONOMIC, AND ENVIRONMENTAL DIRECT AND INDIRECT COSTS AND BENEFITS OF WATER USE IN IRRIGATED AGRICULTURE AND FORESTRY

A CASE STUDY OF THE CROCODILE RIVER CATCHMENT, MPUMALANGA PROVINCE

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EXECUTIVE SUMMARY

1. BACKGROUND AND MOTIVATION

A study comparing the economic efficiency of water use by sub-tropical fruits, forest plantations and sugar cane in the Crocodile River catchment was completed in 1999 with funding from the Water Research Commission (WRC) (Olbrich and Hassan 1999). This study analysed water use efficiency based on direct economic benefits generated in specific primary production activities (forestry, irrigated sugarcane and five irrigated sub-tropical fruits), i.e. at the farm level. Accordingly, indirect economic benefits realized upstream or downstream from the primary sector in question were not accounted for. The social costs and benefits of the major environmental impacts of the studied activities were also not investigated. As the demand for water by the agricultural production activities remain central to future economic development and efficiency of resource use in the Crocodile River catchment, a follow-up study was commissioned by the WRC. The aims of the present study were therefore to account for total economic benefits (direct and indirect) of water use in the catchment, and to investigate the environmental (natural) and social costs and benefits of the studied activities.

1.2 OBJECTIVES OF THE STUDY

The specific objectives of this research project were as follows:

- To refine data on water use within the respective sectors, and within their value chains;
- To quantify water use per crop per sector;
- To obtain representative figures of full private costs for small and large growers in each sector;
- To establish forward and backward linkages for each sector;
- To examine product flows;
- To determine external (public) effects – economic, social and environmental costs and benefits. (It was understood that the term “environmental” referred to in the contract was used in the context of the natural environment.)

1.3 APPROACH AND METHODOLOGY

The point of departure of the study was the mapping and quantification of the value chains of each of the three land use types analysed: forestry, irrigated sugarcane and five irrigated sub-tropical fruit types. This was done in a two-stage process where, firstly, the product flows of the relevant land uses were mapped through the identification of forward and backward linkages. Secondly, each value addition activity was quantified in terms of price, intermediate consumption and value added, through extensive survey and primary data collection in each of the three value chains in Mpumalanga.

Economic, social and environmental impact analyses were then completed for each value chain. *Direct impacts* were defined as the economic, social and environmental impacts occurring within each of the land uses (i.e. at farm level) as the result of an event such as a water trade-off decision. *Indirect impacts* were defined as the resultant impacts occurring in the forward and backward linkages of the respective value chains. The *economic impact analysis* set out to measure and compare total economic benefits (direct and indirect) from water use by plantation forestry, irrigated sugarcane and five types of irrigated subtropical fruit (oranges, grapefruit, bananas, avocadoes, mangoes) in the Crocodile River catchment. The *environmental impact analysis* identified the value chain of direct and indirect product flows within each sector. This was used as a basis from which to build a hybrid life-cycle assessment of the respective sectors and focused on the environmental aspects of the life-cycle analysis. The *social impact analysis* set out to measure the impact of the respective value chains on households and individuals. This part of the study examined direct and indirect employment and enterprise linkages, and assessed the external social benefits and costs on households that result from these three land uses. Finally, a *comparative analysis* of the results was done in order to combine the outputs from each of the economic, social and environmental analyses into one model where some of the trade-offs involved in water allocation and associated policy implications could be assessed.

The above approach required an intensive data acquisition process, matrix-based spreadsheet modelling involving transfer studies, a validation process and analyses of results.

1.4 CONCLUSIONS

Water apportionment decisions remain, for the largest part, dependent on accurate water use information. This study has shown for instance how estimates of forestry water use figures changed with the adoption of new forest hydrology modelling data. The measurement of irrigation water use remains an important issue in the determination of actual on farm water use, and prediction models for this are not adequate. Comparative analysis of forestry and irrigation water use must be done carefully, as the terminology and definitions used in forest hydrology and irrigation planning are different. Water use per ton of product in the respective value chains, defined as indirect water use for the purposes of this study, are very small in comparison to the direct crop water use.

This study revealed the importance of considering indirect economic benefits in comparing the social worthiness of alternative productive uses of water and other economic resources. This was especially evident from the value added (VAD) and employment multiplier effects, which were between 2 and 20-fold larger than the direct benefits. The multiplier effects were more pronounced for the longer value chains, i.e. those that comprised of more intermediate value adding activities between the farm and the final consumer.

The study also provided insight into the trade-offs between economic production and environmental emissions and resource use. The value chains with larger economic and employment yields usually went hand in hand with higher energy use and larger emission factors. Interestingly, the value chains with larger environmental impacts (in this case pine and eucalypt forestry and sugarcane) also produced potentially significant environmental benefits. In the case of forestry, its carbon sequestration ability significantly outweighed its greenhouse emissions impact. In the case of sugar, the use of bagasse as a major energy source reduced net energy requirements of the sugar value chain considerably. All three the land uses also had the potential to produce benefits to society through effective management of natural ecosystems on their estates or management units.

The broader social impacts of the value chains were much more difficult to quantify than the economic, employment and environmental impacts. Within the terms of reference of the study, vulnerable households were the key social group that was focussed on. Vulnerable households were regarded as poor, mostly Black, rural households with low education levels. It was concluded that the three land uses under discussion had large impacts on these households as the bulk of employment opportunities (expressed in man-days per ton) was supplied to them. The effect of these employment opportunities on household income and social adaptive capacity remain an important variable, but was not researched due to data constraints.

Importantly, the study also showed the value of data transfer studies when policy decisions have to be made in the absence of comprehensive primary data. It has to be noted that, in spite of the effort made to obtain best available data, considerable data inadequacies existed. In a study of this nature, where data form many different sources are compared, high quality, homogenous data is required. Unfortunately the unavailability of such data was one of the limitations to the study (see section 8.3)

1.5 EXTENT TO WHICH THE OBJECTIVES HAVE BEEN MET

- To refine data on water use within the respective sectors, and within their value chains:

This was completed satisfactorily through the value chain analyses, and through intensive primary data collection.

- To quantify water use per crop per sector:

Plantation forestry water use was refined satisfactorily, using updated (2002) plantation water models. The determination of net irrigation of sub-tropical fruits was investigated, but was not completed, based on data deficiencies and modelling complexities. The rationale for this is explained in section 5.3.1.

- To obtain representative figures of full private costs for small and large growers in each sector:

This was completed satisfactorily through the value chain analyses, and through intensive primary data collection.

- To establish forward and backward linkages for each sector;

This was completed satisfactorily through the value chain analyses, and through intensive primary data collection.

- To examine product flows:

This was completed satisfactorily through the value chain analyses, and through intensive primary data collection.

- To determine external (public) effects:

The environmental and social costs and benefits were determined through qualitative and quantitative methods, and yielded satisfactory results. This part of the study showed, however, that much more research is required to enable comprehensive internalisation of external effects.

1.6 RECOMMENDATIONS FOR FURTHER RESEARCH

Two avenues of future work were identified:

- The environmental and social externalities identified here can be linked to a Social Accounting Matrix in order to model the effects of various water policy decisions.
- Research is required on selected pilot study areas in order to generate a comprehensive data base from which benefit transfer studies may be done to inform water policy decision-making.

1.7 CAPACITY BUILDING REPORT

It is expected that one M.Sc. degree will be forthcoming from the final report.

Project Members	Role	Approximate Time Spent	Institution, Designation	Highest qualification at time of Research
Bekker, Simon	Project Design	<1%	University of Stellenbosch, Professor	PhD
Crafford, Jackie	Project Leader, Researcher; Data Acquisition	~ 18%	CSIR, Environmentek	MSc
Damon, Margot	Researcher and Development of Chapter 2 & 6	~16%	CSIR, Environmentek – Internship programme	Hons
De Wit, Martin	Development of Chapter 7 & 8	~4%	CSIR, Environmentek	PhD
Dicks, Mark	Data Acquisition	~4%	CSIR, Environmentek	Hons
Gouws, Marnus	Data Acquisition	~4%	University of Pretoria, Student	Hons
Hassan, Rashid	Project Design and Development of Chapter 4	~10%	University of Pretoria, Professor	PhD
King, Nicola	Researcher and Development of Chapter 5	~16%	CSIR, Environmentek	MSc
Kruger, Fred	Project Design	<1%	Private Consultant	PhD
Meyer, Ferdi	Data Acquisition	~4%	University of Pretoria, Student	Hons
Olbrich, Bernie	Project Design and Researcher on Chapter 6	~10%	Private Consultant	PhD
Rapholo, Blondie	Data Acquisition and Editing	~4%	CSIR, Environmentek – Internship programme	Hons
Van der Merwe, Marna	Data Acquisition	~4%	CSIR, Environmentek	MSc

1.8 ARCHIVING OF DATA

Environmental impact coefficients are available in Excel spreadsheet format.

1.9 KNOWLEDGE TRANSFER

The knowledge resulting from this study relate mostly to water policy formulation for national government, catchment management agencies and water user associations. In addition, knowledge in terms of adaptation strategies for industries was developed. It is proposed that the key findings of this report be communicated to these stakeholders through direct mail or other personal contact, and that follow-up actions be undertaken as warranted by stakeholder feedback.

ACKNOWLEDGEMENTS

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"A comparison of the economic efficiency of water use of plantations, irrigated sugarcane and sub-tropical fruits – a case study of the Crocodile River Catchment, Mpumalanga Province."

The steering committee responsible for this project consisted of the following persons:

Dr G R Backeberg	Water Research Commission (Chairman)
Mr H Maaren	Water Research Commission
Mr JG Crafford	CSIR, Environmentek
Mr JM Bosch	CSIR, Environmentek
Prof MF Viljoen	University of the Free State
Dr AB Emmet	Human Sciences Research Council
Dr SF du Plessis	Agricultural Research Council
Prof PJT Roberts	Forestry SA
Mr EJ Schmidt	SA Sugar Association
Mr M Warren	Department of Water Affairs and Forestry

The project team would like to acknowledge the contribution of Mr Hugo Maaren to this project, who sadly passed away shortly before the completion of the final report. Mr Maaren has, over many years, made very significant contributions to water research in SA, and his presence will be sorely missed.

We would also like to express our appreciation to the steering committee for their guidance during the course of this project. In particular, we would like to thank Dr Backeberg for his assistance in guiding the project. We would also like to thank Dr F Kruger (Fred Kruger Consulting) and Prof S Bekker (University of Stellenbosch) for their assistance in designing the environmental and social components of the study.

The study required intensive data collection, during which the project team received tremendous industry assistance. We would like to extend our appreciation to the following representatives of the Forestry, Sugarcane and Sub-tropical fruit sectors, for their assistance.

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LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMS

AR	Annual runoff (m^3/a)
BOD	Biological oxygen demand
CMA	Catchment management agencies
DWAF	Department of Water Affairs & Forestry
EIA	Environmental Impact Assessment
GDP	Gross domestic product
GGP	Gross geographic product
IFR	In-stream flow requirement
IWMI	International Water Management Institute
MAI	Mean annual increment (m^3/ha/a)
MAP	Mean annual precipitation (mm/a)
MAR	Mean annual runoff (m^3/a)
NRA	Natural resource account
NWA	National Water Act of 1998 for RSA
RSA	Republic of South Africa
SEIA	Socio-economic impact assessment
SIA	Social impact assessment
SIC	Standard industrial classification
TSS	Total suspended solids (parts/million)
VAD	Value added
WC&DM	Water conservation and demand management
WDM	Water demand management
WfW	Working for Water programme
WMA	Water management area
WRA	Water resource account
WSAM	Water situation assessment model for RSA
WUA	Water user association

CHAPTER 1:

INTRODUCTION

1.1 OVERVIEW AND BACKGROUND

South Africa is classified as one of the few Southern hemisphere countries that will face *absolute water scarcity* between 2020 and 2030 (Seckler, 1999). Therefore, the apportionment of water resources between sectors is expected to become ever more critical, sensitive and controversial. The National Water Act (no 36 of 1998) regulates the use of water in South Africa. The overarching objective of the Act is to ensure the beneficial use of water in the public interest. The fundamental principles of the Act focus on the need for sustainability and equity, in the protection, use, development, conservation, management and control of water resources. With increasing economic development, and an associated increased demand for water, a thorough understanding of water beneficiation and much information are required to ensure that water apportionment decisions remain in line with the principles of the Act.

In a first step towards this, the Water Research Commission (WRC) funded a study comparing the economic efficiency of water use by forest plantations, irrigated sugarcane and irrigated sub-tropical fruits in the Crocodile River Catchment (Olbrich and Hassan 1999). The study analysed water use efficiency based on direct economic benefits (gross margins minus establishment costs) generated in the primary production activities, i.e. only at the farm level. These benefits translated to ratios of direct economic returns (annualised net returns) to water use, ranging between 1 and 10 Rand per cubic meter water used for sub-tropical fruits, and below 1 Rand per cubic meter water used for forestry and sugarcane (Olbrich and Hassan 1999).

However, indirect economic benefits realized upstream or downstream from the respective primary sectors, and the respective social costs and benefits of the major environmental impacts were not investigated. As water allocation and competition for its use by the analysed agricultural production activities remain central to future economic development and efficiency of resource use in the Crocodile River Catchment, a follow-up study was funded by the WRC. The work presented in this report constitutes, first, an account of total economic benefits (direct and indirect) of water use in the catchment and to refine the economic analysis results of the previous study. Second, the social and environmental costs and benefits of the studied activities are presented.

The specific focus and scope of the study were guided by the 1999 study (Olbrich and Hassan 1999):

a. The study was not concerned with land use options other than irrigation agriculture, such as dry land farming and nature conservation.

b. Only industrial forest plantations and not natural forests or woodlands were investigated.

c. Other uses of water, such as domestic and industrial, were not considered.

d. Whereas the hydrological boundary of the Crocodile catchment defined direct water use impacts, the provincial boundary of Mpumalanga was used to define the indirect social, environmental and economic impacts area.

Results of the analyses and findings of the study are expected to inform policy making processes and strategic planning for land use and water resources development and allocation at both, the regional and national levels.

1.2 AIMS

The objectives of this research project were as follows:

- To refine data on water use within the respective sectors, and within their value chains;
- To quantify water use per crop per sector;
- To obtain representative figures of full private costs for small and large growers in each sector;
- To establish forward and backward linkages for each sector;
- To examine product flows;
- To determine external (public) effects – economic, social and environmental costs and benefits. (The term "environmental" refers to the natural environment.)

1.3 DATA REQUIREMENTS

The five categories of data required for each of the crops were the water use, product flow, environmental impact data, social impact data, and economic data (economic return, value added and intermediate consumption). This data were used to map and quantify the value chains of the three respective sectors in terms of direct and indirect social, environmental and economic impacts. New data were collected for product flow determination, and for water use, economic return, value added, and intermediate consumption in the respective value chains.

1.4 ANALYTICAL FRAMEWORK AND METHODS

1.4.1 Value chain analysis

The main objective of this part of the study was the mapping and quantification of the value chains of each of the three land use types (forestry, irrigated sugarcane and irrigated sub-tropical fruits). A value chain is a network of economic transactions, and describes the physical flows of goods and services. Value chain analyses produce a variety of information about a value chain, but its most powerful attribute is its ability to explain the so-called multiplier effect (or "ripple effect") of an event (social, environmental or economic).

The value chains associated with the three land uses under discussion were produced in a two-stage process, where, firstly, the product flows of the relevant land uses were mapped and forward and backward linkages identified. Secondly, each value addition activity was quantified in terms of price, intermediate consumption and value added, through extensive survey and primary data collection in each of the three value chains in Mpumalanga.

Economic, social and environmental impact analyses were completed using each value chain as a point of reference. Direct impacts were defined as economic, social and environmental impacts occurring within each of the land uses as the result of an event such as a water trade-off decision. Indirect impacts were defined as those impacts occurring in the forward and backward linkages of the respective value chains as a result of the event.

The following approach was adopted towards achieving the stated objectives:

- Develop product flow charts for downstream and upstream sectors linked to the land use activities under study.
- Trace flows of inputs and output through all levels of the mapped economic activities.
- Compile basic information and preliminary estimates of:
    - Shares of product flows and input costs at different levels of the chain of processing and input supply activities.
    - Gross revenues and value addition at various activity levels.
    - Employment at various levels of economic activity.
    - Water use at various levels in the forward and backward linkages' chain.
    - Use the compiled estimates in consultation with industry to identify priority areas for data capture for each of the product flows.
- Validating and improving the results of the previous step.

1.4.2 Economic impact analysis

The main objective of this part of the study was to measure and compare total economic benefits from water use by plantation forestry, irrigated sugarcane and irrigated subtropical fruit in the Crocodile River Catchment. To attain this goal, direct as well as indirect economic benefits realized in backward and forward sectors linked to the production activities under study were defined and measured. This study adopted value added in the chain of primary, secondary and tertiary forward and backward sectors as a proxy measure of total economic benefits. In addition, the employment benefits (direct and indirect jobs) were also cetermined. The results were used to conduct comparative analysis of the efficiency with which water is used by the three sectors under investigation in terms of derived total economic benefits. The analytical framework and methods were developed to be of value to future extensions of this type of analysis to other river basins.

The following approach was adopted towards achieving the stated objectives:

- Develop the analytical framework for calculation of total economic benefits.
- Present the framework and preliminary estimates to the steering committee for consideration before proceeding with completion of the intended analysis.
- Validating and improving the results of the previous step.

1.4.3 Environmental impact analysis

The economic impact analysis identified the value chain of direct and indirect product flows within each sector (forestry, irrigated sub-tropical fruits and irrigated sugarcane). These value chains were used as the basis from which to build a hybrid life-cycle assessment of the respective activities. This component of the overall study focused on the environmental aspects of the life-cycle analysis. (Environment here implied the natural environment and includes the impacts of the three activities on the source, sink and service characteristics thereof.) The aim of this component of the study was to provide information on the environmental impacts of each crop type.

The following approach was adopted towards achieving the stated objectives:

- Modelling respective value chains in terms of product flows.
- Defining the value chain components in terms of industry description and practices.
- Characterising each value chain component in terms of its environmental impact.
- Prioritising the environmental impacts with a view to data gathering.
- Doing preliminary environmental impact analyses based on available resource use and emission intensity data.

- Validation of the results of the previous steps.

1.4.4 Social impact analysis

The social impact analysis or assessment set out to measure the impact that respective value chains have on households and individuals. This part of the study examined direct and indirect employment and enterprise linkages, and assessed the external social benefits and costs on households that result from these three land uses. Employment and enterprise development was calculated as man-days per ton (sub-tropical fruit and sugarcane) or per cubic meter (forestry). The external social benefits and costs on households were approached in a qualitative manner rather than a numerical manner.

The following approach was adopted towards achieving the stated objectives:

- Design a framework for the social model.
- Data gathering through a literature and data survey of existing data and information.
- Identifying labour force components in each value chain component.
- Classifying labour force and enterprise components in terms of type of employment and skill levels, and classifying households in terms of race, gender, and location.
- Identification and description of small grower schemes, and incentives for small grower schemes.
- Quantification of small grower schemes on race, gender, and household asset acquirement.
- Validation of the results of the previous steps.

1.4.5 Integrated Analysis

The integrated analysis combined the outputs from each of the economic, social and environmental analyses into one model where the trade-offs involved in water allocation and associated policy implications were assessed.

1.5 REPORT STRUCTURE

The report is presented in eight parts: Chapter two sets the context of the investigation by presenting an overview of the Crocodile River catchment, this is followed by four chapters where the value chains and the economic, social and environmental analyses are discussed respectively. The comparative analysis is discussed in Chapter seven, while Chapter eight discusses policy implications.

CHAPTER 2:

CHARACTERISTICS OF THE CROCODILE RIVER CATHCMENT, MPUMALANGA

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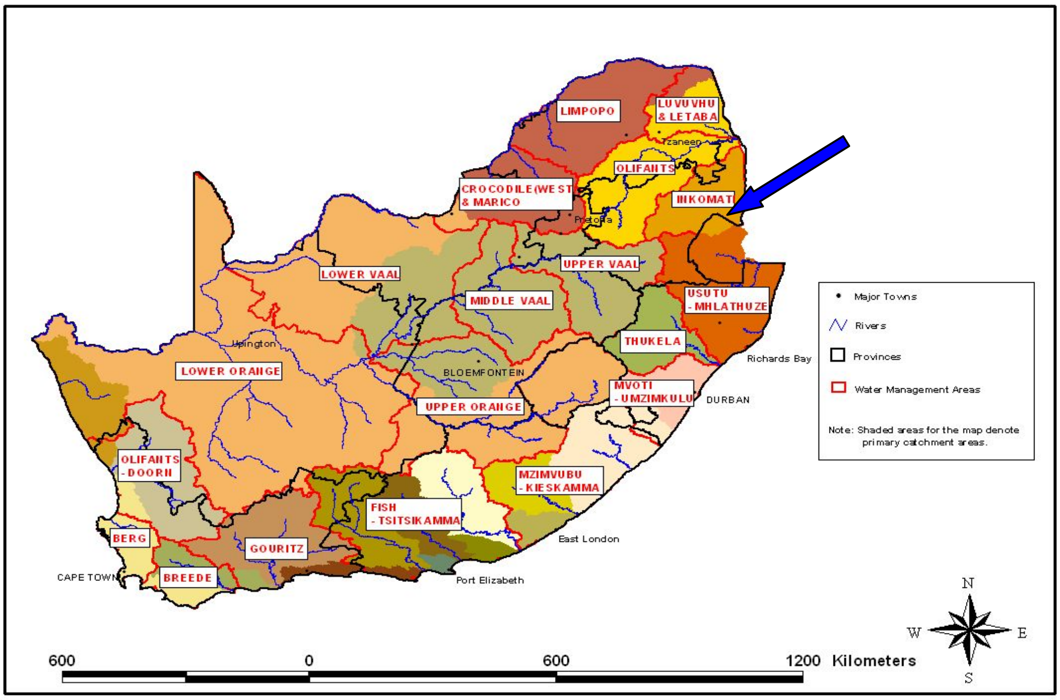
2.1 INTRODUCTION

This chapter provides background on the Crocodile River catchment and the province of Mpumalanga. The characteristics described include locality, water availability, water use and land use in the Crocodile River catchment, and a brief overview of the economy of Mpumalanga.

2.2 LOCALITY

The Crocodile River Catchment forms part of the Inkomati Water Management Area, it is located approximately 300km east of Johannesburg, and covers an area of approximately 10 500km^2, which is 14% of the land area of Mpumalanga. The Crocodile River is the largest tributary to the Komati River, and joins the Komati River shortly before it enters Mozambique.

Figure 2.1: Water Management Areas of South Africa, the Crocodile River Catchment is highlighted.



In terms of geographical co-ordinates, the Crocodile River basin lies between longitude 30°03’53” and 32°00’23’ East, and between 25°05’26” and 25°54’02” South. The study area comprises the X200 drainage region as defined by the Department of Water Affairs and Forestry (DWAF) Quaternary Drainage Regions Map (Olbrich and Hassan, 1999).

2.3 RUNOFF AVAILABILITY AND USE IN THE CROCODILE RIVER CATCHMENT

The Crocodile River catchment falls within the summer rainfall zone of southern Africa and approximately 85% of the annual rainfall is received during the hot summer months (November to March). Mean annual precipitation (MAP) is approximately 865mm, and varies gradually from about 500mm in the lower eastern reaches to above 1600mm in the northern and central mountainous areas. The catchment receives approximately 13% of the total precipitation of Mpumalanga, and carries nearly 17% of the province’s runoff.

Many factors influence the availability of water. Rainfall is the major source of fresh water supply. High rainfall leads to larger base flows and surface streamflow during the rainy summer months. Spatial rainfall variation as well as variation in evaporation, impacts water availability. In addition, dramatic year on year variations impacts significantly on water availability (Olbrich and Hassan, 1999).

Several water supply impoundments have been constructed on the Crocodile River and its tributaries. These have primarily been aimed at ensuring adequate water supplies for irrigation during the dry winter months. In addition to eight major dams, with capacity ranging from 0,85 to 161 million m^3, there are over 200 small farm dams within the catchment (Olbrich and Hassan, 1999). Total storage capacity in the catchment is 221,7 million m^3 or 17,6% of MAR (the comparative figure for South Africa is 57% of MAR) (DWAF, 2000).

Table 2.1: Published runoff availability and water use in South Africa, Mpumalanga, and the Crocodile River Catchment.

	Total precipitation (10^6 m^3 yr^{-1})	MAP (mm yr^{-1})	Virgin MAR (10^6 m^3 yr^{-1})	Water Use (10^6 m^3 yr^{-1})			
				Households	Forestry (SFR)	Irrigation (Irrigation)	Industrial*
South Africa	611,601 [c]	500 [c]	54,677 [c]	2,026 [b]	840 [d]	9,026 [b]	1,973 [b]
Mpumalanga	66,173 [a]	883 [a]	7,509 [a]	213 [b]	538 [d]	1,503 [b]	462 [b]
Crocodile	8,614 [a]	865 [a]	1,263 [a]	19 [b]	108 [d]	243 [b]	37 [b]

*Industrial, mining, commercial, strategic, other

Sources: Olbrich & Hassan, 1999 [a]; DWAF, 2000 [b]; Crafford, 2001b [c] ; Gush 2002[d]

Table 2.2: Comparative water use ratios of forestry and irrigation.

	Proportional forestry water use		Proportional irrigation water use	
	as a ratio of Total Precipitation	as a ratio of MAR	as a ratio of Total Precipitation	as a ratio of MAR
South Africa	0.14%	1.54%	1.5%	16.5%
Mpumalanga	0.81%	7.16%	2.3%	20.0%
Crocodile	1.25%	8.55%	2.8%	19.2%

Source: Calculations based on Table 2.1

Forestry water use is calculated as incremental water use or stream flow reduction. Published figures at a national level have varied widely, and the sources of data used are not always clear:

- A rule of thumb incremental water use value of 100mm (or 1000m^3) has been used widely. For an afforested area of 1.5 million hectares, this rule would result in a water use estimate for forestry of 1,500 million m^3.
- The Water Situation Assessment Model of DWAF (DWAF, 2000) estimated water use at 1,673 million m^3.
- The National Water Resources Strategy uses a value of 488 million m^3.

The most reliable forestry water use data was published by the WRC in 2002, based upon the research work for DWAF and the WRC by the CSIR's Forest Hydrology group (Gush et al, 2002). These estimates calculated incremental water use (or stream flow reduction) per plantation species per quaternary catchment. These values are converted to total incremental water use (reduced stream flow) by multiplying with afforested area. Based on this work, the total forestry water use in 1999 was 840 million m^3."

Irrigation water use figures are calculated as the water volumes allocated to irrigation activities. Tables 2.1 and 2.2, which reflect published data, show that irrigation water use in the Crocodile River Catchment is nearly double that of forestry. They have a combined water use of nearly 28% of MAR, of which irrigation uses 19.2%; and a combined water use of 3,1% of total precipitation.

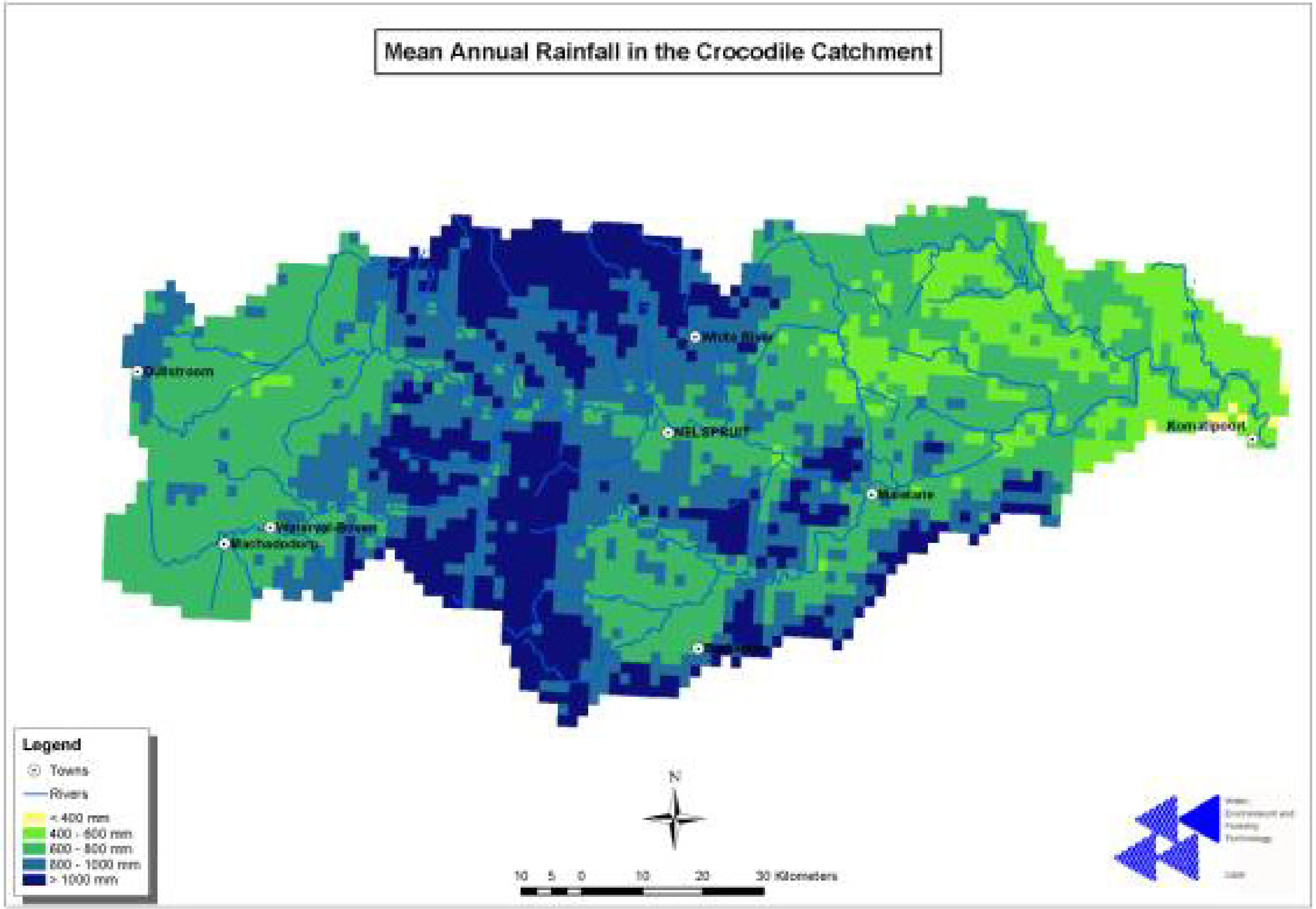


Figure 2.2: **Mean annual rainfall in the Crocodile River catchment.**

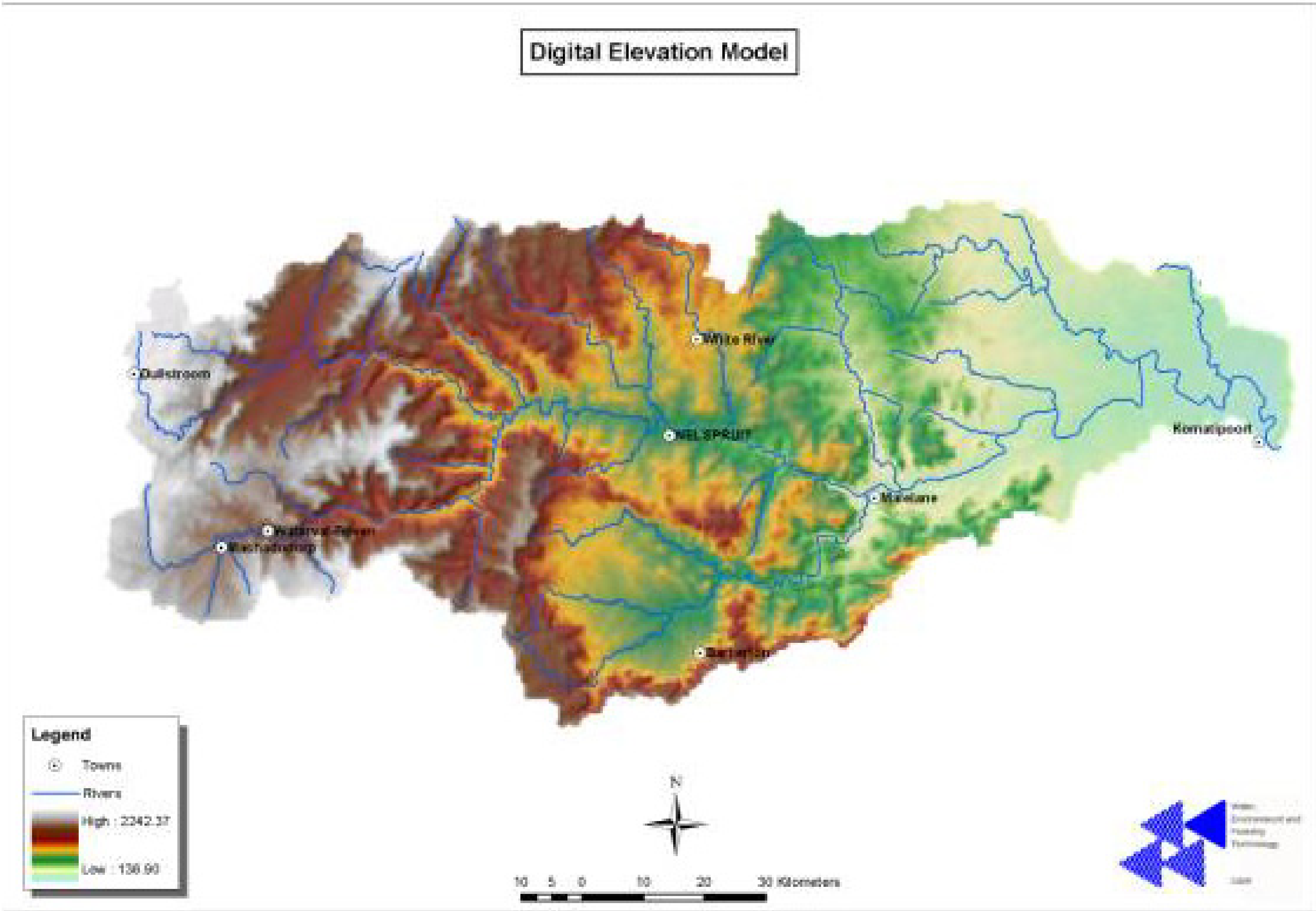


Figure 2.3: **Elevation map of the Crocodile River catchment.**

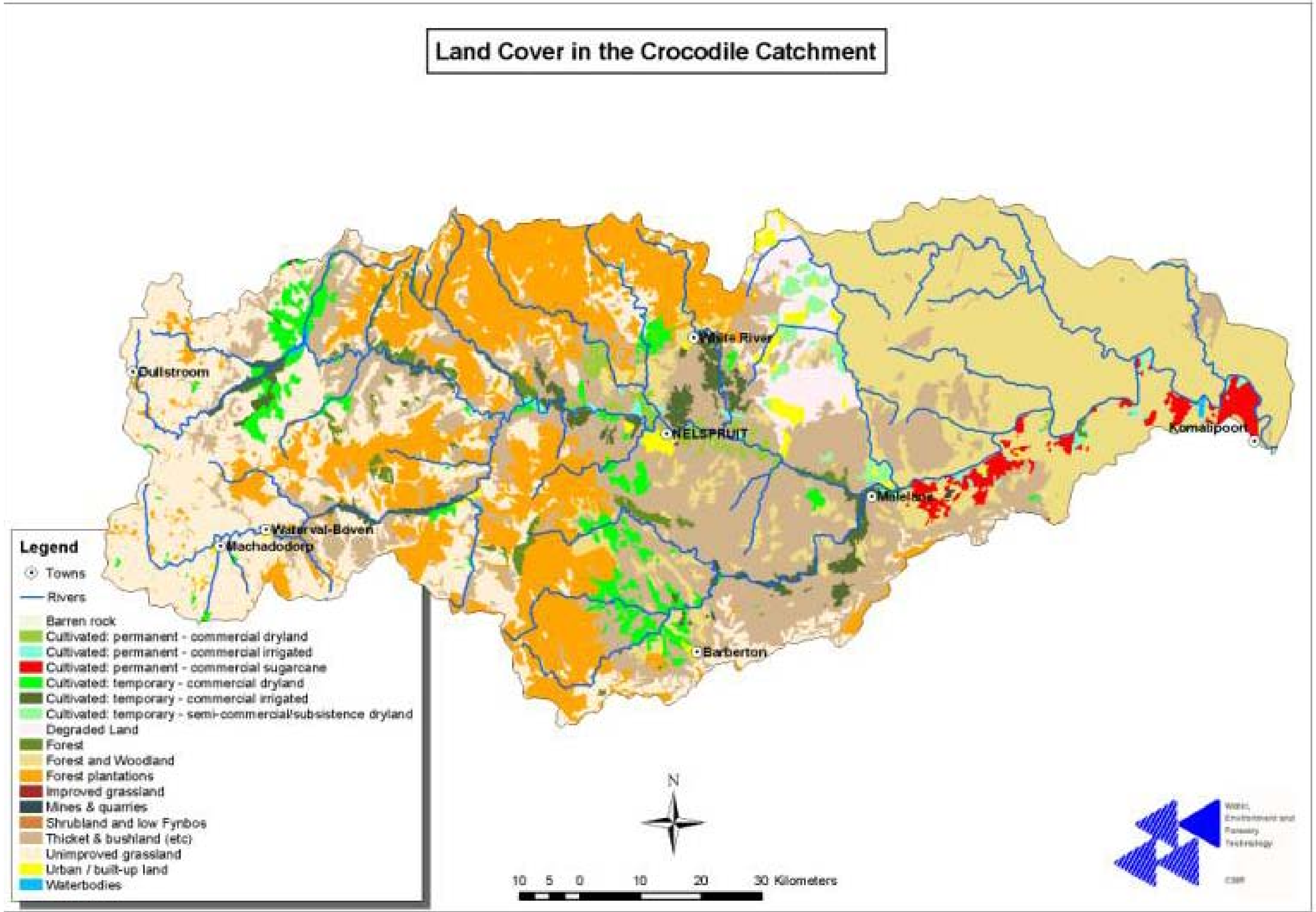


Figure 2.4: Land use in the Crocodile River Catchment

2.4 LAND USE IN THE CROCODILE RIVER CATCHMENT

Land uses are, for the most part, determined by water availability and gradient. Figures 2.3 and 2.4 show how forestry is clustered on the high rainfall escarpment slopes, whereas sugar irrigation and permanent (sub-tropical fruit trees) irrigation are clustered along the major water courses in the lower lying region of the catchment.

2.4.1 Forestry

Forestry comprises the largest intensively managed land-use in the catchment, and is concentrated in the escarpment region, to the west of Nelspruit. These plantations cover some 172 200ha (16,5%) of the catchment. About two thirds of this area is planted under Pine species, mostly *Pinus patula* and *P. elliotii*, with the remainder consisting mostly of Eucalypt species (*Eucalyptus grandis*, *E. camaldulensis* and *E. nitens*).

The ***Pinus species*** are grown on (average) 18-30 year rotations, at 12.1-15.5 m^3/ha/a mean annual increments (MAI). The harvest yield rages between 166-563 m^3/ha, and the roundwood commanded an average price of R138/m^3 (R90-R314/m^3 for the different log classes) in 1998. The ***Eucalyptus species*** are mostly grown on shorter 10-year rotations, at an average MAI of 20.5 m^3/ha/a. They yield on average 122 m^3/ha/a on a 10-year rotation, and sold for an average price of R100/m^3 (R35-R190/m^3 for the different log classes) in 1998.

Forestry and irrigation agriculture does not compete for land, although some forestry areas were replaced with citrus crops during droughts in the 1980's (Olbrich and Hassan, 1999).

2.4.2 Irrigation Agriculture (sugarcane and sub-tropical fruit)

The water allocation for irrigation agriculture is 8 000m^3/ha/annum between the Kwena dam and the Crocodile River Gorge – a total area of 11 206 ha; and 13 000m^3/ha/annum below the gorge – a total area of 17 089 ha (mostly sugarcane) (DWAF, 2002a).

Sugarcane is typically grown on a 6-year rotation, yields 103 tons/ha/a cane (13.9 tons/ha/a sucrose) and sold for R126/ton in 1998 (Conningarth, 1998a). ***Avocadoes*** are grown on a 25-year rotation, yield 11 tons/ha/a and sold for R2 108/ton in 1998. ***Mangoes*** are grown on a 16-year rotation, yield 26 tons/ha/a and sold for R2 456/ton in 1998. ***Oranges*** are grown on a 20-year rotation, yield 52 tons/ha/a and sold for R835/ton in 1998. ***Grapefruit*** are grown on a 12-year rotation, yield 95.3 tons/ha/a and sold for R847/ton in 1998. ***Bananas*** are grown on a 10-year rotation, yield 35 tons/ha/a and sold for R1 566/ton in 1998 (Olbrich & Hassan, 1999; Dept of Agriculture, 2001).

Some farmers grow both sugarcane and sub-tropical fruit crops on one management unit as an price hedging strategy.

In the national context Mpumalanga plays an important role in the production of specifically avocados, bananas and citrus of which it produced 57%, 65% and 75% respectively of total national production in 1993 (Conningarth, 1998a).

2.4.3 Other land uses

Fairly sizable portions of land are used for dryland agriculture. Approximately 20% (the north-eastern portion of the catchment) consist of woodlands and lies within the southern sector of the Kruger National Park. Large areas of thicket and bushland occur in the central and southern region. The main urban centre is around Nelspruit. The former homeland area of Kangwane is densely populated with rural villages.

2.5 THE REGIONAL ECONOMY OF MPUMALANGA

2.5.1 Overview

Mpumalanga is predominantly a resource-based economy (factor driven) but is moving into an investment-driven phase of its development (Erasmus 2001: 9). The gross geographic product (GGP) of the province was estimated between R50 billion and R55 billion in 1998, contributing 8% of total South African production. The main contributors to GGP are manufacturing (25%), mining (20%), electricity and water (20%), and agriculture and forestry (8%). Electricity gas and water sector is an important generator of national electricity, constituting more than 40% of national electricity output. (Erasmus 2001: 10; MII S.a.; Mpumalanga Provincial Legislature S.A.)

The infrastructure is well established within the province with a good network of roads, railway connections and small airports. Discrepancies do however exist in the provision of infrastructure and services to local communities and to the former homeland areas (Erasmus 2001: 11). Current spatial development initiatives such as the Maputo Development Corridor will contribute to improving transport and infrastructure systems and services. These initiatives may still not have an impact on underdeveloped communities as they are focussed on specific spatial areas.

Mpumalanga has a variety of tourist attractions and facilities. The province displays natural features and beauty like God's Window, the Mac-Mac Waterfalls, Blyde River Canyons, the Three Rondavels and a range of vegetation biomes. There are also historically and culturally significant sites such as Sudwala Caves. Mpumalanga is also the gateway to the Kruger National Park and other national parks. There is an abundance of opportunities for the tourism industry. (Erasmus 2001: 11-13; MII S.A.; Mpumalanga Provincial Legislature S.A.)

2.5.2 Demographics and employment

Mpumalanga is one of the smaller provinces, covering 74 940 km^2 (6,5%) of the surface area of South Africa. According to the Census '96, 6,9% (2.8 million) of South Africans reside in Mpumalanga (StatsSA, 2000). Population growth in South Africa is expected to decline due to lower life expectancy (the effect of HIV/AIDS) and slow fertility. Assuming these two assumptions hold for Mpumalanga, the expected population in 2020 is 3.5 million people rather than earlier projections of 5.3 million people. The population of Mpumalanga is predominantly African (89%) and White (9%), with few Coloureds (0.7%) and Indians (0.5%). Over 60% of the population live in non-urban areas. Most Africans live in non-urban areas, while the majority of the White population reside in urban areas. (Erasmus 2001: 3-4; Mpumalanga Provincial Legislature S.a.; Statistics SA 2000: 1, 8-9)

In 1996, 32% of the population was economically active, of which between 33% (Statistics SA 2000: 40) and 36% (Erasmus 2001: 4) were unemployed, according to the expanded definition of unemployment. Unemployment is mostly concentrated among Africans and women. Unemployment within the non-urban areas was at a rate of 35% in 1995 compared to 30% in urban areas.

The agricultural and forestry sectors employ 22% of workers (27% of male workers and 12% of female workers). Fourteen percent of employees work in the manufacturing sector (16% of male workers and 11% of female workers) (Statistics SA 1998: 15, 19-20; Statistics SA 2000: 41). Estimations of direct formal employment for the agricultural and forestry sectors showed that forestry created one job per 33 hectares (Scholes *et.al.* 1995: 7), field crops (sugar) one job per 4 hectares (SASA, 2000a) and horticultural crops (sub-tropical fruit) created one job per 5.5 hectares (Scholes *et.al.* 1995: 7).

There are large disparities between skill levels among races. The African population tend to be unskilled or semi-skilled, with a very small proportion of workers attaining managerial or highly skilled levels. The White population on the other hand are skewed towards the higher skill levels. African women tend to be the least skilled employees, while white female employees tend to be concentrated within the semi-skilled spheres. (Statistics SA 1998: 17-20)

2.5.3 Poverty in Mpumalanga

A provincial poverty rate of 57% was reported for Mpumalanga. This figure was based on the lowest 40% of the population being classified as poor. This classification considers households with a monthly income of R353 or less per adult equivalent as poor. (May and Wilkins 1998)

CHAPTER 3:

PRODUCT FLOWS

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3.1 INTRODUCTION

This chapter provides background on the product flows of the land uses under discussion. The method used, value chain analysis, is defined and described, and the value chains for each of the crops are discussed.

3.2 METHOD

Product flows were identified for each of the sectors by means of a literature survey, where after industry representatives identified by the Project Steering Committee were consulted to assess its accuracy. The industry representatives also identified the relevant companies that needed to be interviewed to obtain data for the value chain analysis.

A questionnaire was compiled and sent to the relevant forestry, sugarcane and sub-tropical fruit companies to determine product flow (backward and forward), industrial water use in the forward linkages, economic returns, value added (including employment), and intermediate consumption data (see Appendix 1). This data was sourced from the income statements of the individual companies. Value added is defined as the sum of employment costs, interest, tax, net profit and dividends. Intermediate consumption is defined as the expenditure on inputs such as raw materials, contractors, electricity, transport and all other expenses required for operation.

A value chain describes the flow of goods and services through a particular network of transactions at a micro-economic or firm level. The economic, social and environmental aspects of these transactions for 1998 were analysed here, and the locations of these transactions were defined within the following boundaries:

- Value chains were identified for forestry, sugarcane and the five sub-tropical fruits: avocadoes, mangoes, oranges, grapefruit and bananas.
- The spatial boundary of the study was enlarged beyond the catchment boundary of the Crocodile River catchment to the provincial border of Mpumalanga, in order to include a number of significant indirect value adding activities; to facilitate data gathering; and to enable the analyses of trans-catchment cost and benefit transfers. Any goods and/or services purchases or sales outside of Mpumalanga were classified as export activities.

- The value chain activities were traced through its forward linkages, to a tertiary level of value adding.
- Forward and backward linkages were included or excluded based on a 80:20 rule of product flow and price, i.e. value adding activities that contributed a weighting of less than 20% to the total value addition in the chain, were not included.

The backward linkages were defined through the intermediate consumption categories identified by the companies that were interviewed.

3.3 RESULTS

3.3.1 The forestry plantation value chain

Figure 3.1: The forestry value chain

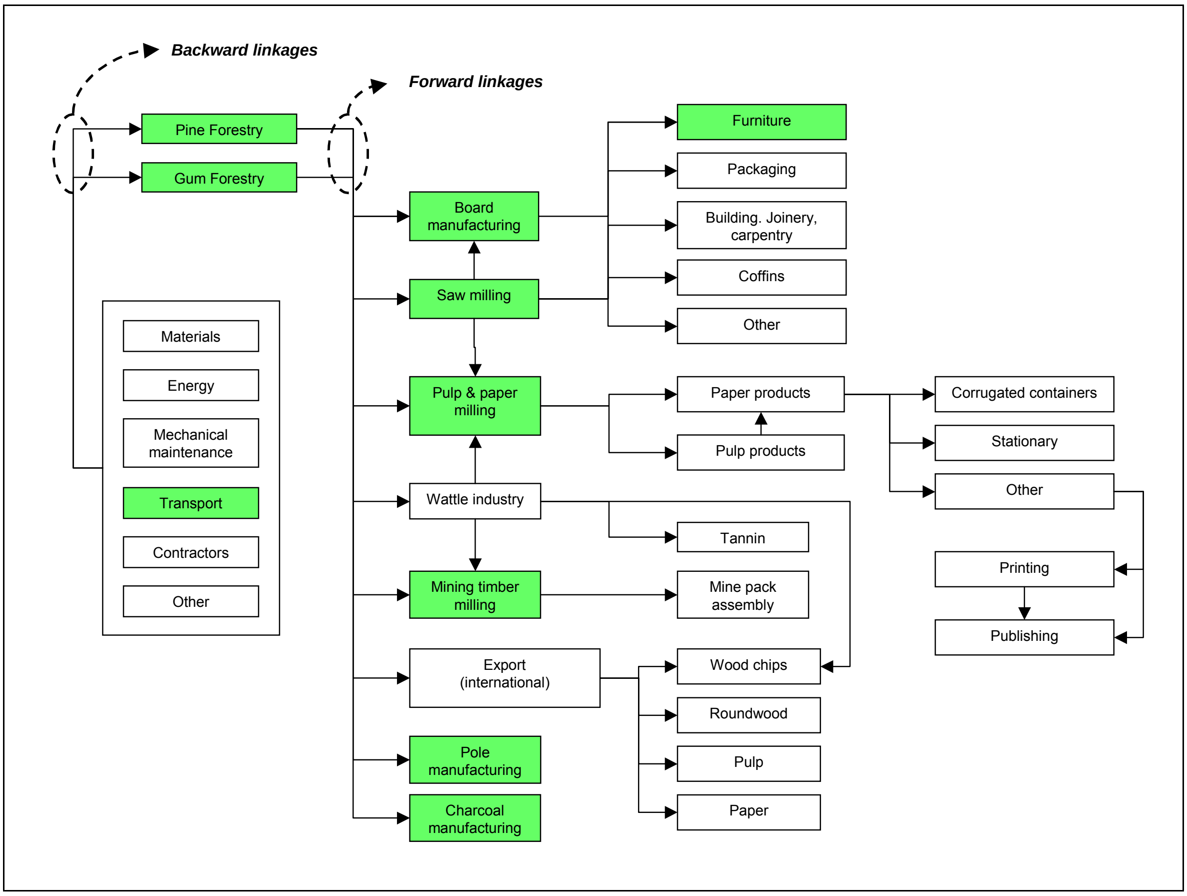

Figure 3.1 shows the forestry value chain. The highlighted industries were selected for value chain analyses based on the criteria set out in the previous section. All the backward linkages were analysed.

Pine and gum forestry are essentially plantation tree farming with exotic species at relatively (for forestry) short rotations of 25 and 10 years respectively. These forests supply a number of secondary conversion industries with roundwood, or logs. The species, tree size and position in the stem influences roundwood quality and price. ***Saw mills*** purchase mostly pine roundwood and convert it to timber for various uses from packaging and building materials to furniture. Integrated ***pulp and paper mills*** purchase pine and eucalypt roundwood for conversion to pulp and paper products. The wood fiber may be sold either in pulp form, or in paper form. Paper can be sold in different classes, ranging from newsprint (for newspaper) to fine paper (for high quality printing) to paperboard (for packaging). ***Mining timber mills*** exclusively purchase eucalypt roundwood for conversion to (underground) mine support packs. ***Pole manufacturers*** purchase mostly eucalypt roundwood for conversion to telephone, transmission and fencing poles, through a preservation treatment. Although ***charcoal manufacturers*** prefer wattle as a carbon source, high-density eucalypt is also converted.

Table 3.1 summarises the product flow in the forestry value chain. Forestry in Mpumalanga produced 2.82 million m^3 of pine roundwood and 1.78 million m^3 of eucalypt roundwood in 1998. An additional 0.39 million m^3 of roundwood was exported outside the boundary of Mpumalanga. Pulp and paper manufacturers (1.42 million tons) and saw mills (1.39 million m^3) had the largest intake of roundwood. The third most significant roundwood user was the mining timber industry, with 0.61 million m^3. These three value adding activities constituted 86% of the roundwood intake in Mpumalanga. Conversion to secondary products yielded saw timber, mine packs, poles, charcoal, pulp and paper products, furniture and structural board products. The yield achieved for each secondary product depended on the technology used and product required.

This data was used as a basis for the further analysis of economic, social and environmental impacts.

3.3.2 The irrigated sugarcane value chain

Figure 3.2: The irrigated sugarcane value chain

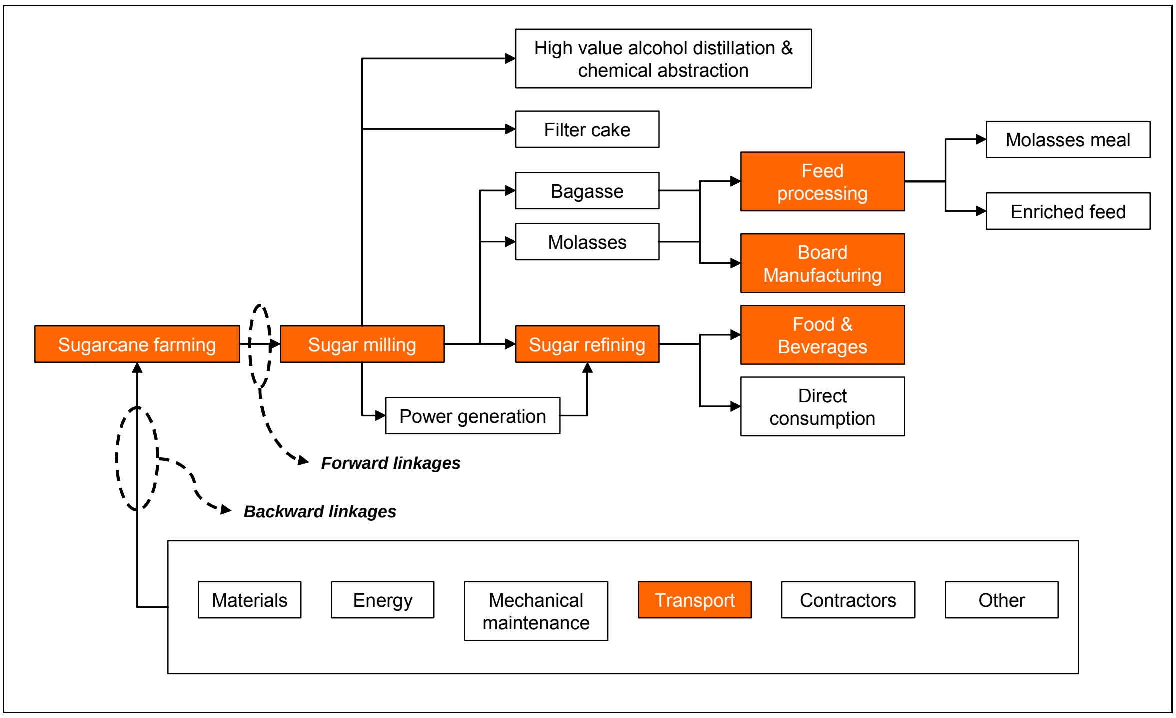

Figure 3.2 shows the sugarcane value chain. The highlighted industries were selected for value chain analyses based on the criteria set out in section 3.2. All the backward linkages were analysed.

Irrigated sugar cane is grown on a six-year rotation. The cane is converted, through a ***milling*** process, to raw sugar. The raw sugar is ***refined*** for use in direct consumption and/or in the ***food and beverage industry***. By-products from the sugar milling process are the molasses and the fibrous bagasse. Molasses and bagasse are converted to animal feed by ***feed processing industries***, while bagasse is also converted to ***paperboard and other composite board products***. High value alcohol products are other by-products from the process. No such distillation plants exist as part of the value chain in Mpumalanga yet.

Table 3.2 summarises the product flow in the sugarcane value chain. Sugarcane growers produced 3.03 million tons of sugarcane, all of which were milled and refined in Mpumalanga. The milling process produced raw sugar, bagasse, molasses and water. A raw sugar yield of 0.36 million tons was converted to 0.27 million tons of refined sugar, of which 32% (0.087 million tons) were sold to the food and beverage industry, and rest to final consumers. The sugar milling process also yielded 0.52 million tons of bagasse for boiler fuel, a smaller volume of bagasse was used in board manufacturing. Molasses (0.15 million tons) were sold to the animal feed processing industry.

This data was used as a basis for the further analysis of economic, social and environmental impacts.

3.3.3 The irrigated sub-tropical fruits value chain

Figure 3.3: The irrigated sub-tropical fruits value chain

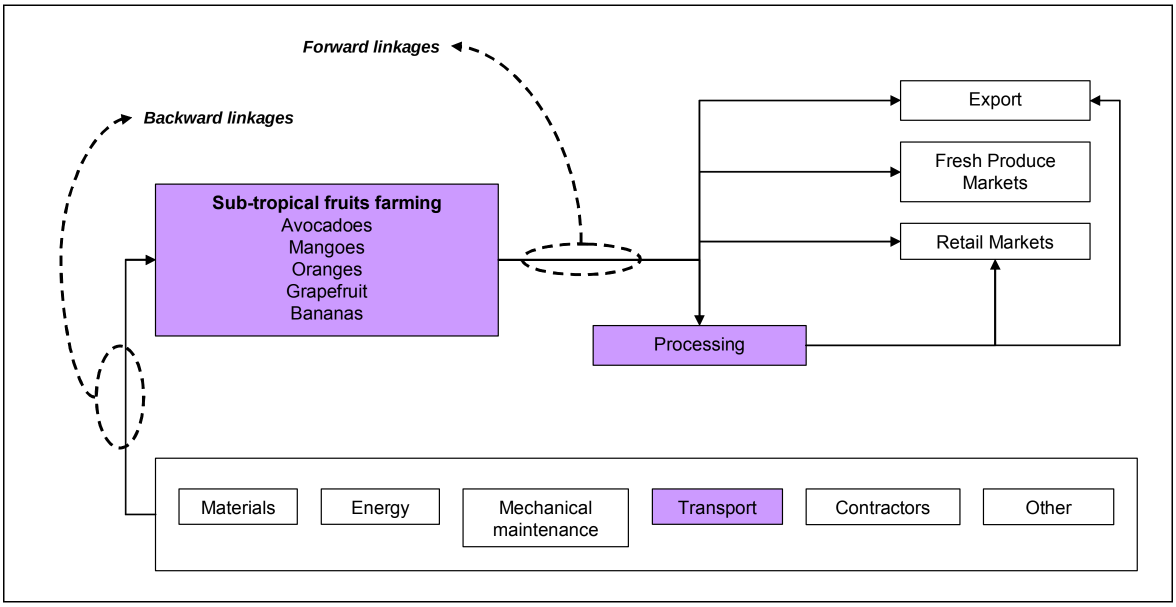

Figure 3.3 shows the value chain for sub-tropical fruit. The highlighted industries were selected for value chain analyses based on the criteria set out in section 3.2. All the backward linkages were analysed.

The ***sub-tropical fruit crops*** have the shortest of the value chains. In most cases the fruit itself are the main products sold to final consumers. Secondary ***processing*** activities, which included the manufacturing of fruit juice and marmalades, were identified for mangoes oranges and grapefruit.

Table 3.3 summarises the production of the five sub-tropical fruit types analysed. Oranges (307 262 tons) and bananas (215 075 tons) produced the largest harvests. Approximately 30% of each of the mango, orange and grapefruit harvest were sold to secondary fruit processing industries (juices, jams, etc), the remainder were sold to final consumers in Mpumalanga, other parts of South Africa and internationally.

This data was used as a basis for the further analysis of economic, social and environmental impacts.

Table 3.1: Product flows in the forestry value chain in Mpumalanga (1998).

Industry	Pine forestry (m^3)	Gum forestry (m^3)	Export - roundwood (m^3)	Saw milling (m^3)	Mining timber milling (m^3)	Pole manuf. (m^3)	Charcoal manuf. (tons)	Pulp and Paper manuf. (tons)	Furniture manuf. (m^3)	Board manuf. (m^3)
Round-wood in	Not applicable	Not applicable	Not applicable	1,388,012	605,277	39,608	180,000	1,414,500	18,005	307,900
Products out	2,821,353 (roundwood)	1,778,148 (roundwood)	392,904 (roundwood)	884,858 (saw timber)	586,490 (mine packs)	39,608 (poles)	122,456 (charcoal)	625,000 (pulp & paper products)	16,745 (furniture)	250,000 (board products)

Source: Forestry Industry Questionnaires, 2000

Table 3.2: Product flows in the sugarcane value chain in Mpumalanga (1998).

Industry	Sugarcane farming (tons)	Sugar milling (tons)	Boiler Fuel (tons)	Sugar refining (tons)	Food & Beverages (tons)	Feed Processing (tons)	Board Manufacturing (tons)
Products in	Not applicable	3,030,372	520,120 (bagasse)	362,636	87,174	153,357 (molasses)	89,715 (bagasse)
Products out	3,030,372 (sugarcane)	362,636 (raw sugar)	energy	272,627 (refined sugar)		180,420 (animal feed)	72,844 (board products)

Source: Sugar Industry Questionnaires, 2000

Table 3.3: Product flows in the sub-tropical fruit value chain in Mpumalanga (1998).

Industry	Avocado farming (tons)	Mango farming (tons)	Mango processing (tons)	Orange farming (tons)	Orange processing (tons)	Grapefruit farming (tons)	Grapefruit processing (tons)	Banana farming (tons)
Products in			9,150		82,961		25,078	
Products out	46,497 (avocados)	27,388 (mangoes)	2,722 (juice & marmalade)	307,262 (oranges)	24,678 (juice & marmalade)	92,880 (grapefruit)	7,460 (juice & marmalade)	215,075 (bananas)

Source: Fruit Industry Questionnaires, 2000

CHAPTER 4:

ECONOMIC IMPACT ANALYSIS

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4.1 INTRODUCTION

This chapter provides the economic analysis of the respective crop value chains.

4.2 METHOD

4.2.1 Concept and definition of total economic benefits

Total economic benefits (TEB) are used here to represent the sum of direct and indirect benefits in the sectors under study. Direct benefits refer to benefits generated directly by the economic activity in question. Indirect benefits on the other hand, measure benefits generated in sectors other than the activity in question, which either process produced output or supply inputs to the sector under study (benefits from forward and backward linkages in production).

Benefits directly generated in the sector in question do not capture the total benefits from that activity. As output produced is further processed by other economic activities, which add further value downstream, the chain of value addition in all sectors linked forward with this activity is considered part of the total economic benefits indirectly emanating from the activity in question. Accounting for indirect economic benefits is particularly important and of large orders of magnitude for primary production activities such as cane and timber farming. That is because in these industries the farming operation is only a source of the raw material, which supports extensive further processing for higher values in secondary and tertiary phases of economic activities downstream. Similarly, value addition in the chain of activities supplying inputs to the primary sector in question and all its downstream processing activities is also considered part of the total benefits indirectly resulting from the primary activity investigated. Accordingly, the present study made an attempt to calculate total benefits from compared activities as the sum of all value addition and employment opportunities created in the forward and backward chains of production activities linked to the industry in question.

One should, however, note that the indirect benefits discussed above represent spin-off effects of production multipliers only. That means additional output need to be generated by sectors supplying the required extra intermediate inputs or processing the extra output downstream per unit increment in primary sectors' output or income. Demand-side multiplier effects caused by spin-offs resulting from spending of the additional value (income) generated throughout the forward and backward chains on more goods and services for final consumption are not captured. This is referred to in the literature as the “income leakage” (Pyatt and Round, 1985). While calculation of production and demand multipliers are very demanding in terms of data requirements, the study will make an attempt to account for a feedback effect from consumption or final demand to close the loop of income leakage from the system.

Various measures of value were considered for the analysis, such as gross margins, net returns exclusive of fixed costs, value added (VAD), etc. For many reasons, VAD was considered the most suitable measure of total social benefits and hence VAD will be used as the basis on which the total economic returns of the three sectors will be compared. Every economic activity uses final goods and services produced by other sectors as intermediate inputs to generate new goods and services. The proceeds from the new production (value of the generated products) minus the cost of intermediate inputs bought from other sectors give VAD in the economic activity in question. This represents an extra value generated from the employment of primary factors of production such as labor, land and capital over and above the cost or value of intermediate inputs produced and supplied by other activities. Accordingly, VAD contains the returns to all resource factors employed in the production process, i.e. wages and remuneration of employees, profits and surplus margins to resource/capital owners, taxes to government, etc. In general VAD is defined as:

VAD = Remuneration of employees + Operating surplus + Government tax revenue

Gross margins were considered as an alternative measure to VAD. These are calculated by subtracting all variable costs (including wages and taxes) from gross proceeds or total revenue. Similarly, social values such as returns to labor, water, taxes as well as fixed costs are subtracted from revenue to calculate net returns. Accordingly, the value of labor, capital and other resource factors, which are part of the total social benefits generated by the economic activity in question are excluded from measures of value other than VAD. VAD however, does not derive an estimate of the price of or return to an individual resource factor, but rather the residual value of the total contribution of all resource factors exclusive of intermediate input costs. It is important to emphasize that while VAD provides a better crude proxy to the average residual benefits from resources’ use than the above described alternatives, it is not the proper measure of the marginal value of water. Measures of the marginal contribution of water to total benefits are more appropriate for water pricing purposes. Such measures however, require micro level data on water productivity to enable estimation of its marginal contribution to production (e.g. the marginal value product - MVP). This is typically derived from water demand functions specified for the respective production activities under study.

Various techniques can be used to specify and estimate demand parameters. The direct and easiest approach to estimation of demand functions requires the use of data on quantities (volume) of water use at different price levels. Unfortunately, such data is not available for most of the cases investigated here. For instance, water has never been sold to forest plantations, which use rainfall water. Therefore, information on changing plantation management decisions in response to changing water charges or prices does not exist. At the same time, while irrigation agriculture pays water charges, these are set at fixed flat rates based on a quota system and not varied marginally with level of use (e.g. volume). As irrigators pay a fixed flat charge on their water quota, the current water rates' system in South Africa does not provide an incentive for them to vary levels of use in response to varied schedule of volumetric charges. Therefore, the data required to allow direct estimation of water demand parameters for irrigation agriculture does not exist either.

Alternative positive (econometric) marginal pricing methods include the use of a two-step approach to derive the MVP of water (e.g. the water demand curve) from a specification of water yield response functions. This approach requires data for the specification of water production functions, which again proved to be lacking or at best inadequate for our case studies. Normative approaches to marginal pricing based on farm programming models that include a constraint on water availability to derive a shadow price (marginal value) for the constrained water supply have also been used in the literature[1]. In addition to its other limitations, this approach is more suitable for annual cropping systems and not as easy to use for the case of perennial tree crops such as the ones compared here[2].

It is however, important to remember that the objective of this study is not to derive an estimate of the value of water for water pricing purposes but rather to compare total benefits to society from alternative uses of resource factors including water. Due to the difficulties in the use and application of the proper marginal valuation methods reviewed above, VAD is considered a better crude measure of total benefits (the social opportunity cost) of water for the purposes of this investigation compared to others such as gross margins and average net returns. This study used VAD in forward and backward linkages to calculate economic multiplier effects. Direct benefits for example, generated in the sector in question are expressed as VAD in Rand/unit water used. In addition to direct benefits, VAD per unit water indirectly generated in downstream and upstream linkage sectors are divided by direct benefits (VAD) in the sector under study to calculate forward and backward multipliers. This gives an estimate of how much value is generated elsewhere in the economy (downstream and upstream) per unit VAD directly generated in the primary sector in question. For instance, a forward multiplier of the value of 2.5 indicates that for every Rand directly generated in the primary sector, an additional value of R 1.5

[1] See Hassan et al. (1996) for an application in SA.

[2] In addition to the reviewed approaches to average and marginal valuation of water resource use in production, the value of water for direct final consumption and other uses such as ecological services is derived using other techniques. A wide range of methods have been applied in the literature for that purpose ranging from the use of non-market valuation methods such as contingent valuation to estimation of recreation and environmental services' values. Other benefit as well as cost-based techniques for water pricing have also been used in different circumstances including the cost of developing alternative water supply sources such as the Netback analysis (Bates et al, 1998) and the opportunity cost of time spent in fetching water in rural areas, among others.

is generated downstream as a result (forward multiplier = direct VAD/Rand + indirect forward VAD/Rand). The same applies to backward (input supply) sectors.

4.2.2 Analytical Framework

We argued in the previous section that this study considers not only direct economic benefits generated in the sector under investigation, but also benefits generated elsewhere in the economy caused indirectly by the studied sector activities. The aggregate of direct and indirect economic benefits gives a measure of total benefits. Since VAD was chosen as the desired measure of economic benefit, one needs to estimate VAD directly and indirectly generated as a result of the analysed activities. Total VAD is then derived as the sum of direct and indirect benefits. This allows the derivation of what is known as the economic multipliers that measure the ratio of the indirect economic effects to direct VAD in the sector in question. Accordingly, suitable measures of multiplier effects in the forward and backward links are necessary to calculate total economic benefits. The following section reviews various methods commonly used to derive multiplier effects and consequently total economic benefits.

4.2.3 Approaches and measures of multiplier effects and total economic benefit

A number of approaches and methods have been used in the literature to derive economic multipliers. This section briefly reviews some of the most commonly used methods, and presents and discusses approaches adopted by the present study.

4.2.3.1 The multi-sector input-output (I-O) tables framework

Multi-sector models capture the economy-wide effects of sector-specific as well as macroeconomic policies. They provide a powerful tool for regional and macroeconomic planning, and are extensively used in the literature to generate production and operations plans and to perform general equilibrium analysis. The I-O framework based on the linear structure of inter-industry production linkages pioneered by Wassily Leontief (1953) marked the beginning of multi-sector planning. The most important product of the I-O framework is what is known as “the total input requirements matrix”, which is used to calculate the direct and indirect intermediate inputs’ requirements per extra unit of output or VAD to be generated in any particular sector. For more details on the structure and use of I-O tables models see the more technical Appendix 2.

I-O models and multipliers have been extensively used in the early literature analyzing growth linkages between various economic sectors and especially investigating the role of agriculture and industry as engines for economic growth. The said literature arrived at the conclusion that agriculture had weaker linkages to other sectors of the economy compared to manufacturing industries and hence the focus on promoting growth should be placed on non-agricultural sectors (Hirschman 1958). The major problem with and limitations of the I-O framework stem from the fact that it only captures production or supply-side linkages. It has been later argued by others that while agriculture may have small effects on growth outside agriculture due to its relatively weaker production linkages, demand linkages from agriculture through consumption spending have large impacts on growth in other economic sectors. This is thought to be mainly due to the high impact of agricultural expansion on income and consequent demand for consumers goods by rural population, especially in developing countries where large segments of the population is employed in agriculture (Mellor 1976, Adelman and Morris 1973, Hazell and Roell 1983).

The later views and research results led to the emergence of alternative approaches to analyzing growth linkages that incorporate demand and consumption feedback effects (Mellor 1976, Bell and Hazell 1980, Delgado et al. 1998). Most of this literature was based on the use of one or another version of the social accounting matrix (SAM) based general equilibrium approaches with variations in modeling demand and measuring marginal propensities of consumption (MPC) out of current income.

4.2.3.2 The social accounting matrix framework

This approach basically extends the I-O framework to include demand components of the multi-sector structure of the economic system into the endogenous (values, which are solved for and not set externally) segments of the model. This meant that most of the final demand sectors (household and government consumption and investment demand, foreign trade, etc.) became part of the Leontief I-O model requirements' coefficient matrix discussed above (Dervis et al., Pyat, etc.). The consequence is larger multiplier effects as feedback and spin-offs from spending on final consumption are captured.

Agricultural multiplier estimates of selected literature based on the described approaches are presented in Appendix 3. Estimates of multipliers from studies using the above multi-sector models and other approaches in South Africa are also presented and compared to international estimates in Table 4.1. It is clear from Table 4.1 that production multipliers are of a larger magnitude when the effect of feedback from consumption spending is taken into account (i.e. SAM-based compared to I-O based multipliers). For the same reason, I-O multipliers tend to underestimate economy-wide impacts (total economic benefits) compared to SAM multipliers. In general, multiplier estimates for South Africa are relatively higher than international estimates, especially the SAM-based ones.

4.2.3.3 Direct approach to estimating VAD multipliers

As seen from Table 4.1 estimates of economic multipliers in South Africa are available for only a few of the economic activities under study. More over, even estimates available for some selected sectors reflect national aggregate figures and not provincial, catchment or regional industry-specific. Because of that, this project had to make an effort to derive industry-specific estimates for the area under study. For the present investigation, multiplier effects were estimated using a simplified version of the semi-I-O models' approach described above. Production multipliers were derived using data on forward and backward value chains collected from surveys of the studied sectors as well as other secondary sources. Accordingly, an estimate of the total economic benefits realized throughout the forward and backward activities linked to the primary sector in question were calculated for each of the three sectors (forest plantations, irrigated sub-tropical fruit, and irrigated sugarcane). The simple additive method presented below was employed to derive total economic benefits.

The present study traced the chain of value addition between primary (origin) production (e.g. farm/plantation) and final use (e.g. end product for final consumption) by mapping production linkages chain starting from the end or final product (furniture for instance) to primary sector activity (e.g. timber plantation). Using furniture, for instance as an example of an end product from timber needed for final use, a country may choose to either import ready furniture or manufacture its own. When furniture is produced locally, VAD generated from furniture manufacturing is realized. On the other hand, if ready furniture is imported no value addition takes place within the country's boundaries. To manufacture furniture locally, sawn logs and other intermediate inputs are needed by the furniture industry. Again, a country may choose to either import sawn logs and other inputs or produce those inputs locally, leading to further value addition in input supply sectors (saw milling, fertilizer and chemicals, etc.). This sequence continues all the way to the primary production spheres, where timber logs have to be either imported as round wood or grown locally in plantations. Accordingly, VAD in all production activities supporting local furniture manufacturing within the country can be attributed to delivering the final product (furniture) for final use[3]. The same logic applies to other products compared in the present study (sugar, fresh or canned fruits, etc.) and is typical of all production activities in the economy.

The following computational method was followed: Let V_i denote VAD directly generated in sector i and V_{iB} refer to VAD generated in the backward chains for sector i that are attributed to the sectors' output expansion. Then total economic benefits V_{iT} can be calculated as the sum of direct and indirect contributions of sector i to total VAD in the production spheres of the economy along the backward chain:

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[3] The chain of value addition can also be mapped "up the forward chain" starting from primary production (e.g. farm/plantation). Using the furniture example once more for illustration, VAD in activities supporting the delivery of furniture for final use can also be traced forward along the value chain. For example, a country may choose to use its land, labor, water and other resources to produce timber or fruits. When timber plantations are established and cultivated, the country may choose to export its timber produce as round wood or further process the wood downstream (e.g. saw milling, furniture or pulp manufacturing, etc.). Similarly, a share of VAD in wood-based processing industries up to the final product as well as VAD in sectors supplying other inputs to this chain can be attributed to forest plantations.

$$V_{iT} = V_i + V_{iB} \quad (4\text{-}1)$$

Where V_i (direct VAD in sector i) is defined as:

$$V_i = X_i - \sum_j a_{ji} X_i = X_i (1 - \sum_j a_{ji}) \quad (4\text{-}2)$$

Where

X_i Is total output of sector i

a_{ji} Is the input-output coefficient denoting intermediate demand for units of product j per unit of sector i's output

The product $a_{ji} X_i$ therefore calculates the value of intermediate inputs from all j's sectors purchased by sector i. Using $a_{ji} X_i$ one can then derive VAD in the backward (V_{iB}) chain as follows:

$$V_{ij} = (a_{ji} X_i) * (V_j / X_j) \quad (4\text{-}3)$$

Where

V_{ij} Measures VAD in input supply sector j attributed to its use by sector i

$a_{ji} X_i$ As defined earlier measures the total (gross) value of intermediate input j used to produce the total value of output i (X_i)

V_j Denotes VAD in input supply sector j and hence (V_j / X_j) is the share of VAD in total (gross) value of output in the sector of origin j

Total VAD generated in all backward sectors supplying inputs to sector i (V_{iB}) is therefore derived as the sum of all the V_{ij}s (VAD in input supply sector j caused by its use in sector i)

$$V_{iB} = \sum_j V_{ij} = \sum_j a_{ji} X_i (V_j / X_j) \quad (4\text{-}4)$$

The production VAD multiplier is then calculated as:

V_{iT} / V_i Total VAD generated in the economy per unit VAD in sector i

The fact that all forward and backward activities have their own upstream and downstream linkages, makes the chain of indirect benefits realized elsewhere in the economy very long and difficult to entirely track down. As a result, some way of narrowing down the search for major components of indirect value addition was used.

Table 4.1: Estimates of agricultural multipliers in South Africa

Study/Source	Agriculture	Sugarcane	Citrus fruit	Sub-tropical fruit	Forestry	Sugar refining	Food processing	Wood products	Pulp and Paper
Production multipliers									
I-O Based	*1.49-2.13*	*1.28-1.61*	*1.625*	*1.33-1.50*	*1.42-2.15*	*1.21-2.43*	*1.26-2.73*	*1.52-2.17*	*1.5-2.09*
1988 RSA I-O Tables	1.49	NA	NA	NA	NA	1.21	1.26	1.52	1.5
1993 RSA I-O Tables	2.127	NA	NA	NA	NA	2.434	2.731	2.171	2.03
1995 RSA I-O Tables	1.846	1.611	NA	1.381	2.148	2.013	2.155	2.007	2.089
1996 RSA I-O Tables	1.822	1.423	1.625	1.331	1.524	2.262	2.337	1.94	2.08
Kirsten and van Zyl (1990)	1.863	NA	NA	NA	NA	NA	NA	NA	NA
Hassan (1998)	1.870	1.28	NA	1.500	1.42		NA	NA	NA
SAM Based									
1988 RSA SAM[1]	2.48	NA	NA	NA	NA	NA	3.39	3.18	3.04
Total SAM multipliers	*4.39-5.54*	3.46	NA	*NA*	*NA*	*5.06*	*5.44*	*5.38*	*5.24*
1988 RSA SAM[1]	4.39	NA	NA	NA	NA	5.06	5.44	5.38	5.24
Hassan (1998)	5.540	3.46	NA	5.84	NA	NA	NA	NA	NA
Other studies									
Woodhouse and Hassan (1999)	1.81	1.61	2.11	1.63	1.85	NA	NA	NA	NA
International Average[2]	1.26 – 2.88				1.12– 1.61		1.33– 1.98	1.42	1.53
Africa average[2]	1.48 – 2.88						1.33– 1.98		
Asia average[2]	1.64 – 1.82								

Sources: The 1988 and 1993 I-O and SAM tables are produced by Statistics South Africa (SSA, 1989 and 1995). The 1995 I-O table is compiled by WEFA (1995). The 1996 I-O tables have been compiled by Conningarth (1998b).
From Townsend and McDonald (1998)
From Appendix 3

The following criteria were used to focus the search on major segments of the chain of value:

- Backward linkages have been limited to only first level chains, e.g. suppliers of inputs to the primary sector only and to forward processing activities taken into account. That meant activities servicing industries supplying inputs to the primary sector are not traced further upstream (e.g. to sectors supplying inputs to the fertilizer industry).
- The forward sectors' chain has been mapped to the end product delivered for final consumption, e.g. traced through secondary and tertiary levels of processing.

Estimates of total economic benefits in production and VAD multipliers for the crops under study are presented and compared in section 4.3.

4.2.4 Total production benefits for perennial crops

While perennial crops (e.g. plantations and orchards) are harvested at maturity, which happens after few or many years after planting, they are typically managed in an optimal rotation where some level of output is harvested annually. Accordingly, this study considered two approaches to derive estimates of total annual benefits realized over the given crop rotation. The first is based on *annualized benefits*, which are derived by dividing the total yield over the production cycle by the length of the rotation in years to calculate average annual production. This approach does not account for the effect of timing of expenditures and receipts of benefits that usually do not occur concurrently and hence may yield biased estimates. The direction and magnitude of the bias depend on the nature and length of the production cycle. For example most timber production systems have long rotations where harvesting only happens at the end of the cycle compared to short and medium rotations where harvesting starts after few years and continues over the production cycle as in fruit crops. Sugarcane on the other hand, is harvested annually over a short rotation. The second alternative approach is the *net present value (NPV)* method, which calculates total economic benefits based on actual timing of cost outlays and receipt of revenue employing discounted cash flows of VAD over the entire crop rotation.

The NPV method, the most commonly used criteria to account for the timing of expenditures and returns over the life cycle of the enterprise is derived as follows:

$$NPV = \Sigma_{t=1}^{T} [P_t Q_t - C_t Q_t] / (1+r)^{t} \quad (4\text{-}5)$$

Where:

NPV = Present worth at the beginning of the stream of net benefits, e.g. gross returns minus variable costs, expected from the project or investment

P_t = Price per unit of output

Q_t = Quantity or units of output produced

C_t = Variable cost per unit of output

r = The discount rate

t = Time in years

T = The last (terminal) year (end of project or life cycle, e.g. rotation length)

Equation 4-5 discounts the stream of benefits from a project or activity to be realized in future years to its present worth (time when investment is made). Typical NPV calculations use either constant or nominal prices and either actual prices and costs over the entire production cycle (rotation length) or projections of future price and cost trends based on their observed past behavior. This last mentioned approach is mainly due to lack of information about the future. Both approximations have limitations. While computationally convenient, the constant prices method assumes that prices and costs (e.g. prices of products and inputs) remain unchanged over the entire production cycle. Similarly, the price trends forecasting method assumes that future prices and costs will follow the same patterns of the past. These are considered very strong assumptions given the fact that results of NPV analyses are highly sensitive to movements in relative prices and shifts in production costs. Also constant pricing typically discriminates against longer production cycles as values at present prices to be received in a relatively distant future become increasingly smaller with discounting as the cycle gets longer. This is of particular importance to our study considering the long rotation cycle of some of the enterprises under study (e.g. 30 years for pine to mature for saw log purposes).

In light of the said limitations of the NPV analysis and the fact that almost all cultivated tree crops (for fruit or timber) are typically managed in optimal rotations in South Africa led to the decision to adopt the *annualized benefits* (AB) approach[4]. In such optimally managed production systems a relatively stable total harvest is taken every year. In other words, part of the plantation is always at maturity and ready for harvesting in the case of both, timber or fruit bearing crops. It is important however, to note that the AB approach adopted in this study corrects for variation in yield or growth with age or maturity. As said earlier, average yield over the production cycle rather than yield at mature age is used in this case as the measure of annual production.

[4] The study research team presented results of both approaches to the project steering committee meeting of April 2000 in which the steering committee recommended following the AB method.

4.3 RESULTS OF ECONOMIC IMPACT ASSESSMENT

4.3.1 Forestry

Apart from limited thinning during sawlog rotations, timber is usually harvested at the end of the production cycle when it is mature. Due to the fact that all cultivated timber plantations in South Africa are managed in balanced rotations, the mean annual increment (MAI), which estimates average annual growth of trees, is assumed available for harvesting from the plantation. This does not mean that young immature trees are felled for sale, but rather part of the optimally balanced rotation of the plantation is mature for harvesting to provide for that MAI. Estimates of average annualized yield (MAI), production costs and timber prices have been used to derive annual direct and indirect benefits and multipliers for plantation forestry.

Two main tree species (pine and gum) and two main production systems (pulp and sawlog rotations) characterize the bulk of forest plantations in South Africa. This study analyzed the two species in their two rotations using data representing the Mpumalanga province, where the Crocodile catchment is located. The Forest Economic Services (FES) is the main source of data on forest plantations' yields and production costs. FES, however, publishes its statistics based on annual average estimates of production costs and revenues for an average plantation by species, e.g. not by production system, although some information on shares of the two products (pulp versus sawlog) in total sales is provided. Therefore, the present analysis considered average plantation regimes (e.g. pine and gum for mixed pulp and sawlog)[5].

Tables 4.2 and 4.3, respectively derive the direct and indirect annualized benefits in terms of VAD and employment from plantation forestry using the additive semi I-O method presented in section 4.2.3.1 above. Indirect economic benefits from forest plantations represent VAD realized in input supply and timber processing industries up and down stream. A product and input flow chart showing the forward and backward linkages in forest products industry is presented in Appendix 4. Appendix 4A shows that about 76% (37.7%+22.5%+15.7%) of the timber harvested in Mpumalanga province end up at saw and pulp mills (equally shared by the two). Another 17% go to mining timber mills and the rest of the timber goes to poles (2.2%) and charcoal manufacturing (2.6%) and other uses (2.4%). Therefore, VAD generated in those timber-based economic activities is considered an indirect benefit of timber farming.

4.3.1.1 VAD benefits from forest plantations

The highest VAD directly generated in the sector ***per m^3 intake of round wood logs*** is realized in the furniture and wood products (F&WP) from sawn logs (R 760) followed by the pulp and paper (P&P)

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[5] Regimes distinguishing species grown for the two different end products were considered separately (e.g. pine for pulp, pine for sawlog, etc.) in deriving net present value over the crop rotation.

sector (R 596) (Table 4.2). Lowest direct benefits are found in the charcoal manufacturing (R 24), primary production sectors (plantations) and mining timber (R 87). Boards (R 219) and poles (R 193) manufacturing show an intermediate position.

When indirect economic benefits are accounted for, growing timber for F&WP gave the highest total (direct and indirect) VAD (R 1,433) in the forestry chain with timber grown for P&P trailing slightly behind (R 1131). In addition to the R 760 directly generated in F&WP per m^3 of timber harvested from plantations, this sector indirectly generates VAD in the magnitude of R 673/m^3 timber, which is 0.89 times its direct contribution to gross domestic product (GDP measured as VAD). The total VAD multiplier of 1.89 of the F&WP sector implies that for every Rand of VAD directly generated in the sector, an additional benefit of R 0.89 VAD is realized in other spheres of economic activity supporting the delivery of F&WP for final use. Total VAD production multipliers estimated by this study ranged between 1.49 to 2.88 (Table 4.2) and almost all of them are at the upper end of respective international and national production multiplier estimates derived by other studies (Table 4.1). Since this study calculated only production multipliers, its estimates were lower than corresponding multipliers based on SAM frameworks that take into account production as well as consumption effects.

As mentioned earlier total VAD benefits are derived additively down the backward chain. The following section uses the F&WP and the P&P products as examples to illustrate the additive calculation of total VAD based on Table 4.2 data.

VAD chain of furniture and wood products: Total VAD for each activity is calculated based on how much further processing of its product takes place downstream. The following are examples of how VAD in Table 2 is aggregated through the value chain.

1. Total VAD in primary (gum plantations)

Direct VAD in sector	76.35
Indirect VAD in input supply sectors	56.23
Total VAD	132.58

Gives a total multiplier of R 1.74 per R of direct VAD in plantations

2. Total VAD in saw milling (sawn logs)

Direct VAD in saw milling	147.71
Indirect VAD in non-timber input supply	26.61

Indirect VAD in logs used = 79.64 * 1.615[6]	128.62
Total VAD	302.94

Giving a total multiplier of R2.05 per R of direct VAD in saw milling

3. Total VAD in F&WP

a. Direct VAD in F&WP	760.00
b. Indirect VAD in non-timber input supply to F&WP	18.92
c. Indirect VAD in saw milling (318.92) * total multiplier of direct VAD of saw milling (R2.05 per R)	654.14
Total VAD	1433.38

Giving a total multiplier of R 1.89 per R of direct VAD in F&WP.

The same applied for all other forestry activities.

The total VAD ***per m^3 of water used*** in the primary sector (plantations)[7] was calculated to be highest in F&WP processing followed by P&P (Table 4.2). Growing timber for F&WP generated R36.9 of total VAD per m^3 of water used in plantations, which amounts to more than R 36,891 total VAD per ha of timber (considering an average of 1000 m^3 water abstraction per ha in the primary sector). **The high total benefits from F&WP compared to other timber processing activities is attributed to the fact that there are more stages in the F&WP manufacturing process each adding incremental layers of further value beyond milling into the tertiary processing activities.** Total benefits from forest plantations in Mpumalanga were then calculated using total VAD estimates for the various final products weighted by the share of each product in final sales of timber out of plantations (Table 4.2). Pine plantations generated VAD of R32.1/m^3 of water used at 1998 prices compared to the VAD of only R19.9/m^3 water used by gum plantations. The difference is due to the higher share proportion (59%) of timber from pine plantations sold for saw milling, and hence proceeding to the high value F&WP. By contrast, saw milling sales from gum plantations account for only 22% of gum production. Also, more than 33% of the gum plantations' harvest was processed as mining timber, which generates a much lower total VAD of only R6.8/m^3 water. The VAD of R32.1/m^3 water used in pine plantations is equivalent to a total VAD of R32,060/ha of pine (assuming the average water use of 1000 m^3/ha). Total VAD from pine is much higher than the average direct VAD of R 1187/ha of pine derived based on an average MAI (mean annual increment) of 15.00 m^3/ha, i.e. 15*R 79/ha). This

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[6] Note that 1.615 is the average total multiplier of pine and gum plantations (Table 2)

[7] Note that we still missing data on water use in forward and backward sectors and hence only water abstracted by plantations was used to derive VAD per unit water.

translates into a large total VAD multiplier for pine of 27.2[8] directly obtained from pine farming compared to a total VAD multiplier of only 13.2 for gum (assuming an average MAI of 19.76 m^3/ha). This is mostly due to the high value adding component of furniture manufacturing in the Pine value chain.

4.3.1.2 Employment benefits from forest plantations

Table 4.3 shows that F&WP is the most labor-intensive timber processing activity giving the highest direct employment in terms of man-days (MD) per m^3 timber (2.5) followed by the P&P (1.63). Lowest direct demand for labor is found in charcoal manufacturing (0.39). Growing timber for F&WP also gave the highest total employment demand of 8.08 MD/ m^3 timber with a total job multiplier of 3.23 compared to multipliers of 3.28 and 2.48 for P&P and board manufacturing, respectively[9]. The weighted average total demand for jobs for pine plantations was estimated to be 0.172 MD/m^3 water used compared to only 0.113 for gum plantations (Table 4.3). This means that total employment benefits from cultivation of pine in Mpumalanga amounts to 172 MD/ha, which is equivalent to 0.688 full-time job/ha of pine[10]. Similarly, total employment generated by gum plantations amounts to 0.454 jobs/ha. Given total areas under pine and gum in the province, these estimates indicate that forest plantations (based on 550 498ha afforested in 1998 (DWAF, 2000d) in Mpumalanga contribute to about 214,300 full-time jobs employed directly in plantations and timber processing sectors and indirectly in other input-supply sectors throughout the economy. Using this study's estimates to extrapolate to the national level gives an aggregate national employment figure of more than 790,000 jobs directly and indirectly attributed to forestry (at an average of 0.571 full-time jobs/ha). This estimate is much higher than national employment estimates in the forestry sector provided by the 1997 LHA study (111,550 jobs) and the 1995 labor survey (258,919 jobs) cited in Jaakko Poyry (1999) study. However, neither of the mentioned studies considered indirect employment in other economic activities linked to the forestry sector (i.e. sectors supplying inputs to plantations or processing timber products).

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8 Note that the weighted average forward multiplier of 17.91 of pine plantations is equivalent to a backward multiplier of 1.89 of F&WP with a direct VAD base of R 760/m^3 timber, which is about ten times the low pine plantation direct VAD base of only R 79/m^3 timber.

9 Total employment benefits and job multipliers were calculated the same way as total VAD and multipliers described earlier (Table 2).

10 Based on 250 MD per man year as a proxy of a full-time job.

4.3.2 Sugarcane

Sugarcane farming is an important activity in South Africa. About 420,000 ha were under sugarcane production during the 1997/98 season, out of which about 300,000 ha were harvested for milling (SASA, 2000a). The sugar industry in South Africa is a vertically integrated economic activity involving milling, refining and packaging and distribution to industrial users and to final direct consumption. In 1998, 33.7% of the 2.3 million tons of sugar produced in the country was sold to industrial users and the rest (66.3%) sold for direct consumption (SASA, 2000a). About 14% (3030372 ton cane) of the total cane crushed in the country in 1998 was milled in the Melalane and Komati mills of the Mpumalanga province. This supported the production of more than 273,000 tons of refined sugar and significant volumes of raw sugar, molasses and bagasse for further processing within and outside the province (TSB, 1999).

The chain of down and upstream value addition activities of the integrated sugar industry in Mpumalanga is depicted in Appendix 5. While sugarcane is also a perennial crop, unlike cultivated forests and most fruit trees, the cane crop reaches maturity in one year and gives an annual harvest from year two. Accordingly, actual annual cane harvests are used to derive the annualized benefits measure described above. After leaving the farm, sugarcane is crushed, refined and distributed to industrial users and final consumers. In this process, the sugar industry uses many intermediate inputs from other industries to process the raw cane, raw sugar, bagasse and molasses into various final products. Refined sugar, animal feed and boards are the main products of cane processing (Appendix 5).

Sugarcane is also a major user of water for irrigation in the Crocodile catchment and hence a true competitor to plantations and other high value water using crops such as the irrigated fruit tree crops. Data used for measuring the flow of VAD and employment benefits in the sugar industry were collected from various sources. The major source of data was the published and unpublished statistics of the Mpumalanga sugar industry on cultivation, milling and further processing of the cane crop (TSB; SACGA; Molatek). Other pieces of information have also been collected from regional and national sources (Conningarth, 1998b; SSA various issues) to support the analysis. More details on the data sources for the sugar sector are given in Appendix 6.

4.3.2.1 VAD benefits from sugarcane

VAD benefits for the sugar industry were calculated using the same procedure followed for forestry in the previous section. Table 4.4 summarizes the results of the VAD analysis. The highest direct VAD per ton cane (R 882.00) was realized in industrial uses of refined sugar (food, beverages, chocolate and confectioneries processing). Cane farming gave the second highest direct VAD (R 75.00) followed by sugar refining (R 36.87) and feed manufacturing (R 27.70) per ton of cane crushed. The transport activity for sugar, which shows the lowest VAD represents a self provided transport service integrated within the industry.

When total VAD was derived, sugar refining and milling naturally added more value than the primary farming operation. The VAD multipliers' results showed that sugar milling generates an additional VAD of R 8.70 in backward linkages for every extra Rand directly generated in the sector itself compared to only R6.70 in sugar refining. The higher multiplier of milling compared to refining is due to the smaller base value of direct VAD generated in the milling activity (R 16.23) compared to a direct VAD base in refining of R 36.87. The same can be said about the higher multipliers of feed manufacturing and transport activities when compared to sugar farming.

Aggregation of VAD to arrive at total VAD for all sugar activities follows the same framework used for forestry as described above. An illustrative example is given in Appendix 4 (Figure 2).

Total value added for the sugar industry is calculated to equal the sum of total VAD in sugar refining (which automatically includes sugar milling and cane farming in its backward), feed and board manufacturing and transport activities. A weighted share of VAD generated in the food and beverages processing was attributed to industrial use of refined sugar based on the 33.7% ratio in Mpumalanga mentioned earlier. Total VAD in the sugar sector was accordingly calculated to be R 814.7 per ton cane crushed. This is equivalent to R 9.9 per m^3 water used in the primary cane farming activity[11] and R 85,226 per ha of sugarcane.

4.3.2.2 Employment benefits from sugarcane.

As in the case of forestry, employment benefits for the sugar sector were calculated in terms of man-days (MDs) (Table 4.5). Industrial use of refined sugar showed the highest direct employment in terms of MD/ton cane produced (3.1 MD) followed by sugar farming (0.17 MD), milling (0.081 MD) and refining (0.046 MD). When indirect demand for labor was taken into account, sugar refining, milling and board manufacturing dominated sugar farming as total employment benefits rose to 2.14 MD, 1.23 MD and 0.89 MD per ton cane in refining, milling and board manufacturing, respectively, compared to 0.6 MD in sugar farming. This is consistent with the fact that total benefits from refining and milling cane include benefits from farming as a backward sector supplying raw cane inputs for processing. Using a weighted share of total employment in industrial use of refined sugar (food and beverage processing), total employment for the sugar sector was calculated to be 3.58 MD/ton cane, which gave 0.044 MD per m3 water used for irrigating sugarcane (primary sector water use).

[11] Based on net irrigation.

The above estimates suggest that total employment benefits (direct and indirect) from the sugar industry amount to about 1.02 full-time jobs per ha[12]. Based on total tonnage of cane harvested and processed in 1998 (22,93 million ton), the above results suggest that the sugar industry employed more than 300,000 full-time jobs directly in sugar farming and indirectly in milling, refining and various other down and upstream activities linked to sugar production. This estimate of total employment benefits (direct and indirect) is about 27% higher than the South Africa Sugar Association (SASA) estimate of 240,000 people in direct and indirect employment in the sugar industry (SASA, 2000a).

4.3.3 Sub-tropical fruits

Total economic benefits from water use by the five main sub-tropical fruit crops grown in the Crocodile catchment: grapefruit, oranges, mangos, avocados and bananas are derived in this study. Like timber, fruit trees are managed in optimal rotations allowing for regular annual harvest of mature produce. Accordingly, the same annualised benefits method has been also applied to the fruit tree crops. However, similar to the case of plantation forestry, yields and costs used in the analysis represent the average over the entire production cycle and not at maturity. In addition to the detailed crop budgets provided by the COMBUD (DA-Mpumalanga, 1999), farmers' surveys have been conducted in the study area during the year 2000 to collect primary information on the costs of and returns to production of sub-tropical fruits. In the said surveys primary information on post-harvest activities of fruits for export and local markets (packaging, transport and processing) have also been gathered to trace value addition downstream. However, the bulk of fruit is exported or sold fresh in local markets. Only about 15% of the grapefruit and oranges and 5% of the mango harvests receive further processing mainly into juices and canned food (NDA, 1999). Approximately 12% of the avocado crop is processed (oil and guacamole).

4.3.3.1 VAD benefits from sub-tropical fruits

The same procedure used for deriving annualised direct and indirect VAD benefits for forestry and sugarcane was followed in the case of fruits. The results are presented in Table 4.6. Avocados generated the highest direct VAD in 1998 followed by mangos and bananas, with citrus fruits (grapefruits and oranges) ranking lowest. Fruit processing gave the second highest direct VAD. Total VAD benefits were again highest in avocado and mango fruits production generating R1805 and R1755/ton fruit. Fruit processing gave higher total VAD than the rest and banana production dominated citrus fruits. However, when corrected for the amount of water used by the different crops

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[12] Based on an average yield of 71.35 ton cane/ha harvested in 1998 (SASA, 2000) and 250 MD per man year as a proxy to a full-time job.

and processing values, the highest total VAD per m^3 water used in the primary farming activity was obtained under mango production (R8.91) followed by oranges (R6.55) and grapefruits (R4.94). While avocados and bananas dominated citrus fruits in direct and total VAD per ton fruit, the position of citrus improved when indirect VAD in processing was accounted for (note that bananas undergo no further processing). Due to the lower level of water use in citrus crops, they were superior to banana and avocados in terms of total VAD per unit water used at the farm level.

4.3.3.2 Employment benefits from sub-tropical fruits.

The highest number of directly employed MDs per ton fruit was in fruit processing. Among fruit crops mango directly employed more people (4.04 MD) than the rest, which all require less than 3 MD/ton fruit (Table 7.1). With indirect employment benefits accounted for, mangos and citrus crops generated the highest total employment benefits per m^3 water used to irrigate the tree crops. Using this study estimate of total employment benefits from the compared fruit crops and areas cultivated to the respective crops in the Mpumalanga province, one arrives at the total number of full-time jobs of in subtropical fruits in the province[13].

4.4 SUMMARY

The direct VAD/water use multipliers (in Rand/m^3) for the different land uses were 1.8 for pine and 2.6 for eucalypt plantations; 1.3 for sugarcane farming and varied between 3.2 (bananas) and 8.7 (mangoes) for sub-tropical fruits. According to these figures, sub-tropical fruit production appears to be most productive land use in terms of water consumption. However, when the indirect economic impacts were evaluated, the total forestry value chain had VAD/water use multipliers of 19.9 and 32.1 R/m^3 for eucalypt and pine forestry respectively (ranging between 1.8 for charcoal and 36.9 for F&WP (furniture and wood products)); the sugarcane value chain had a multiplier of 9.91 R/m^3 (ranging between 0.2 (board manufacturing) and 19.7 (food and beverages)); while the fruit value adding activities had multipliers ranging between 3.2 R/m^3 (bananas) and 8.9 R/m^3 (mangoes). Similar trends are evident from the employment multiplier results. (Tables 4.2-4.7.) Forestry has a long value chain in the Mpumalanga province, and therefore the multiplier effect of forestry in its indirect activities is high. Fruit processing, on the other hand, has shorter value chains, and while the direct value added component of these industries were larger than for sugar and forestry, their indirect value adding effects were limited. These results show the consideration indirect economic impacts therefore need to be considered in water allocation decision-making. The multiplier value is also very sensitive to the

[13] Based on 250 MD per man year as a proxy to a full-time job.

number and type of industries included in the value chain analysis. In the case of the forestry value chain, the high value addition in the F&WP and Pulp & Paper activities has a very large influence on the total VAD/water use value for forestry.

Table 4.2: Total value added in forestry in R/m^3 Logs and m^3 water (Mpumalanga 1998 prices)

	Gum Plantations	Pine Plantations	Saw Milling	Mining Timber	Poles	Charcoal	Boards	Pulp and Paper	Furniture and Wood Products
VAD in sector (R/m^3 round wood logs)	**76.35**	**79.00**	**147.71**	**86.78**	**193.49**	**24.00**	**218.74**	**596.36**	**760.00**
VAD in backward chain (R/m^3 logs)									
Sawn logs									318.92
Round wood/chips			79.64	95.28	73.66	27.7	61.65	199.86	
Other backward sectors	56.23	39.05	26.61	9.59	102.27	0.43	206.19	211.93	18.92
VAD multipliers (R/R VAD of sector)									
VAD multiplier for logs only			1.54	2.10	1.38	2.15	1.28	1.34	1.42
VAD multiplier for other backward sectors	1.74	1.49	1.18	1.11	1.53	1.02	1.94	1.36	1.02
VAD multiplier for logs and other sectors	1.74	1.49	1.72	2.21	1.91	2.17	2.22	1.69	1.44
Total VAD in chain (R/m^3 logs)	132.58	118.05	302.97	261.82	414.75	69.18	524.52	1131.06	1433.37
Total VAD multiplier (R/R VAD of sector)	1.74	1.49	2.05	3.02	2.14	2.88	2.40	1.90	1.68
Water use in primary sector (m^3/m^3 logs)	39.6	38.1							
Total VAD in R/m^3 water in primary sector	**3.4**	**3.1**	**7.8**	**6.6**	**10.7**	**1.8**	**13.5**	**29.1**	**36.9**
Weighted average for pine plantations[a]		24.1							
Weighted average for gum plantations[a]	15.6								

Source: This data is the result of the modelling done as described in this Chapter.

[a] Weighted by the proportion of each of the respective products in the product mix based on shares of tons sold from each plantation in 1996 (FES, 1996).

Table 4.3: Total employment benefits in forestry (Number of full-time jobs in mandays (MD)/m^3 logs and m^3 water

	Gum Plantations	Pine Plantations	Saw Milling	Mining Timber	Poles	Charcoal	Boards	Pulp and Paper	Furniture and Wood Products
VAD in sector (R/m^3 logs)	**76.35**	**79.00**	**147.71**	**86.78**	**193.49**	**24.00**	**218.74**	**596.36**	**760.00**
Direct employment in sector (MD/m^3 logs)	**0.62**	**0.45**	**1.05**	**0.75**	**1.15**	**0.39**	**1.46**	**1.63**	**2.5**
Employment in backward chain (MD/m^3 logs)									
Sawn logs									2.267
Round wood/chips			0.550	0.658	0.509	0.191	1.141	1.381	
Other backward sectors	0.891	0.598	0.218	0.134	0.640	0.022	0.426	0.430	0.030
VAD multipliers (MD/MD of sector)									
VAD multiplier for logs only			1.52	1.88	1.44	1.49	1.29	1.85	1.91
VAD multiplier for other backward sectors	2.44	2.33	1.21	1.18	1.56	1.06	1.78	1.26	1.01
VAD multiplier for logs and other sectors	2.44	2.33	1.73	2.06	2.00	1.55	2.07	2.11	1.92
Total employment in chain (MD/m^3 logs)	1.51	1.05	2.58	2.45	3.00	0.87	3.62	5.35	8.08
Total employment multiplier (MD/MD)	2.44	2.33	2.46	3.27	2.61	2.22	2.48	3.28	3.23
Water use in primary sector (m^3/m^3 logs)	38.6	64.7							
Total employment in MD/m^3 water in primary sector	**0.04**	**0.03**	**0.07**	**0.06**	**0.1**	**0.02**	**0.1**	**0.1**	**0.2**
Weighted average for pine plantations[a]		0.172							
Weighted average for gum plantations[a]	0.113								

Source: This data is the result of the modelling done as described in this Chapter.

[a] Weighted by the proportion of each of the respective products in the product mix based on shares of tons sold from each plantation in 1996 (FES, 1996).

Table 4.4. Total value added in sugarcane in R/ton cane and R/m3 water (Mpumalanga 1998 prices)

	Sugar Farming	Sugar Milling	Sugar Refining	Sugar Transport	Feed Manufacturing	Board Manufacturing	Food and Beverages
Direct VAD in sector (R/ton cane)	**75.90**	**16.23**	**36.87**	**7.44**	**27.65**	**11.35**	**882.71**
VAD in backward chain (R/ton cane)							
Raw cane		75.9					
Raw sugar			22.92				
Refined sugar							19.57
Baggase					1.76	1.03	
Molasses					2.26		
Other backward sectors	26.95	22.27	10.98	3.92	8.48	8.00	587
Total VAD multipliers (R/R VAD in sector)	**1.36**	**7.05**	**1.92**	**1.53**	**1.45**	**1.80**	**1.69**
Multiplier Level 1 (Other backward sectors)		1.36	0.30	0.53	0.31	0.70	0.66
Multiplier Level 2 (Cane intermediate		4.68	0.62		0.15	0.09	0.02
Total VAD in chain (R/ton cane)	102.85	141.35	247.46	11.36	40.20	20.38	1620.63
Total VAD multiplier (R/R)	1.36	8.71	6.71	1.53	1.45	1.80	1.84
Water use in primary sector (m^3/ton cane)	82.2						
Total VAD in R/m^3 water in primary sector	**1.3**	**1.7**	**3**	**0.1**	**0.5**	**0.2**	**19.7**
Total VAD for industry in R/ton cane	814.701						
Total VAD for industry in R/m^3 primary	9.91						

Source: This data is the result of the modelling done as described in this Chapter.

Water use based on 8600 m^3 per ha per annum and 104.6 ton cane per ha yield (SACGA, 1998)

Table 4.5: Total Employment in Sugar (full-time jobs in man-days (MD) per ton cane and per m^3 water (Mpumalanga, 1998)

	Sugar Farming	Sugar Milling	Sugar Refining	Sugar Transport	Feed Manufacturing	Board Manufacturing	Food and Beverage Processing
Direct VAD in sector (R/ton cane)	75.9	16.23	36.87	7.44	27.65	11.35	882.71
Direct employment in sector (MD/ton cane)	1.03	0.081	0.046	0.011	0.027	0.037	3.1
Raw cane		1.03					
Raw sugar			0.11				
Refined sugar							0.069
Baggase					0.002	0.003	
Molasses					0.002		
Other backward sectors	0.43	0.55	0.36	0.11	0.37	0.85	0.80
Total employment multipliers (MD/MD) in	1.42	20.49	11.32	11.06	14.86	24.12	1.28
Multiplier Level 1 (Other backward sectors)		7.78	8.83	11.06	14.72	24.03	1.26
Multiplier Level 2 (Cane intermediate products)		12.72	2.49		0.15	0.09	0.02
Total employment in chain (MD/ton cane)	1.46	2.09	3.36	0.12	0.04	0.89	11.03
Total employment multiplier (MD/MD)	1.42	25.80	72.96	11.06	14.87	24.12	3.56
Water use in primary sector (m^3/ton cane)	82.2						
Total employment in MD/m^3 water in primary	0.018	0.025	0.041	0.001	0.005	0.011	0.134
Total employment for industry in MD/ton cane	19.355						
Total employment for industry in MD/m^3 primary	0.2355						

Source: This data is the result of the modelling done as described in this Chapter.

Water use based on 8600 m^3 per ha per annum and 104.6 ton cane per ha yield (SACGA, 1998)

Table 4.6: Total value added in Fruits in R/ton fruit and R/m^3 water (Mpumalanga 1998 prices)

	Avocados Fresh Fruit	Mango Fruit	Mango Processing	Orange Fruit	Orange Processing	Grapefruit Fruit	Grapefruit Processing	Banana Fruit
VAD in sector (R/ton fruit)	**917.60**	**553.60**	**650.00**	**264.44**	**650.00**	**282.23**	**650.00**	**420.66**
VAD in forward/backward chains (R/ton fruit)								
Farm/Fruit			76.05		76.05		76.05	
Packaging/Marketing	646.16	1000		378.05		393.82		382.77
Other backward sectors	241.39	201.46	497.25	87.53	497.25	91.26	497.25	242.8
VAD multipliers (R/R VAD of sector)								
VAD multiplier (farm only)	1.00	1.00	1.12	1.00	1.12	1.00	1.12	1.00
VAD multiplier packaging/marketing (forward)	1.70	2.81	1.00	2.43	1.00	2.40	1.00	1.91
VAD multiplier in backward chain	1.26	1.36	1.77	1.33	1.77	1.32	1.77	1.58
Total VAD multiplier	1.97	3.17	1.88	2.76	1.88	2.72	1.88	2.49
Total VAD in chain (R/ton)	1805.15	1755.06	1388.35	730.02	1357.20	767.31	1354.01	1046.23
Water use in primary sector (m^3/ton)	528.3	200.7	200.7	137.8	137.8	190.27	190.27	330
Total VAD in R/m^3 water in primary sector	**3.4**	**8.7**	**6.9**	**5.3**	**9.8**	**4.0**	**7.1**	**3.2**
Total VAD including processing in R		**1787.56**		**902.11**		**939.40**		
Total VAD including processing in R/m^3	**3.4**	**8.9**		**6.6**		**4.9**		**3.2**

Source: This data is the result of the modelling done as described in this Chapter.

Table 4.7: Total employment in Fruits (Number of full-time jobs in man-days (MD)/ton fruit and MD/m^3 water)

	Avocados Fresh Fruit	Mango Fruit	Mango Processing	Orange Fruit	Orange Processing	Grapefruit Fruit	Grapefruit Processing	Banana Fruit
VAD in sector (R/ton fruit)	**917.60**	**553.60**	**650.00**	**264.44**	**650.00**	**282.23**	**650.00**	**420.66**
Direct employment in sector (man days/ton	**2.67**	**4.04**	**4.88**	**2.42**	**4.88**	**2.37**	**4.88**	**2.14**
Employment in backward chain (MD/ton fruit)								
Farm/Fruit			0.55		0.70		0.64	
Packaging/Marketing	0.85	2.19		1.73		1.69		1.10
Other backward sectors	0.32	0.44	0.93	0.40	0.93	0.39	0.93	0.70
Employment multipliers (MD/MD of sector)								
Multiplier (farm only)	1.00	1.00	1.11	1.00	1.14	1.00	1.13	1.00
Multiplier packaging/marketing (forward)	1.32	1.54	1.00	1.71	1.00	1.71	1.00	1.51
Multiplier in backward chain	1.12	1.11	1.19	1.17	1.19	1.17	1.19	1.33
Total multiplier	1.44	1.65	1.30	1.88	1.33	1.88	1.32	1.84
Total employment in chain (MD/ton fruit)	3.84	6.67	6.72	4.55	7.11	4.45	7.00	3.94
Total employment multiplier (MD/MD)	1.44	1.65	1.38	1.88	1.46	1.88	1.44	1.84
Water use in primary sector (m^3/ton fruit)	528.3	200.7	200.7	137.8	137.8	190.27	190.27	330
Total employment in MD/m^3 water in primary	**0.01**	**0.03**	**0.03**	**0.03**	**0.05**	**0.02**	**0.04**	**0.01**
Total employment incl processing (MD/ton fruit)		**7.45**		**5.42**		**5.32**		
Total employment incl processing in (MD/m^3 water)		**0.04**		**0.04**		**0.03**		

Source: This data is the result of the modelling done as described in this Chapter.

CHAPTER 5:

ENVIRONMENTAL IMPACT ANALYSIS

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5.1 INTRODUCTION

This Chapter deals with the environmental impacts of the different crops and their associated value chains. The approach is explained, refinements to the water use model developed in the previous study (Olbrich & Hassan, 1999) are discussed, where after qualitative and quantitative aspects of the environmental impact analysis are discussed.

Environmental impact analyses may have varied focus areas, and follow different methodologies. On the one hand Environmental Impact Assessments (EIA), focuses on participative governance. Scientific environmental impact analyses, on the other hand, may focus on specific species, river systems, or ecosystems or other environmental impacts. For the purposes of this study, it was decided to follow a generalist approach often used in environmental economic applications.

5.2 METHOD

5.2.1 The concept of environmental impact analysis

The goal of this analysis was to enable direct and indirect environmental impact comparisons of the different land uses and their value chains. An environmental impact analysis is data intensive and can be done in a four phase modeling process where, firstly, emission factors are quantified, secondly, dosage models are developed, thirdly, the response of the environment is determined and finally, the environmental impact is quantified. In the first phase, emissions and resource use are identified and quantified. In the second phase, environmental variables related to transpiration, and air and water flow are used to model the dosage effect of emissions and resource use on humans and ecosystems. In the third phase, the response of humans and ecosystems to emission dosages are quantified in terms of changes in risk profiles, abatement costs, productivity or other relevant measures. The third phase results quantify the environmental externalities of emissions & resource use, to which a fourth phase, involving environmental economic techniques may be added. The goal of this, the final phase of the analysis, is to convert the environmental impacts to monetary values, with the ultimate purpose of informing policies (mostly subsidies, trading systems, or taxes) on how to best internalize them into the formal economic system.

The data requirements of environmental impact analysis grow progressively more site specific through the first three phases. There is also a progressively larger influence of management variables on the outcomes of the modeling.

This study was only concerned with quantifying emission factors and modeling dosage (Phases 1 and 2) at a provincial level for Mpumalanga. Although an extensive list of emissions was identified, data limitations prevented the list from being comprehensive. Some of the more important emission factors for which data was not available, were therefore dealt with in a descriptive manner.

5.2.2 Environmental impacts and their structure

Work done by the ERE Group at the CSIR has shown that environmental impacts can be classified into three frameworks: a production framework, an ecological framework or a sustainability framework. The ***production structure*** follows the methodology of conventional life-cycle analyses, and groups environmental impacts based on two criteria: raw materials acquisition and manufacturing. The former specifically includes all aspects related to the direct extraction or use of raw materials such as water, soil, biodiversity and air. The latter incorporates all aspects involved in the transforming of energy and raw materials into products such as transportation, equipment, chemicals, energy and fuel and water. The ***ecological structure*** classifies environmental impacts into the four categories that constitute the natural environment. These are the lithosphere (soil components); the biosphere (biological diversity); the hydrosphere (water) and the atmosphere (air). The ***sustainability structure*** classifies environmental impacts into ***sources*** (providers of materials and inputs), ***sinks*** (accumulators of waste and pollutants) and ***services***. For the purposes of this study, the sustainability structure was selected.

For the identification of specific environmental impacts, an approach similar to conventional Environmental Impacts Analyses (EIA's) was followed. For the purposes of this study, the Department of Environmental Affairs, EIA practitioners and literature were consulted to identify environmental impacts. Thirty-two environmental impacts were selected and modeled. These impacts are shown in Table 5.1.

The ***Source Impacts*** included electricity, energy, and various soil and water impacts. Electricity use is the use of electricity in kW-hr. Energy use included electricity use and other fuels, such as petrol, diesel, coal, wood and bagasse. Soil impacts were broken down into the main fertiliser classes, and estimated the usage of fertilizers, the usage of soil nutrients to support each value chain. Water impacts were broken down into five categories: precipitation use, incremental water use, water intake from water supply sectors other than irrigation schemes, recycled water and discharged water. Incremental water use was defined as the so-called stream flow reduction due to forestry and the irrigation water use of agriculture (sub-tropical fruits and sugarcane). The combination of Precipitation use and Incremental water use were defined as the total primary water use. The Industrial Water Use is the water used in the secondary and tertiary activities in the value chain, hence values for intake water were zero for the primary land-use activities and precipitation and incremental values were zero for the other activities.

The ***Sink Impacts*** included solid waste generated, water pollution and air emissions. Solid Waste included dust, sludges and other waste that required land filling. Although river water quality monitoring and research programmes are in place for the study area, only limited data on point-source water emissions for the various value chain activities was found. The two emission factors used were Biological Oxygen Demand (BOD) and Total Suspended Solids (TSS). BOD and TSS are both indicators of water pollution levels, the former describes the level of organic pollution in a water system and the latter describes the levels of non-dissolved solids that are found in the water system. The direct impacts of these indicators are however, not measured and explained in this study. Air emissions included all the major emissions that contribute to local pollution (SO_2, CO, NO_2, VOC, Lead, PM10) and greenhouse gas effects (GWP, CO_2, CH_4, N_2O, CFCs).

Two forms of environmental services were identified. These two ***Service Impacts*** included carbon sequestration and biosphere functioning. Carbon sequestration is becoming increasingly prominent in the forestry sector particularly in light of carbon trading initiatives. Biodiversity functioning is a complicated ecological system where data is often qualitative rather than quantitative. Included in the biosphere component is biodiversity, a term used to describe the number, variety and variability of living organisms with respect to genes, species and ecosystems (Brown *et al.,* 1993:8). Biodiversity is critical for maintaining the resilience of ecosystems allowing them to respond to changes induced by economic activity. The resilience of ecosystems refers to the capacity of an ecosystem to maintain its characteristic patterns and rates of processes such as primary productivity in response to environmental conditions. Therefore, the more diverse a system, the greater its ability to withstand shocks and stresses (Khan, 1995:360). Key biodiversity concepts identified were linked to the national indicator priorities for South Africa. Table 5.2 identifies the respective biophysical issues. Most of these types of data are extremely site specific, complex to evaluate, and not easily available. Therefore, the approach taken here was to analyse the total natural and riparian area under conservation/management.

Table 5.1: Environmental emissions & resource uses investigated.

Source			
1	Soil	Nitrogenous substances	MT
2		Ammonium nitrate substances	MT
3		Ammonium sulfate substances	MT
4		Organic substances	MT
5		Phosphatic substances	MT
6		Super phosphates substances	MT
7		Mixed substances	MT
8	Electricity	Electricity use	MkW-h
9	Energy	Energy use	MJ
10	Water	Precipitation use	m^3
11		Incremental water use (tree and crop water use)	m^3
12		Industrial water use (water supply system)	m^3
13		Water recycled/reused	m^3
14		Water discharged	m^3
Sink			
15	Solid Waste	Generated	MT
16		Managed	MT
17		Shipped	MT
18	Water pollution	Biological oxygen demand	MT
19		Total suspended solids	MT
20	Air emissions	SO_2	MT
21		CO	MT
22		NO_2	MT
23		VOC	MT
24		Lead	MT
25		PM10	$MTCO_2E$
26		GWP	$MTCO_2E$
27		CO_2	$MTCO_2E$
28		CH_4	$MTCO_2E$
29		N_2O	$MTCO_2E$
30		CFCs	$MTCO_2E$
Service			
31	Air	Carbon sequestration	$MTCO_2E$
32	Biodiversity	Area under conservation	Ha

Table 5.2: Indicators of ecosystems functioning.

Biodiversity	**Ha or m^3**
Threatened and extinct species	**Number**
Endemic and alien species	**Number**
Population trends / dynamics	**Analyses**
Distribution of selected alien species	**Number or ha**
Landscape composition	
Impacted area through economic activity	**Ha**
Extent of conserved areas	**Ha**
Extent of natural areas	**Ha**
Riparian vegetation	**Ha**
Fish populations	**Number**
Habitat fragmentation (fencing)	**km^2**

5.2.3 Analytical framework

Life-cycle assessment is a technique used to assess the inputs and outputs of a product, process, or service (Life Cycle Inventory), and the associated wastes, human health and ecological burdens (Impact Assessment) throughout the life cycle of the products or processes under review. The term "life cycle" refers to the major activities in the course of the product's life span from its manufacture, use, maintenance, and final disposal; including the raw material acquisition required to manufacture the product. Figure 5.1 illustrates a hypothetical life-cycle and the typical inputs/outputs measured (LCA 101, 2001; Cowell, 1999).

Figure 5.1: A hypothetical life cycle, source (LCA 101, 2001)

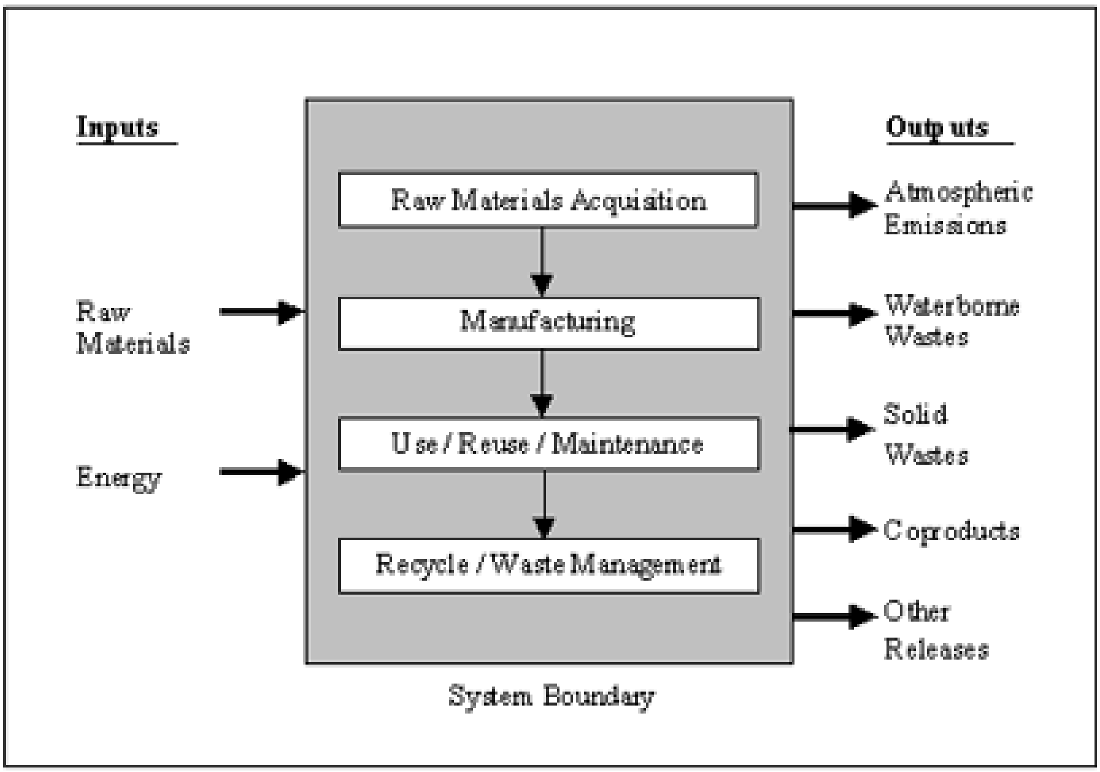

Exhibit 1-1. Life Cycle Stages (Source: EPA, 1993)

Using the value chains developed in the product flow analyses (Figures 3-1, 3-2 and 3-3) as points of departure, raw material and energy inputs and outputs were quantified for each value adding activity. The environmental impacts, resulting from each value adding activity, on the lithosphere, hydrosphere, atmosphere and biosphere were therefore grouped into ***source***, ***sink*** and ***service*** impacts. The result was an environmental impacts coefficients matrix, or a hybrid life cycle analysis.

5.2.4 Data acquisition

Financial data for the value chain analyses described in earlier chapters was relatively easy to collect, as accounting practices of firms ensure reliable financial data capturing. Environmental data, on the other hand, was considerably more difficult to obtain, as there are relatively few or no incentives or legislative measures that guide the capturing and auditing of such data. Even EIA's contain little or no environmental impact data, unless specific specialist studies are commissioned during the EIA (Batchelor, 2001). EIA's typically rely on extensive stakeholder participation and on qualitative data in order to make value judgments.

Ideally the data input into environmental impact analyses should be primary measured data, specific to the study area. However, in the absence of such data in this study area, transfer studies were used to quantify emission factors. A random-effects approach was adopted. Consequently, data were based on surveys[14], Eicola[15], NIPR[16], government and industry censuses[17], and scientific literature. These data may deviate from actual data in the study area due to two factors: raw material composition, technology and legislation differences. Raw material composition may influence the environmental impact coefficient by producing either more or less of a specific residue or pollution component. Process technologies and conversion efficiencies due to technology differences may also influence emission emissions. Newer technologies are normally more efficient and more environmentally friendly than older technologies. Areas (regions or countries) with stricter environmental regulations will tend to put management practices in place that reduce environmental impacts. The application of emissions coefficients from an environmentally aware country, such as the USA, may underestimate emissions impacts if applied in a less environmentally aware area.

Environmental benefits and costs were quantified based on a physical accounting approach, as very little work has been done internationally on quantifying the monetary impacts of benefits and costs, and transfer studies were therefore not possible. The Eiolca and NIPR data were the most comprehensive of the data sources.

The specific impacts were identified and verified as far as possible through a broad process of stakeholder interviews, literature surveys and environmental impact assessment analyses.

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[14] 1999 Forestry, Sugarcane and Sub-tropical fruit surveys completed as part of this study.

[15] Eiolca – Internet source

[16] NIPR – internet source - elaborate

[17] StatsSA, DWAF, DoA, Transport, FES

5.2.5 The environmental impact model

The environmental impacts model was designed to report results according to the aggregated format of direct and indirect linkages in the different value chains, identical to that of the economic analysis.

The sectoral environmental impacts were determined in a two-phase process, as follows:

Phase 1: Quantification of emission factors

$$A_{ij} \times C_{ij} = T_{ij} \quad (5\text{-}1)$$

$$T_{ij} + O_{ij} = E_{ij} \quad (5\text{-}2)$$

where,

A_{ij} is the vector of Eiolca and NIPR data for all value chain activities (j) over all environmental impacts (i), with the data unit of emission/production output (expressed in United States Dollars),

C_{ij} is the vector of conversion coefficients for all activities (j) over all environmental impacts (i), with the data unit of price/quantity (expressed as United States Dollars),

T_{ij} is the vector of EIOLCA sourced environmental impacts for all value chain activities (j) over all environmental impacts (i), with the data unit of emission/production output (expressed in m^3 or tons),

O_{ij} is the vector of survey, government and industry census, and scientific data for all value chain activities (j) over all environmental impacts (i), with the data unit of emission/production output (expressed in m^3 or tons),

E_{ij} is the vector emission coefficients for all value chain activities (j) over all environmental impacts (i), with the data unit of emission/production output (expressed in m^3 or tons).

Phase 2: Quantification of dosages for Mpumalanga

$$E_{ij} \times P_j = D_{ij} \quad (5\text{-}3)$$

where,

P_j is the scalar of product flow in the value chain, expressed in m^3 or tons,

D_{ij} is the vector of dose impacts for all value chain activities (j) over all environmental impacts (i) represented as a physical unit of environmental impact.

The environmental impacts of the value chain activities (j) can be grouped into direct and indirect impacts. The direct impacts refer to the direct impacts of the different crops, while the second group refers to the environmental impacts in the forward and backward linkages.

Due to the need for decision-making around water allocations and use, the model was set up to allow for scenario modelling, based on changing water quantities.

5.3 REFINING WATER USE DATA

5.3.1 Background

Commercial plantation forestry water use in South Africa is expressed as incremental water use. The rationale for this is that the impact on the natural state of water resources in a catchment is quantified through the incremental increase in water use by the plantations that replaces the natural vegetation. A change in vegetation type from the native vegetation whether it is from the winter-dormant grassland, or semi-deciduous bush to evergreen forests would result in changes in the evapotranspiration, percolation (because of changes in the rooting patterns and depth), and therefore also the streamflow. The resultant incremental water use translates to a reduction in the stream flow of watercourses. The total water use of these plantations, or evapotranspiration, is therefore equal to the sum of incremental water use and the water use of the natural vegetation that was replaced. **Irrigation water use** is expressed as a “per hectare” water allocation, and is allocated from irrigation systems that extract water from surface water sources (rivers and dams). The irrigation requirement of a crop (or incremental water use) is calculated from the difference between the total crop water use requirement (evapotranspiration) and rainfall. Forestry and irrigation water use can therefore be compared either in their impact on stream flow (incremental water use), or in terms of their total crop water use (evapotranspiration).

For the current study, the most recent plantation forestry water use data were obtained from a DWAF and WRC co-funded study (Gush et al, 2002) which modelled both the evapotranspiration and incremental water use of plantation forests (pine and eucalyptus species).

The best available **irrigation water use data** at the time of the previous study (Olbrich & Hassan, 1999) was available for irrigated fruit crops based on data drawn from irrigation trials. In most cases this data was not in the form of a complete water budget, and was viewed as one of the major weaknesses of the 1999 study. Some of the assumptions made in the 1999 report also caused inaccuracy; these included an assumption of a 70% effective rainfall, as well as a 70% effective irrigation in the fruit water use model; and **an** assumption of a 70% effective irrigation, as well as an assumption of a fixed rainfall in the sugar water use model (Annandale, 2003).

In order to address these weaknesses, two irrigation modelling software packages were investigated for the purposes of the current study: the University of Pretoria’s 2D Tree Crop model, and the

SAPWAT irrigation scheduling model. Both of these models were developed and commercialised as a result of WRC funding support.

The University of Pretoria's **2D Tree Crop Model** was developed to assist irrigators in modelling site-specific farming conditions for optimal production planning. It requires data input on a number of irrigation management variables such as planting space, irrigation type, and climatic and soil conditions. In order to generate a water use figures of the nature required for this study a great deal of statistical data would have to be sourced and models run for each of the 6 crop types (5 fruits and sugar), for conditions typically found in the Nelspruit and Malelane areas. **SAPWAT** is an irrigation scheduling software package that is more applicable to estimate water requirements for crops over a wider geographic area. SAPWAT requires as input data the crop type, planting season, irrigation type and local weather station data, and was therefore used to estimate the evapotranspiration and incremental water use the fruit tree crops and sugar cane.

5.3.2 Plantation forestry water use

The water use data presented for forestry in this report is based on estimates of the change in streamflow resulting from the change in vegetation from the natural state to commercial forests. This is commonly called the *incremental (or differential) water use*. It has been used because this is the most reliable, spatially appropriate data available for the water use of forest plantations (Gush et al, 2002). The scientific basis for this data lies in several decades of field trials (1950 – 1994) in forestry catchments in South Africa in which the change in streamflow was recorded following a change in land use from indigenous vegetation to forest plantations. The field data was then synthesized into numerical models for the two principal plantation species (Pines and eucalypts).

The best available **forestry water use data** at the time of the previous study (Olbrich & Hassan, 1999) presented the incremental water use (or stream flow reduction effect) by forestry as an average of 109.0 and 117.2 mm/a for eucalypt and pine respectively. For the current study, the most recent plantation forestry water use data were obtained from a DWAF and WRC co-funded study (Gush et al, 2002). Modelling of this data for the Crocodile River Catchment indicated an average annual stream flow reduction of 762 m^3/ha (76,2 mm/a) for Eucalypts and 972 m^3/ha (97,2 mm/a) for Pines. Incorporation of these data into the existing models reduced the modelled water use in the study area by 23,7% for Eucalypts and 2,7% for Pines.

5.3.3 Irrigation water use

Irrigation farming is conducted in the lower reaches of the catchment in a topographically flatter landscape. Our economics field data collection also showed that the majority of farms are mixed farming enterprises. The lower reaches of the catchment are therefore comprised of a spatially mixed patchwork of various crops and land uses. Most significantly from the view of the data required for the research here is that there is a negative or near negative water budget in these parts of the catchment because potential evapotranspiration exceeds annual precipitation. This means that it is not possible to conduct catchment-scale studies of the type used in the forestry areas. As a consequence, the equivalent data available for forestry is not available for the irrigated crop enterprises.

Irrigation water use modelling with the SAPWAT software package used typical crop evapotranspiration values as a point of departure to estimate crop water use requirements in the Nelspruit and Malelane areas. Based on local weather station data, evpotranspiration and irrigation requirement (i.e. incremental water use) estimates were made. Weather station data was available for 1980 to 1999 for Nelspruit and 1986 to 1999 for the Malelane area. The following scenarios and assumptions were modelled:

- Sugar cane was modelled for autumn and spring rotations, and for May-August and September-December harvests respectively;
- A travelling gun irrigation system was used for sugar and drip irrigation for fruit tree crops;
- For perennial crops a foliage cover of 75% and a wetted (evaporative) soil surface area of 50%;
- For sugar cane a foliage cover of 100% and a wetted (evaporative) soil surface area of 100%;
- Efficiencies of 75% and 95% for the travelling gun and drip irrigation systems;
- Distribution efficiencies of 75% in both cases (aim for average production);
- Medium textured soils with a TAM (Total Available Moisture) of 140mm per meter;
- Irrigation at 100% of RAM (Readily Available Moisture) depletion and refill to field capacity.

The SAPWAT modelling was performed by Mr P van Heerden, a consultant in agricultural extension and general irrigation practice.

Irrigation farmers may however require more water than indicated by the irrigation requirement indicated by the SAPWAT results, because there are transmission losses between the ultimate source of the water (in this study the river), and the irrigation system used (in this case the travelling gun or drip irrigation systems). Irrigation water used by the crops passes from the river to the irrigation system in a number of steps generally via irrigation piping or canals and sometimes an intermediate storage dam. Losses may occur in each of these steps as a result of evaporation from open water surfaces (eg. Storage dams), or due to leakage from dams, canals or irrigation pipes. It is important to distinguish between losses that are hydrological losses to the system (such as evaporation), and losses such as leakage from pipes and possibly over-irrigation where some of this water may re-enter the river in the form of return flow. These losses were not accounted for in the model.

A further consideration is that, crops may sometimes be over-irrigated either by design (to prevent salinisation of the soil), or by accident if irrigation coincides with a period of rainfall or the intensity exceeds infiltration. Theoretically this would result in return flow to the river either via runoff or percolation to a soil water table which is hydrologically connected to the river from which irrigation water is abstracted. Given the spatial arrangement of these farming enterprises, the flat topography, and the high evaporative demands it is not realistic to assume all surplus irrigation results in return flow to the river. Such losses were not accounted for in the model.

5.3.4 Considerations for the comparative water use analysis of forestry and irrigated crops

A discussion of the comparative analysis of forestry and irrigation water use requires the definition of the following set of terminology and equations:

Evapotranspiration = E_t where:

E_t = Rain + Net irrigation – Percolation – Surface Runoff - ΔS (1)

For the time purposes of this study and assumption of $\Delta S = 0$ can be made.

Incremental water use = Stream Flow Reduction (SFR) where:

$SFR_{(forestry)} = E_{t(forestry)} - E_{t(natural\ vegetation)}$ (2)

Gross irrigation = Net irrigation – Conveyance $\text{Losses}_{(irrigation)}$ (3)

$SFR_{(irrigated\ crops)} = E_{t(irrigated\ crops)} - E_{t(natural\ vegetation)} + \text{Conveyance Losses}_{(irrigation)}$ (4)

Based on equation (1) above:

$E_{t(forestry)} = \text{Rain} + 0 - \text{Percolation}_{(forestry)} - \text{Surface Runoff}_{(forestry)}$ (5)

$E_{t(natural\ vegetation)} = \text{Rain} + 0 - \text{Percolation}_{(natural\ vegetation)} - \text{Surface Runoff}_{(natural\ vegetation)}$ (6)

Therefore, $SFR_{(forestry)}$ = (5) – (6): $SFR_{(forestry)}$ = dPerculation + dSurface Runoff (7)

And for the irrigated crops:

$E_{t(irrigated\ crops)} = \text{Rain} + \text{Net irrigation} - \text{Percolation}_{(irrigated\ crops)} - \text{Surface Runoff}_{(irrigated\ crops)}$ (8)

Therefore, $SFR_{(irrigated\ crops)}$ = (8) – (6) + Conveyance $\text{losses}_{(irrigated\ crops)}$:

$SFR_{(irrigated\ crops)}$ = Net irrig + dPercolation + dSurface Runoff + Conveyance $\text{losses}_{(irrigated\ crops)}$ (9)

Based on these equations, evapotranspiration is defined by equations (5) and (8) for forestry and irrigated crops, while the incremental water use is defined by equations (7) and (9).

Evapotranspiration and incremental water use values for Forestry were estimated directly by the previously mentioned WRC funded study by Gush and co-workers (Gush et al, 2002).

The SAPWAT modelling estimated evapotranspiration and net irrigation requirements for the fruit and sugar crops. It was not possible to estimate conveyance losses, dPercolation or dSurface Runoff as defined in equation (9). The following method for estimating incremental water use for the fruit and sugar crops were therefore used based upon Equations (8) and (9):

$E_{t(\text{irrigated crops})} \approx E_{t(\text{natural vegetation})}$ + *Extra water consumed by crops*

Where *Extra water consumed by crops* = (Net irrigation – Percolation – Surface Runoff)

Therefore: *Extra water consumed by crops* ≈ $SFR_{(\text{irrigated crops})} = E_{t(\text{irrigated crops})} - E_{t(\text{natural vegetation})}$

Where $E_{t(\text{irrigated crops})}$ were sourced SAPWAT and evapotranspiration values for natural vegetation in the study area were sourced from the WRC funded study by Gush and co-workers (Gush et al, 2002).

A important consideration in the comparative analysis of forestry and irrigated crops is the distance between forestry and irrigation activities in the catchment. The following equation shows that there ia a conveyance loss that occurs due to the distance between the two land uses:

Incremental Forestry stream flow (upstream) – conveyance losses (river) = Gross irrigation (downstream)

It was not attempted to address the scope of these losses in this study.

5.3.5 Industrial water use

Earlier in this report, it was mentioned that it was necessary to account for water used in the forward and backward-linked industries. Our investigation revealed that the consumptive water use in both the supply and demand side activities was so low to be almost negligible relative to that consumed during primary production. It is also important to emphasize that while water is used in many of processing industries, this use is largely non-consumptive, an example being in the washing of fruit. Some industries including sugar mills, and fruit processing plants presented data showing that their consumptive water use was either zero or negative (implying that they returned more water to the system than they extracted). This is possible because the raw material (poles, fruit or cane) contain significant amounts of water much of which is removed during processing. Because water consumption in processing was found to be at least an order of magnitude lower than that consumed during primary production (growing the crop) it was considered negligible. The VAD per m^3 water was therefore calculated on the basis of the water consumed during primary production only.

It is important to emphasize that while the processing and supply sectors mentioned above are not significant consumers of water, they do have an impact on water quality. This may in some instances be significant, and will be one of the factors evaluated in the environmental analysis.

5.4 RESULTS OF ENVIRONMENTAL IMPACT ASSESSMENT

5.4.1 Interpretation and use of environmental impact information

Environmental impact analysis provides information on emissions and resource use coefficients, dosages and responses of the human and ecosystem to the dosages received. Whereas emissions and resource use are industry specific coefficients and is heavily technology dependent, emissions and resource use dosages are calculated from coefficients determined from production modeling. The variables used here depend on the types of emissions and resource use. These variables may be used as indicators of environmental impact if the relationship between them and the human and ecosystem responses are understood. Analyses of the human and ecosystem responses require a modeling exercise where the emissions and resource use variables are related to environmental impacts. These impacts are related to human and ecosystem health and the subsequent ability to maintain productivity (also defined as sustainability). Quantifying these response impacts necessitates specific research programmes and fell outside the scope of this study. For example, the production of the gases CO_2, CH_4, N_2O, CFCs in Mpumalanga may be used as indicators of an industry's contribution to global warming, and is relatively easy to estimate. However, estimating the impact of these gases, emitted in Mpumalanga, on raising the global temperature is a far more complex and controversial exercise. By example, fertilizer use in agriculture, combined with poor irrigation scheduling practices and certain soil conditions, may cause severe soil salinisation to the extreme that land becomes completely inarable. Although it is relatively easy to estimate fertilizer use, the impact, soil salinisation, is complex to model as it contains main management variables. Fertiliser use alone is therefore a poor indicator of soil salinisation.

The results of the Phase 1 environmental impact analyses, the emission coefficients, are presented in Tables 5.10 - 5.12. The results of the Phase 2 environmental impact analyses, the dose for Mpumalanga, are presented in Tables 5.13 – 5.15.

5.4.2 Water

5.4.2.1 Evapotranspiration, incremental and total water use

Table 5.4 summarises the results of the forestry water use figures of Gush (Gush et al 2002) and the SAPWAT irrigation water use figures (Van Heerden, 2004). Columns A-D contained data sourced from the previously mentioned Gush and Van Heerden studies. Columns E and F present the comparative water use for the different crop land use scenarios based on evapotranspiration, while columns G and H present the comparative water use for the different crop land use scenarios based on incremental water use. Column A shows forestry plantations to be located in areas with mean annual precipitation generally exceeding 800mm/a. The Malelane area is the drier of the two irrigation areas at a MAP of 569mm. The Acocks Average evapotranspiration (column C) estimates the water use of the natural vegetation replaced by the irrigation and forestry activities. Table 5.3 provides a summary of the data contained in Table 5.4 and will be used for discussion purposes.

Column E of Table 5.3 calculates crop **evapotranspiration** in millimetres water used per annum. In the case of irrigation this is the sum of the average annual rainfall and irrigation requirement for the modelled period. (The modelled periods were 1980-1999 for the Nelspruit irrigation area; 1986-1999 for the Malelane irrigation area; and 1950-1994 for the forestry data.) Using this criterion, sugar has the largest per hectare water consumption at 2 209mm (2 171-2 381mm); irrigated fruit the second largest 1 523mm (1 139-1 908mm), and forestry the lowest 785mm (662-877mm). The total water use per crop, calculated from the area under land use and **evapotranspiration** (column F of Table 5.3) shows that forestry is by far the largest water user in the Crocodile River catchment area, using 1 359 million m^3 for evapotranspiration. Sugar follows with and average of 377 million m^3 while irrigated fruit is the smallest water user by volume with 171 million m^3.

When incremental water use (or stream flow reduction) is used as the criterion for comparison, shugar remains the largest per unit consumer of water (1714mm), followed by fruit (892mm), with forestry having a much smaller impact of 64mm. Column H of Table 5.3 shows the incremental water use by volume and indicates the impact the specific land use on stream flow. In this case sugar cane uses 293 million m^3 of stream flow followed by forestry (115 million m^3) and fruit (100 million m^3).

Table 5.3 Comparative water use analysis of fruit, sugar and forestry crops (summarised from Table 5.4)

	Crop E(t)		Incremental Water Use	
	mm	Million cubic metres	mm	Million cubic metres
	E	F	G	H
Avocado	1 908	51	1 278	34
Bananas	1 762	60	1 132	39
Citrus	1 139	46	509	20
Mango	1 282	15	651	7
Sugar	2 209	377	1 714	293
Pine	776	500	55	36
Eucalypt	795	859	73	80
Total Fruit	1 523	171	892	100
Total Sugar	2 209	377	1 714	293
Total Forestry	785	1 359	64	115

Table 5.3 shows that the water use of the three sets of land uses studied (fruit, sugar and forestry) can be compared in four different ways. Depending on the basis for comparison one land use may appear a larger or smaller water user. It is therefore extremely important to consider the rationale behind every management and policy decision and to apply a suitable basis for water use quantification.

Table 5.4: Comparative water use figures for the different land uses studied

Tertiary Catchment	Land use scenario			MAP	Area	Acocks Average E(t)	Irrigation Requirement	Crop E(t)		Incremental Water Use	
	Crop	Crop description	Irrigation system	mm	ha	mm	mm	mm	Million cubic metres	mm	Million cubic metres
				A	B	C	D	E	F	G	H
								A + D	(B*E*10)/ 1000000	E - C	(B*G*10)/ 1000000
X22 (Nelspruit area)	Avocado	Standard	Drip	781	2 647	630	1127	1 908	50.5	1278	33.8
X22 (Nelspruit area)	Bananas	Ratoon	Drip	781	3 409	630	981	1 762	60.1	1132	38.6
X22 (Nelspruit area)	Citrus	Average	Drip	781	4 000	630	358	1 139	45.6	509	20.3
X22 (Nelspruit area)	Mango	Standard	Drip	781	1 150	630	501	1 282	14.7	651	7.5
X24 (Malelane area)	Sugar-autumn	May harvest	Travelling gun	569	17 089	495	1624	2 193	374.7	1697	290.1
X24 (Malelane area)	Sugar-autumn	June harvest	Travelling gun	569	17 089	495	1616	2 185	373.3	1689	288.7
X24 (Malelane area)	Sugar-autumn	July harvest	Travelling gun	569	17 089	495	1617	2 186	373.6	1691	289.0
X24 (Malelane area)	Sugar-autumn	Aug harvest	Travelling gun	569	17 089	495	1616	2 185	373.4	1690	288.8
X24 (Malelane area)	Sugar-spring	Sept harvest	Travelling gun	569	17 089	495	1617	2 186	373.5	1690	288.8
X24 (Malelane area)	Sugar-spring	Oct harvest	Travelling gun	569	17 089	495	1602	2 171	371.1	1676	286.4
X24 (Malelane area)	Sugar-spring	Nov harvest	Travelling gun	569	17 089	495	1615	2 184	373.3	1689	288.6
X24 (Malelane area)	Sugar-spring	Dec harvest	Travelling gun	569	17 089	495	1812	2 381	406.8	1885	322.2
X21 (A,B,C,D,E,F,G,H,J,K)	Pine	Not applicable	Not applicable	832	21 927	720	0	775	169.9	55	12.1
X22 (A,B,C,D,E,F,G,H,J,K)	Pine	Not applicable	Not applicable	970	16 786	783	0	850	142.7	67	11.3
X23 (A,B,C,D,E,F,G,H)	Pine	Not applicable	Not applicable	908	11 635	763	0	826	96.1	63	7.3
X24 (A,B,C,D,E,F)	Pine	Not applicable	Not applicable	713	13 897	619	0	654	90.9	35	4.9
X21 (A,B,C,D,E,F,G,H,J,K)	Eucalypt	Not applicable	Not applicable	832	36 845	720	0	793	292.0	73	26.7
X22 (A,B,C,D,E,F,G,H,J,K)	Eucalypt	Not applicable	Not applicable	970	28 207	783	0	877	247.3	94	26.5
X23 (A,B,C,D,E,F,G,H)	Eucalypt	Not applicable	Not applicable	908	19 551	763	0	847	165.5	84	16.3
X24 (A,B,C,D,E,F)	Eucalypt	Not applicable	Not applicable	713	23 351	619	0	662	154.6	44	10.2

E(t) = Evapotranspiration

Sources: Forestry Data: Gush (et al), 2002

Irrigation Data: Van Heerden, 2004

5.4.2.2 *Industrial water use*

Industrial use refers to all the value added activities after the primary production activity within the value chain. These activities are shown in Figures 3.1, 3.2 and 3.3. The aggregated use and pollution impacts across each of these value addition activities for Forestry, Sugarcane and Fruits are depicted in Table 5.4 and 5.5 below.

Table 5.4 quantifies the water extracted and used directly from the river system (incremental water use) and the water use supplied through other water systems such as Water Boards or Municipalities (intake -water supply system), including a breakdown of water recycled and reused. By adding the incremental water use and the intake from other supply sources, the total water removed from the national water system by these three agricultural activities in Mpumalanga amounts to 671,671,147 m^3 for the year 1998, for which about 38% is used by Forestry, 37% by Sugarcane and 24% by Sub-tropical fruits respectively. The direct water use by the primary crop growing activities is by far the largest component of water use, with the indirect/direct water use ratio varying between 0.8% and 2.5% for the three land uses. The forestry and sugarcane value chains do significant recycling of water, mostly in the pulp and paper and sugar refining factories.

Table 5.4: Water use (intake and recycled) by land use activities for 1998

Emission and resource use		Units	Forestry	Sugarcane	Fruit
Incremental water use	Direct	M^3	251,054,124	249,096,578	161,048,879
Intake (Residual product moisture content)		M^3	4,095,196	2,547,838	82,329
Intake (Water supply systems)	Indirect	M^3	6,474,776	2,620,774	1,376,016
Indirect water use / Direct water use		M^3	2.5%	1.0%	0.8%
Recycled/reused water		M^3	17,520,409	3,890,374	-
Recycled water / intake		M^3	165.8%	75.3%	0.0%

Summarised from: Appendix 7: Tables 5.10-5.15

5.4.2.3 *Water Quality*

The quality of water is especially important where water availability is limited. Water quality refers to the quantity of impurities in the water, for instance, dissolved salts, suspended particles or toxic chemicals. Typical water pollution variables for the value chains under discussion are Total Dissolved Solids (TDS), Biological Oxygen Demand (BOD), toxic effluent, salts, pesticides, fertilisers, temperature, NH_4, microbiological activity, etc (Scholes et al, 1995). These variables may lead to salinity, eutrophication, and chemical pollution by pesticides and herbicides:

Irrigation water, no matter how it appears chemically, is capable of creating soil **salinity** problems if high watertables are allowed to develop in the soil. Although the Crocodile River has a very low salinity hazard, a survey of water quality for twelve selected rivers in the South African Sugar Industry undertaken by DWAF from 1983 to 1993 revealed that salinity levels in the lower Crocodile River have more than doubled since the previous assessment was made in 1976.

Eutrophication is the enrichment of water systems with plant nutrients. In the case of the excessive eutrophication, the growth of algae or water weeds can lead to a number of water quality problems such as the increase in alga toxins (health problems), aesthetically (taste) less appealing water, increased water treatment costs and general interference with recreational usage. Factors affecting the growth of algae are normally related to a chemical change within the water impoundment such as release of manganese, iron and phosphates from sediments as well as oxygen depletion. Nutrient levels in several of the river systems in the previously mentioned DWAF study were found to be highly variable, but strongly dependent on rainfall events. Small increases in concentration of N, P and K were noted for a number of rivers, and the peak concentrations of these nutrients were well below accepted world standards for drinking water (Meyer *et al*, 1995).

In order to eradicate weeds, crop diseases, insect and pest problems growers use **synthetic chemicals which may lead to chemical pollution**. Weeds can be controlled effectively and conveniently on a large scale with a range of herbicides, resulting in substantial reduction in time, labour, machinery and fuel costs (some studies have indicated that there may be an association between the shift to minimum tillage and recent massive increases in the use of herbicides). The environmental impacts resulting from weed control include:

- drainage of chemicals to sensitive crop species;
- concerns that the physical environment ultimately becomes an open ”sink” for these chemicals;
- shift from broad leaf to grass weed species;
- amplify pest and disease problems such as rootrot, nematodes and canegrubs;
- herbicide residues which pollute surface water and groundwater;
- increased need to use nitrogenous fertilizers; and
- unknown costs of drift damage to natural ecosystems

All things considered, namely the low quantities applied, relatively rapid degradation, plant uptake, and the delayed movement and dispersion caused by absorption, it is unlikely that the herbicides presently used, will constitute a serious water quality problem (Charles Sellick & Associates, 1997).

The above impacts, and the available DWAF water quality and other data were however, non-point source data and could therefore be used in the modelling done as part of this study.

Table 5.5, depicts the water quality indicators for the three crops. The levels of Biological Oxygen Demand (BOD) and Total Suspended Solids (TSS) are shown for both the primary production processes (direct) and the value added processes (indirect). Organic material has a high oxygen demand, removing oxygen from the water when they decompose, and therefore threatening aquatic life. The results indicate that Forestry has the may have the highest levels of BOD emissions from both its primary and value added activities, followed by Fruits and then Sugarcane for the direct activities and by Sugarcane and then Fruits for the indirect activities. This may be a result of the pulp and paper activities taking place in the Catchment, which generate high concentrations of lignin and dissolved solids. Sugar refineries discharge cooling water, the sugar content of which could be as high as 9mg/lire (Scholes et al, 1995). The sugar content of the water result in elevated levels of ammonia, bacteria and oxygen demand. Fruit processing plants, involved in fruit packing, canning, juice production, drying and citrus preservation, operate seasonally and use water for washing purposes. They consequently have little potential for serious pollution effects. TSS result from non-dissolved particles suspended in water. In the direct land uses, erosion leads to elevated levels of TSS. Although no data was available for direct Forestry TSS modelling the frequency of site disturbance is low as it is a perennial crop. The more intensively farmed irrigated crops will have higher soil disturbance rates. As in the case of BOD, discussed above, the higher TSS levels for the indirect Forestry, Sugarcane and Fruit processing industries are a consequence of the intensity of impurities emitted by the pulp&paper (lignin, cellulose), sugar refining (bagasse and other particles) and fruit processing industries (sand, dust) respectively. Forestry also provides the risk of sedimentation after massive veld fires. As these are abnormal occurrences, it was not possible to model.

Table 5.5: Water pollution by land use activities for 1998

Emission and resource use		Units	Forestry		Sugarcane		Fruit	
			Direct	Indirect	Direct	Indirect	Direct	Indirect
Water pollution	BOD	MT	3.8	988	1	380	1.8	3.8
	TSS	MT	Not avail.	3,364	238	995	354.6	6.0

Summarised from: Appendix 8: Tables 5.10-5.15

The water quality in the Crocodile River Catchment is generally within the guidelines set by the DWAF for domestic, agricultural and industrial use, but on occasion does fall outside the limits, particularly the target water quality guidelines. There are definite temporal and spatial (in a downstream direction) trends of decreasing water quality due to increased land and water use. The decreases in water quality are more significant in the lower Crocodile River. Very high electrical conductivities have on occasion been measured in seepage return flows, particularly in the smaller tributaries draining irrigated fields (Charles Sellick & Associates, 1997).

5.4.3 Soil

Soil is impacted mainly by the direct land uses. These impacts include: soil acidification, soil nutrient content, soil erosion and soil compaction.

Forestry and fruit trees and sugarcane take up cations from the soil during its growth process, this leads to **acidification**. In a natural system, vegetation residues that decompose return the cations to the soil, however, in forestry an irrigation agriculture, the vegetation residues are the products that are harvested. Acidification may be counteracted by returning cations to the soil in the form of fertiliser.

As in the case of soil acidification, the removal of vegetation during harvesting, removes the **nutrients** from the land. Fertiliser has to be added to correct this situation.

Soil erosion is the result of increased tillage of soil for agricultural practices, which make it more susceptible to especially water erosion. As forestry is a perennial crop, tillage is much less than for sugarcane and fruit. However, the steeper slopes on which plantations are established and the occurrence of wild fires may increase the risk of erosion in Forestry. Erosion leads to reduction in soil fertility and increased sedimentation.

Soil compaction is caused by the increasing weight or equipment or vehicle load. This decreases the volume occupied by a given mass of soil and therefore reduces pore space. Reduced pore space reduces the capacity of the soil to store water and makes it more difficult for roots to penetrate. It is unclear what the comparative effect of soil compaction is for Forestry and irrigation agriculture (Scholes et al, 1995, Charles Sellick & Associates, 1997).

These soil impacts are caused and addressed by management practices rather than technology factors. It was therefore not possible to model these impacts. Instead, the amount of fertiliser application was used as a proxy to measure the risk of soil impacts. The rationale for this proxy was that increased fertiliser use indicated and increased intensity of soil impacting activities in the study area.

Table 5.6, gives an indication of the impacts of fertilizer application during the direct production activities for the three land uses and shows that Sugar Cane has the greatest impact of 46%, followed by Fruits at 30% and lastly Forestry at 24% of the aggregated total soil impacts.

Waste impacts generated under this section of the study refer to solid wastes that are dependent on land-fill mitigation activities in order to address the levels of pollution. Waste generated through the respective life-cycles is quantified in metric tons and shows that Forestry generates the highest level of solid waste byproducts at 95% of the total generated, followed by Sugarcane at 4% and Fruits at 1%. These impacts are based on a generic classification and do not include hazardous waste.

Table 5.6: Soil and waste impacts by land use activities for 1998

Emission and resource use		Units	Forestry	Sugarcane	Fruit
Fertiliser use	Direct	MT	8,663	16,772	10,736
Waste	Indirect	MT	363	15	0.8

Summarised from: Appendix 8: Tables 5.10-5.15

5.4.4 Energy

The energy figures reported in Table 5.7 below are defined as source inputs to the direct and indirect processes of each land use activity. Electricity is given as a separate input and is also included in the energy figure that gives an aggregate for all energy inputs including fuels (gas, fossil), other boiler fuels (bagasse) and firewood. Once again, Forestry is the largest user of an input both in the direct and indirect processes at levels of use of 21 and 1,307 MkW-hr, followed by Sugarcane at 12 and 62 MkW-hr and Fruits at 10.2 and 14.9 MkW-hr respectively.

Interestingly, these input dependency ratios change when all fuel sources are included in the analysis, and Sugarcane becomes the largest user of energy inputs for direct production activities, due to the burning of bagasse, followed by Forestry and Fruits. However, Forestry remains the largest energy user for indirect process, followed by Sugarcane and Fruits.

Table 5.7: Energy use by land use activities for 1998

Emission and resource use		Forestry			Sugarcane			Fruit		
		Direct	Indirect	Multiplier	Direct	Indirect	Multiplier	Direct	Indirect	Multiplier
Electricity	M kW-hr	21	1,307	63	12	62	6.1	10.2	14.9	2.5
Energy	TJ	197	21,522	110	275	1,779	7.5	95.3	143.1	2.5

Summarised from: Appendix 8: Tables 5.10-5.15

5.4.5 Air

Air quality is impacted negatively and positively by the direct and indirect activities under discussion. Relative to sources such as power generation, heavy industries and motor vehicles, the Forestry and irrigation activities are minor sources of air pollution. Forest fires are however a source carbon monoxide, methane and nitrous oxide (Scholes et al, 1995). The practice of trash burning in sugarcane farming has also become a greater issue within the last decade as the practice of green cane harvesting has increased. A trash fire emits a large volume of thick enveloping white smoke and can smoulder for long periods of time (Charles Sellick & Associates, 1997). All plants also emit non-methane hydrocarbons which prevent oxidation of toxic gasses. Intensively established agricultural biomass produces more non-methane hydrocarbons than the natural veld they replaced (Scholes et al, 1995). The value adding industries under investigation produces air pollutants such as those listed in Table

5.8 below. The generic emissions are recorded in metric tons and the greenhouse gas emissions are recorded in metric tons of CO_2 equivalent. The different air emissions are discussed in greater details below:

Sulphur oxides of concern to environmental analysts are sulphur monoxide, sulphur dioxide, sulphur trioxide and disulphur monoxide. Sulphur dioxide (SO_2) is the only sulphur oxide present in the atmosphere at significant concentration levels, hence its inclusion in this study (Desvousges et. al., 1998). Forestry was by far the largest emitter of sulphur dioxide for both direct and indirect processes.

Nitric oxide and nitrogen dioxide are the most prevalent ***nitrogen oxides*** in the atmosphere arising from anthropogenic sources such as transportation and fuel combustion, including electricity generation. Nitrogen dioxide is often regarded as the nitric oxide that poses the greatest health risks in epidemiological studies and has also been included here (Desvousges et. al., 1998). Sugarcane showed the highest levels of emissions for direct processes followed by Forestry and Fruit, while Forestry showed the greater level of emissions for indirect processes, followed by Sugarcane then Fruit.

Carbon monoxide produced through vehicle use causes significant respiratory effects. It is included in this study due to its prevalence across all land uses and indications are that Sugarcane has the highest levels of emissions for direct processes while Forestry has the highest levels of emissions for indirect processes.

A number of air pollutants are recognised to impact directly on the ozone and are grouped together as *greenhouse gasses*. These gases are shown in the last five rows of Table 5.8. Their emission levels follow the patterns identified above, switching between Forestry and Sugarcane for direct and indirect processes respectively.

Table 5.8: Air emissions by land use activity for 1998

Air emissions	Units	Forestry		Sugarcane		Fruit	
		Direct	Indirect	Direct	Indirect	Direct	Indirect
SO2	MT	6.3	4,576	2	619	3.1	8.2
CO	MT	0.3	6,567	761	1,214	0.2	80.2
NO2	MT	3.2	3,448	850	750	1.6	38.2
VOC	MT	2.1	1,455	134	240	1.0	17.2
Lead	MT	-	-	-	-	-	-
PM10	MT	4	623	-	152	1.8	2.1
GWP	$MTCO_2E$	11,646	390,662	19,657	141,169	5,647.5	10,088.9
CO2	$MTCO_2E$	11,586	379,706	17,140	137,817	5,618.3	9,967.7
CH4	$MTCO_2E$	51	167	52	106	24.7	10.1
N2O	$MTCO_2E$	9.3	9,983	2,465	2,173	4.5	113.2
CFCs	$MTCO_2E$	-	-	-	1,075	-	-

Summarised from: Appendix 8: Tables 5.10-5.15

Agricultural activities can also produce positive air quality impacts as plants withdraw CO_2 from the atmosphere and convert it to biomass, as they grow. The carbon sequestration benefits, as expected, are the highest for Forestry at 619,972 metric tons of equivalent carbon dioxide, followed by Sugarcane at 4,553 metric tons of equivalent carbon dioxide. No measures are given for Fruits due to data limitations. The reasons for the high levels of carbon sequestration for forestry may be explained by the observation that carbon is stored in plantation forests either when ecosystems with low C densities are afforested or when timber is converted to semi-permanent products. Carbon storage in eucalyptus and pine plantations throughout South Africa offset about 3% of the carbon dioxide emissions for the country as a whole (Scholes et al, 1995).

Table 5.9: Carbon sequestration by land use activity for 1998

Emission and resource use		Units	Forestry		Sugarcane		Fruit	
			Direct	Indirect	Direct	Indirect	Direct	Indirect
Services	Carbon sequestration	$MTCO_2E$	-	619,972	-	4,553	-	-

Summarised from: Appendix 8: Tables 5.10-5.15

5.4.6 Biodiversity and Environmental Services

Biodiversity is the variety and variability among living organisms and the ecological communities of which they are part. Biodiversity is critical for maintaining the resilience of ecosystems allowing ecosystems to respond to changes induced by economic activity. The resilience of ecosystems refers to the capacity of an ecosystem to maintain its characteristic patterns and rates of processes such as primary productivity in response to environmental conditions. Therefore, the more diverse a system, the greater its ability to withstand shocks and stresses (Khan, 1995:360).

Environmental services is a unique classification that gives an indication of the health of the environmental systems linked to the different land uses at both a National and Global level. For the purposes of this study, the achievements of these land uses in reducing carbon emission levels and land area specifically set aside for conservation or conservancy purposes are included as environmental service assets[18].

The impacts of any human activity on ecological processes depend on the area affected by the activity relative to the area which the processes need in order to operate: on average, 60-70% of each forestry estate is planted to trees. The impacts of other land uses can be more severe as Forestry

[18] This definition may differ widely from definitions given in other literature sources

operates under very strict planting regulations (indigenous forest, wetland and riparian zones are not planted but are managed for optimum biodiversity) (Scholes et al, 1995). Reduced biodiversity is also caused by use of herbicides, pesticides and the other water quality and soil impacts discussed above. For the purposes of this study, area under conservation was used as a proxy for biodiversity. Based on the area under conservation (Table 5.10), Forestry has a higher conservation impact area than Sugarcane and Fruits. This is however, a very simplistic approach, and more study is required.

Table 5.10: Environmental service assets by land use activity for 1998

Biodiversity	Units	Forestry		Sugarcane		Fruit	
		Direct	Indirect	Direct	Indirect	Direct	Indirect
Conservation	Ha	52,201	-	8,362	-	4,223.4	-

Summarised from: Appendix 8: Tables 5.10-5.15

Figures 5.3-5.10 provides additional descriptive information of the biological assets in the Crocodile River Catchment.

Figure 5.3: Conservation areas in the Crocodile River catchment

Figure 5.3 shows the conservation areas within the Crocodile catchment. From this map it is evident that the Catchment borders the Kruger National Park and hence has responsibilities in terms of water use and quality controls. There also exists an extensive farm buffer belt along the Kruger Park boundary.

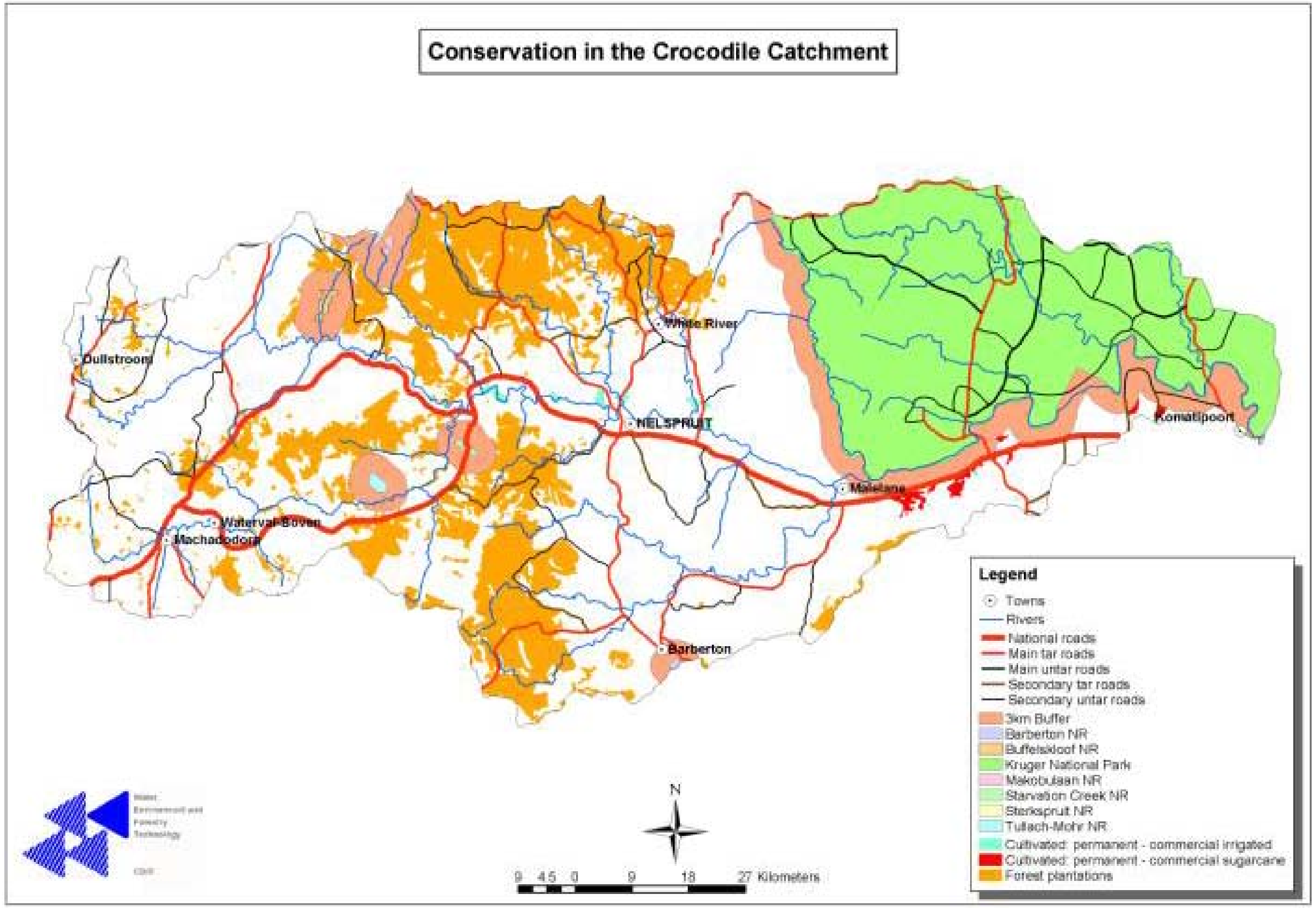


Figure 5.4: Land use activities in the Crocodile River catchment

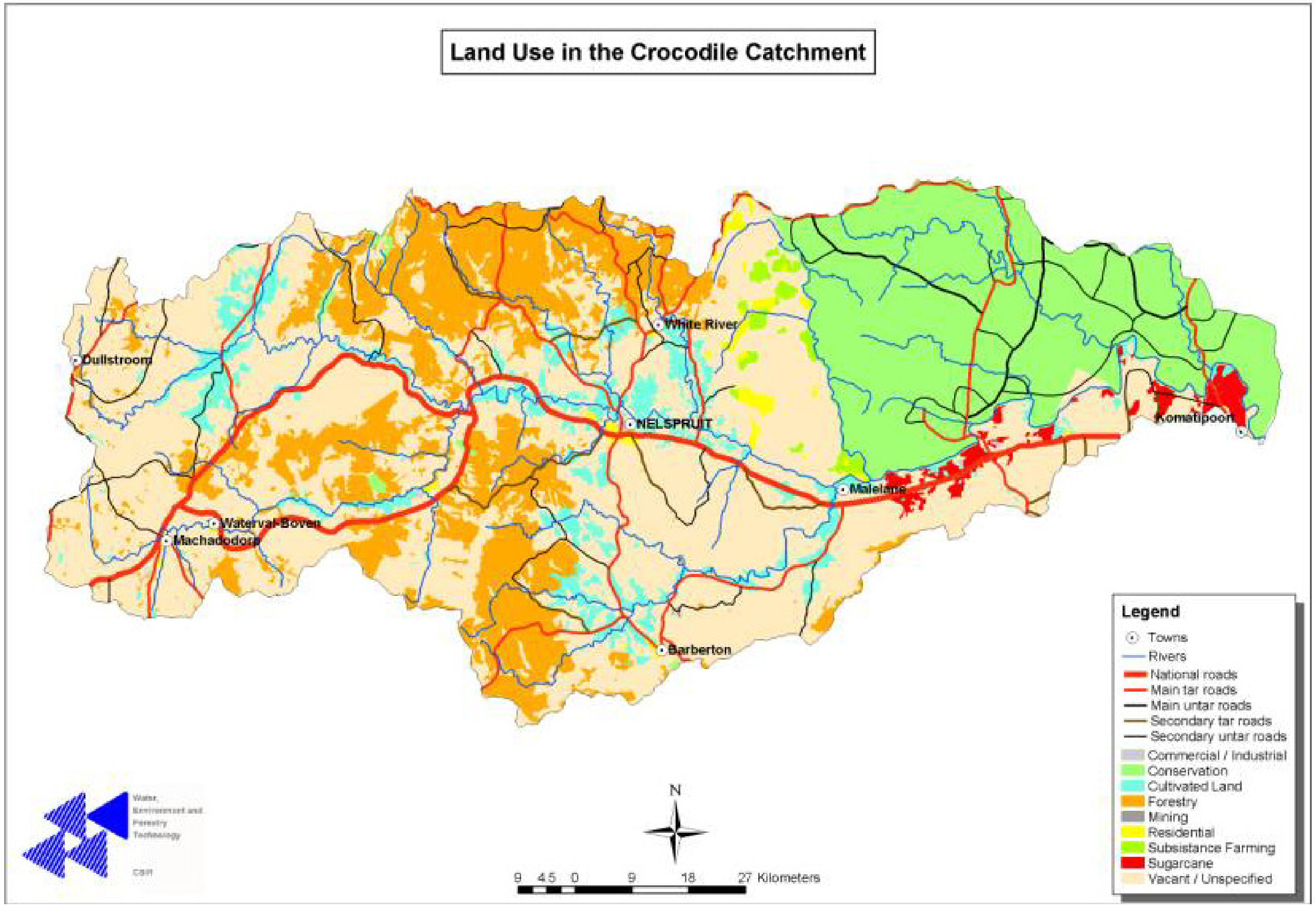


Figure 5.4 shows the land use activities in the catchment. The orange shows the Forestry areas, the blue, the cultivated land areas and the red the areas under sugarcane. The solid green area is the KNP and the fragmented green areas depict the subsistence agricultural areas. This indicates that the Forestry activities extract water from the upper catchment regions while sugarcane extract water along the lower bounds of the catchment.

Figure 5.5: Faune in the Crocodile River catchment

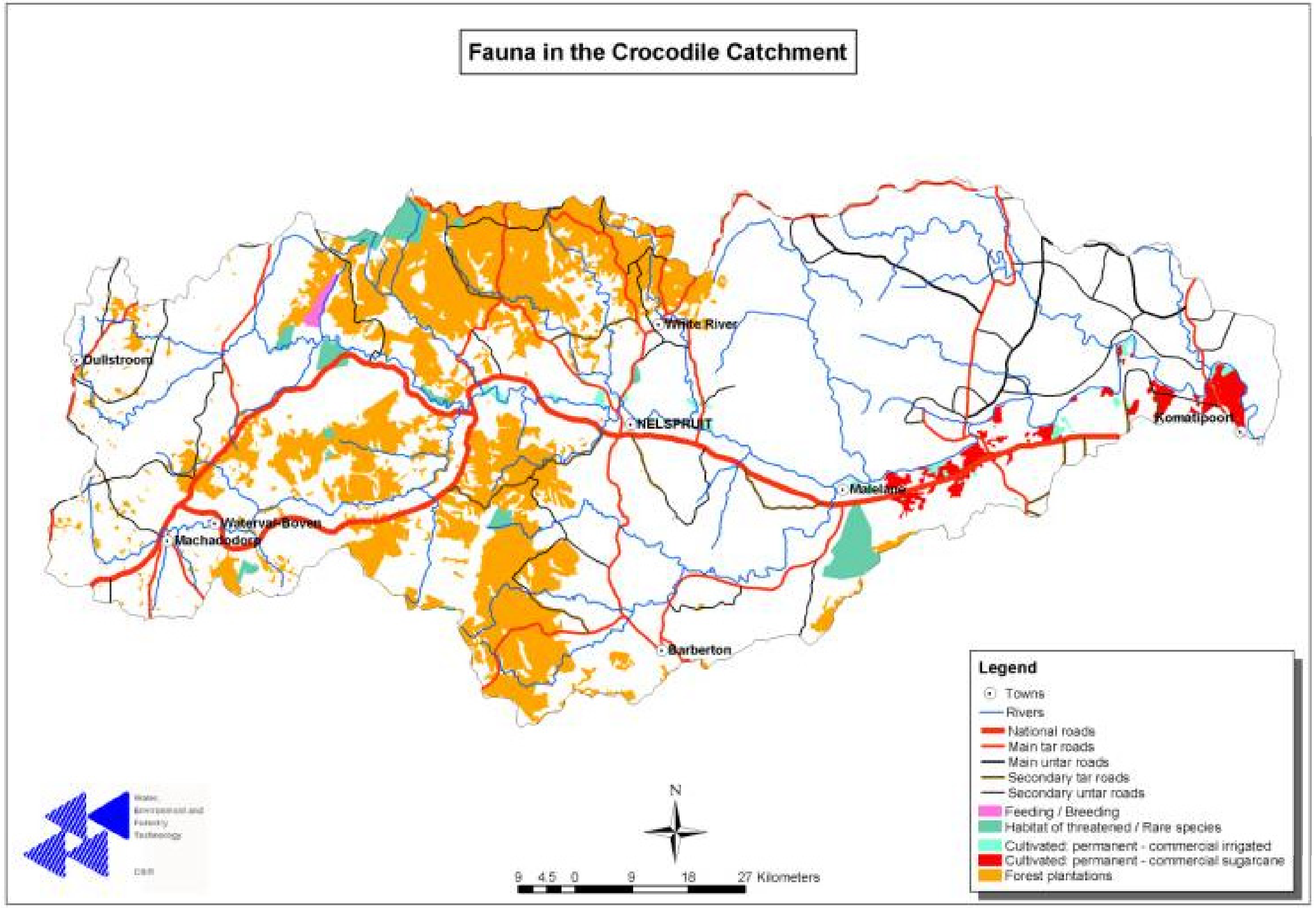
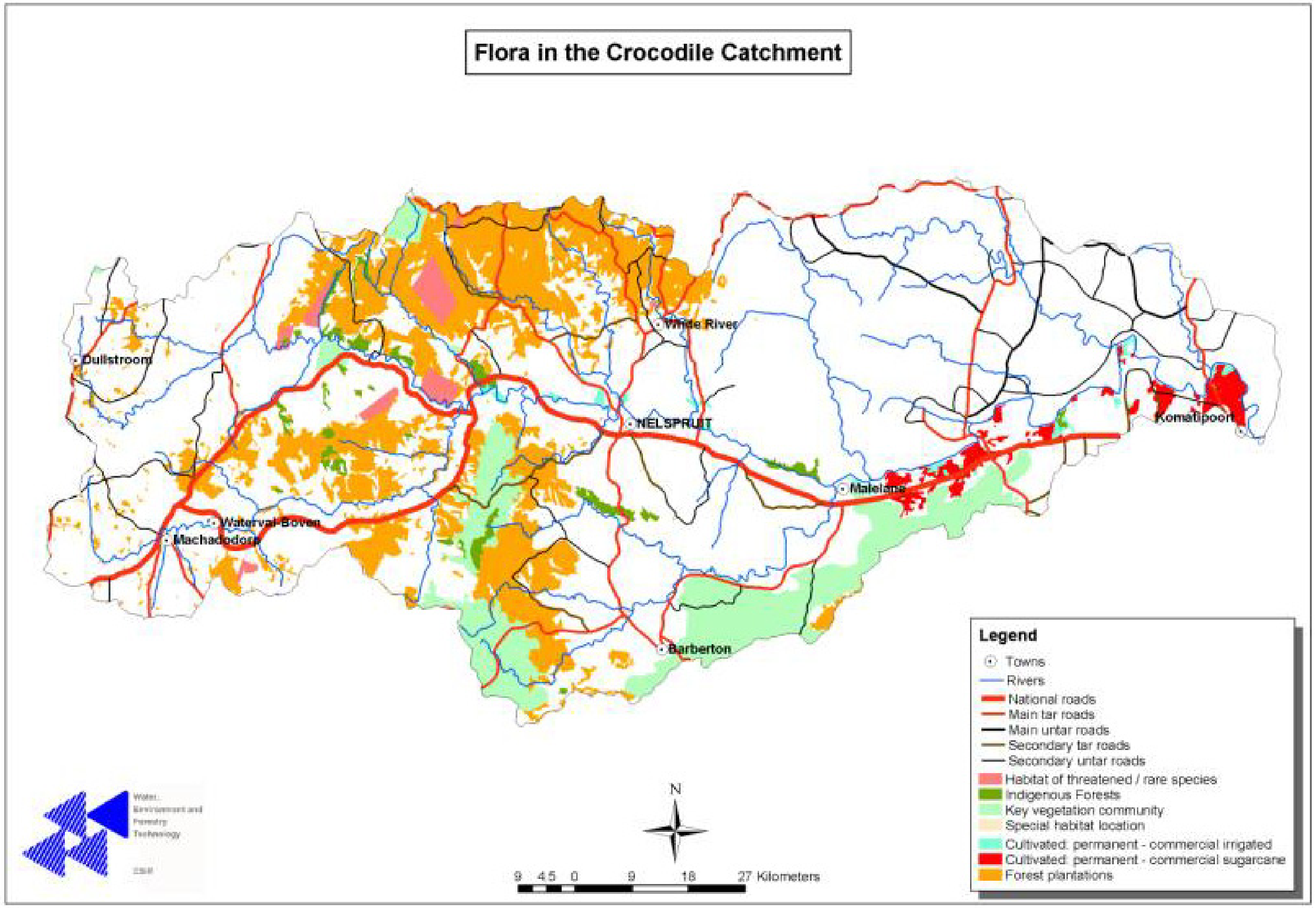


Figure 5.5 shows that the majority of feeding species are located in the upper catchment on the boundary of the forestry area (pink), while the threatened species are more fragmented as seen by the blue.

Figure 5.6: Flora in the Crocodile River catchment



The pink areas show the habitat of threatened species found mainly in the upper catchment while, indigenous forests are found sporadically distributed throughout the catchment (dark green). Key community vegetation areas are also dispersed and are located mainly on the edges of the catchment, only Forestry appears to fall within these areas but the extent of impact is not evaluated or discussed here.

Figure 5.7: Wetlands in the Crocodile River catchment

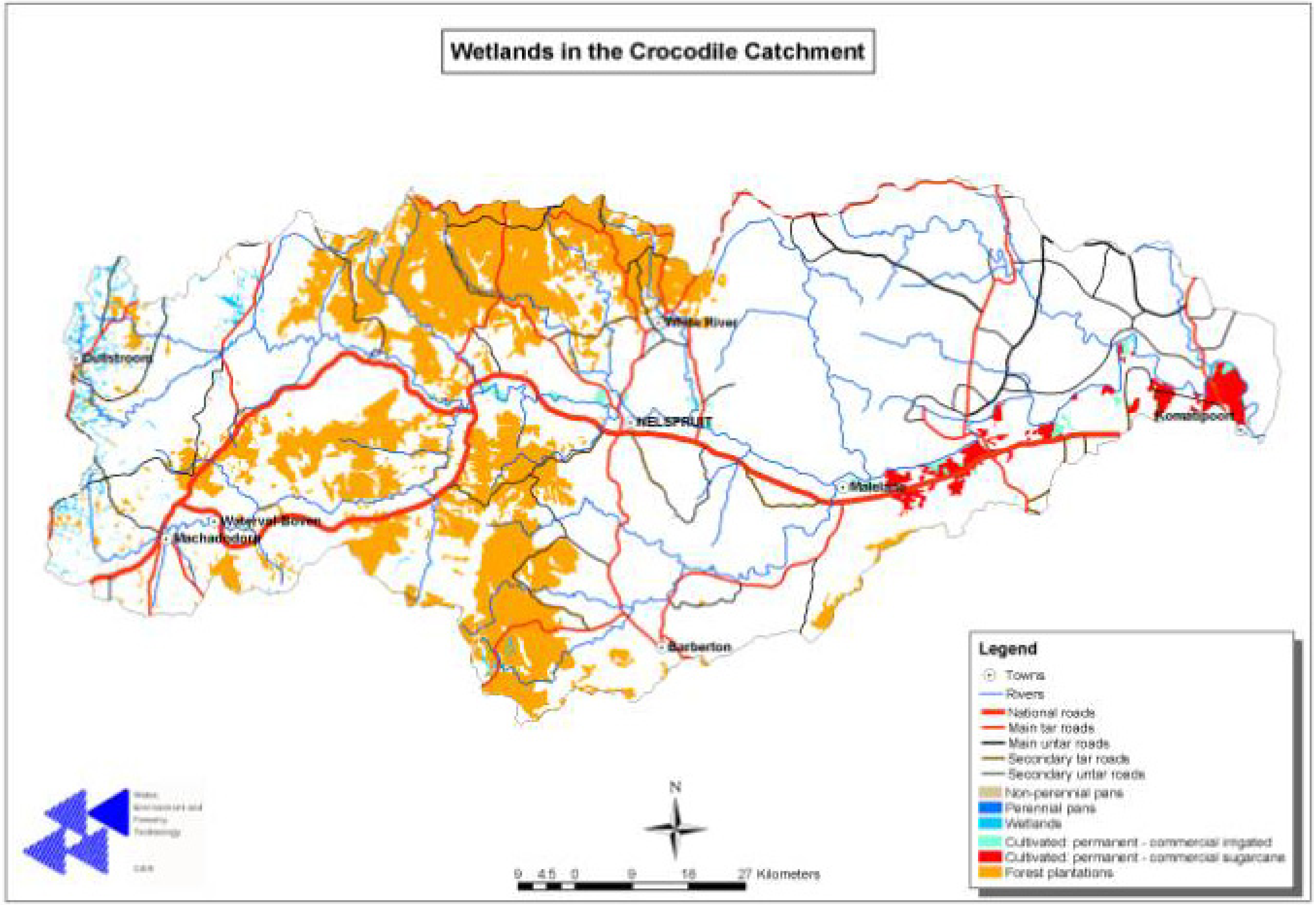


Figure 5.7 depicts the spatial distribution of wetlands within the catchment. These are found mainly in the upper reaches of the catchment and do not appear to be impacted too directly by the three land use activities under review in this study.

Figure 5.8: Conservancies and reserves in the Crocodile River catchment

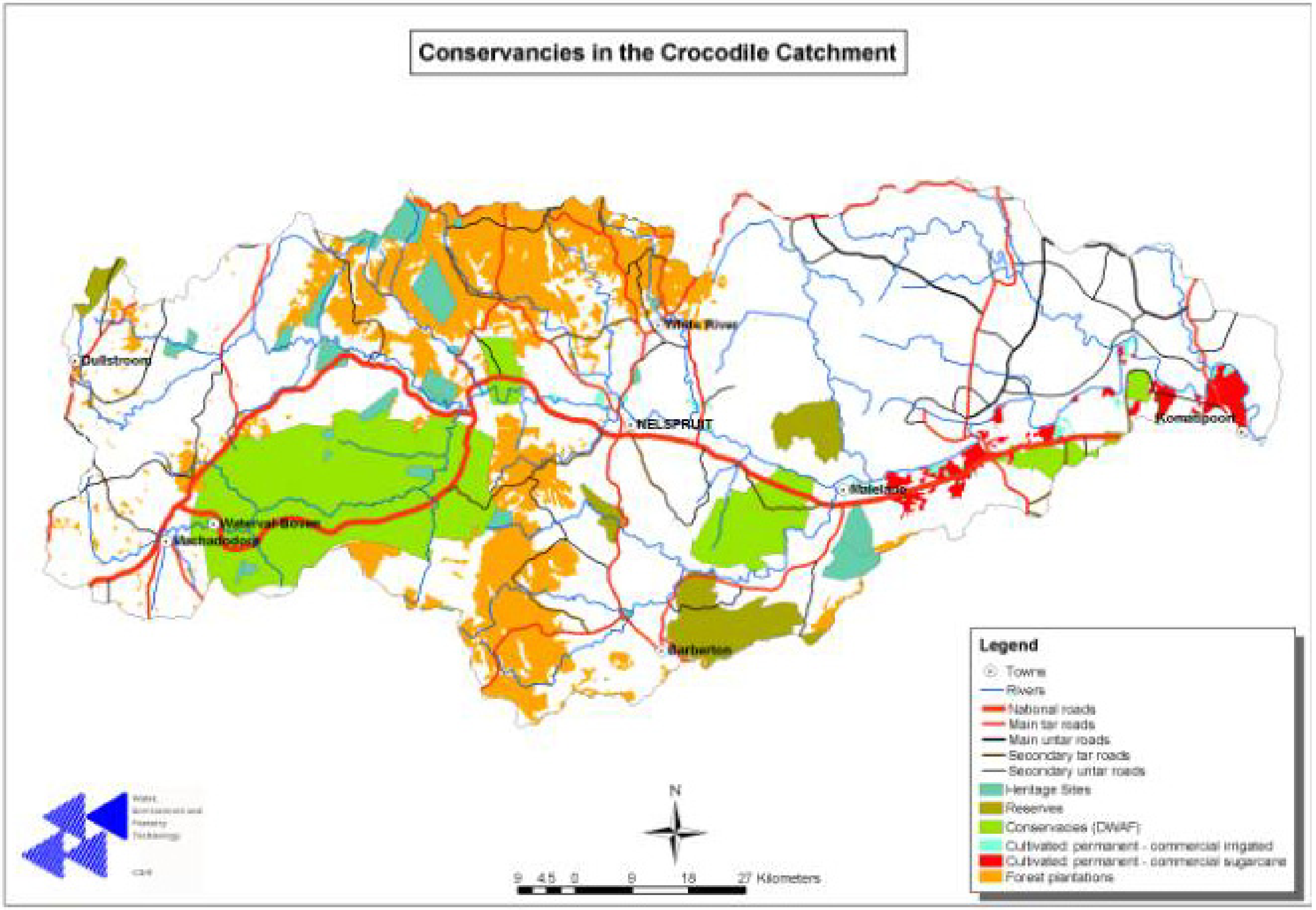


Figure 5.8 depicts the reserves and conservancies within the catchment. The reserves are shown in brown and the conservancies are shown in green. Reserves are barely impacted by the three land use activities. Some Forests and Fruit farming land are incorporated within the conservancy areas.

Figure 5.9: Natural phenomenon in the Crocodile River catchment

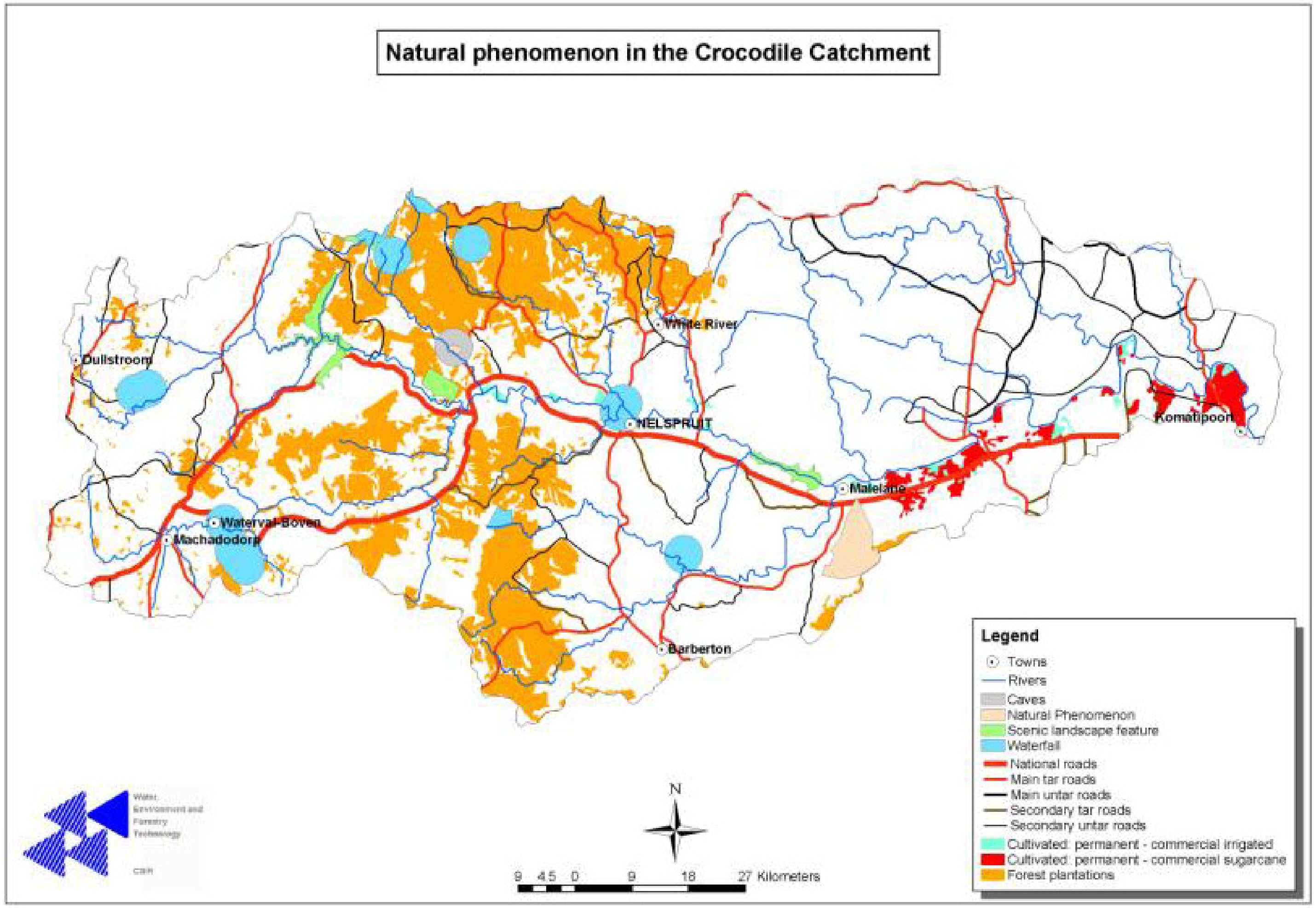


Figure 5.9 shows the occurrence of natural features such as caves, waterfalls and scenic landscape which people value for their beauty and/or uniqueness. These areas are mostly associated with the mountainous areas of the upper catchment region where forestry is the predominant land use.

Figure 5.10: Natural phenomenon in the Crocodile River catchment

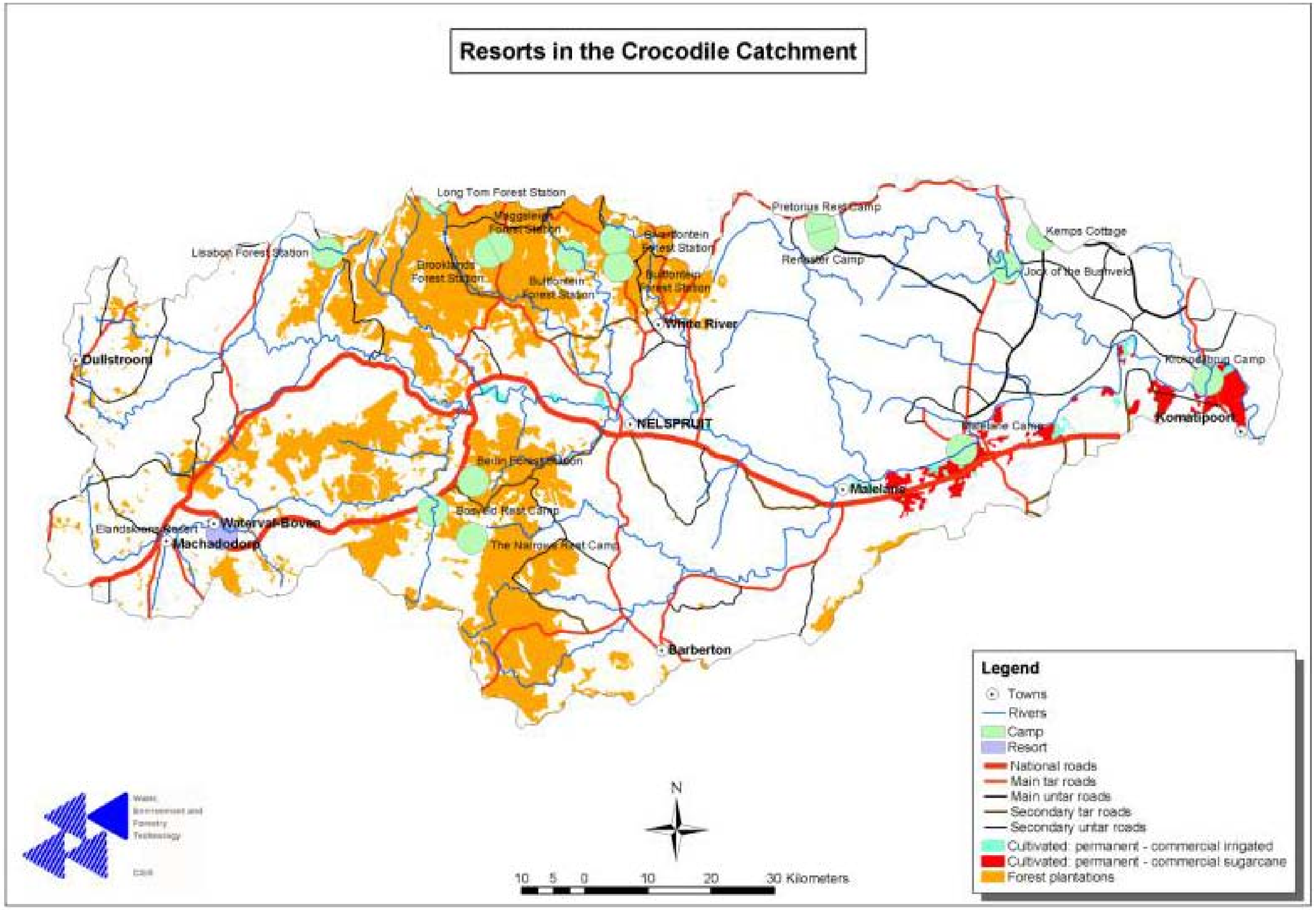


Figure 5.10 shows that the bulk of the resorts in the catchment are located either within or in close proximity to Forestry and the other farming activities.

5.4.7 Human Health

The linkages between environmental degradation and human health are often difficult to quantify directly and are not always clearly observable. This study recognises that this link is a necessary and important one to make, if one is to fully appreciate and internalise all environmental impacts, especially those related to social welfare. However, the majority of studies estimating human health impacts are highly site specific, dependent on clearly defined study parameters and measures the marginal effect of activities. The reason for this is based on the methodology behind these kinds of estimates that applies the quantified dosage level of the pollutant to the number of people affected at a micro-economic level. The degree of these impacts are then also defined by the health profiles of these people in terms of their existing levels of immunity, time of exposure to the pollutant, age and predisposing factors. Dose-response calculations then determine the health risks of contracting certain air-pollution related disorders. Such micro-level analyses were beyond the scope of this study and it is recommended that they be done once level three data is more readily available.

5.5 SUMMARY

The direct water use of the sectors investigated constitutes more than 97% of the water used in their value chains. Incremental water use by Forestry is estimated with a different technique to that of Sugar and Fruit. Although the Sugar water use models have been adapted for the purposes of this and the prior study (Olbrich and Hassan, 1999), the Fruit water use model has not yet been sufficiently refined and may yield marginally different results.

Other environmental impacts of could only be determined as dose impacts at a macro level. SA data-constraints forced the use of USA data, adapted through a benefit transfer study. In addition, determination of dose-responses and the subsequent effect on human and environmental health could not be done due to the macro-economic scope of the study and the absence of dose-response data.

However, the results gathered from the available data showed that the value chains with the larger economic impact have larger environmental dose impacts.

CHAPTER 6:

SOCIAL IMPACT ANALYSIS

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6.1 INTRODUCTION

This Chapter analyses the social impacts of Forestry and irrigated Sugarcane and sub-tropical Fruit.

Social science deals with issues ranging from the drivers of social behaviour in social, environmental and economic systems to ways in which these systems impact on the *quality of life* of society. As was the case with the economic and environmental analyses, a framework for social impact analysis had to be designed to suit the specific purposes of the study. A two tiered approach was followed, involving firstly quantitative modelling, and secondly, qualitative analysis. The quantitative approach modelled distribution of employment income to rural households. The main area of analysis was the impact on rural poverty alleviation. However, it was recognised that income (or low income) constituted only one aspect of poverty. Other aspects, related to the broader concept of quality of life and sustainability of rural livelihoods were also considered.

6.2 METHOD

6.2.1 Concept and definition of Social Impact Analyses

The boundaries between economic, environmental and social analyses are often overlap. In this study, for instance, the benefits of direct and indirect employment formed part of the economic impact analysis, while emissions into the environment may have detrimental effects on human health. Whereas the economic impact analysis quantified the benefits of employment, and the environmental impact analysis investigated indicators of positive and detrimental health effects, it was decided to focus the social impact analysis on describing the recipients of the public costs and benefits (externalities) resulting from the different land uses, and to analyse as far as possible the effect of these impacts on them.

It has to be noted that, due to the nature of the project and size of the study area, social impact ***assessments*** (SIA's) were inadequate tools for the purposes of this study. These assessments often form part of (or are) Environmental Impact ***Assessments*** (EIA's) that precede project or policy developments. They are stakeholder/community-driven processes and are important tools in participatory governance and decision-making. SIA's are typically done when the impacts that a project or policy may have on a specific social environment needs to be investigated. It would characteristically describe the current state of the social environment and predict the most likely changes that would take place after implementing the project or its alternative. In addition, SIA's are intended to develop means of alleviating perceived negative social changes (NEPA Call-In 1998). This process takes on a public participatory or consultative approach, is run according to strong principles (see Appendix 5) and incorporates the opinions and issues identified by the affected entities, along with the impacts identified through social science expertise (Duncker and Ndhundhuma 1997: 3-4, U.S. Department of Commerce 1994). Every SIA is unique as it focuses on individual communities and their specific concerns and issues, and "data" often take the form of stakeholder / community opinion and concerns.

Social impact analyses yield, by nature, qualitative results. The overall framework and purpose of this study did, however, require some quantitative analyses for comparative purposes. At the same time it was recognised that quality of life cannot be modelled, therefore qualitative analyses were also required. A two-tiered approach was therefore adopted where; firstly, the benefits from employment and other quantifiable benefits yielded from the different crops were modelled in order to simulate the distribution effects of changes in water use patterns on households. Secondly, a more qualitative analysis of certain aspects of social importance was conducted.

6.2.2 Analytical framework

6.2.2.1 Benefit distribution modelling

The direct and indirect employment benefits of the three crops were modelled to estimate its distributional effect on households. Employment benefits were measured in Chapter 4 in person-days per m^3 or ton of crop produced (with 250 person days being equivalent to a full-time job).

Households were classified based on specific characteristics that indicated its socio-economic state. These characteristics have roots in the historical background of South Africa as well as the earning potential due to the types of employment and the ability to work. The characteristics used in this model were *Type of employment*, *Skills level*, *Race*, *Gender* and *Location*. Sub-classifications per characteristic were based on classifications documented by Statistics South Africa. *Type of employment* consisted of full-time or permanent employment (regular employment), temporary or seasonal employment and casual employment. *Skill levels* consisted of managerial, skilled, semi-skilled and unskilled job requirements (Skilled occupations are defined as those occupations that require a minimum of two years post-matriculation training or education (CSS 1991: 2.10). For *Race* it was Africans, Coloureds, Asians and Whites. *Location* consisted of urban and non-urban areas.

6.2.2.2 *Descriptive analysis*

The descriptive analysis focussed small grower and contractor schemes and social investment by the industries involved. Spatial analyses were used to investigate and discuss the prevalence of cultural heritage sites and other social infrastructure. The spatial analysis was focussed only on Crocodile River catchment.

6.2.3 Data acquisition

The employment (primary) data captured and reported on Chapter 4 of this report, were used as the totals per industry in this part of the model. An extensive literature survey was done to acquire existing data related to employment benefit distribution and household characteristics in the three land uses and their related industries. The survey concentrated on data from relevant publications, reports and online information specifically relating to these three industries in Mpumalanga. As far as possible, 1998 data for Mpumalanga was used. South African national industry-specific data was used as a substitute to Mpumalanga data where this was unavailable. Statistics South Africa provided the principal sources.

Sub-classification of households into *Type of Employment* were aggregated using occupation level classification from *Census '96* for the sub-tropical fruits and sugar industries, and the *Employment Survey in the Forest Sector* for the forestry industry (LHA Management Consultants 1997a). The managerial level was defined by managers in the *Census '96* data; skilled workers were aggregated from the data for professional, technicians and skilled agricultural employees; semi-skilled employees from clerks, sales, craft and assembly employees and unskilled labourers are determined by the data in the elementary category. The sub-divisions for *Skills Level* in the forestry sector were determined from the survey for plantations; saw milling, pulp and paper milling and contractors, while the other related industries were broken down according to the occupational levels in the related areas within *Census '96* (LHA Management Consultants 1997b).

Spatial data was obtained from the Biobase Database of the Department of Water Affairs and Forestry (DWAF, 2002c), the ENPAT Database of the Department of Environmental Affairs and Tourism (DEAT, 2001), and the SAExplorer Database (DWAF, 2002c) used by the Department of Water Affairs and Forestry for water supply and sanitation planning.

6.2.4 Benefits distribution model

The distribution of benefits to households was expressed as person-days per m^3 or ton. The Household classification defined above was combined with the respective value chains of the crops, in order to quantify the impact of both direct and indirect employment on households. The direct benefits were the result of direct employment in the primary plantation and agriculture activities (i.e. roundwood, sugarcane and sub-tropical fruit production), while the indirect benefits resulted from the sum of all relevant intermediate or final goods produced in the forward linkages of the respective value chains. This yielded an employment benefits coefficients matrix.

The breakdowns per crop type were derived by multiplying the employment values, derived in Chapter 4, by the employment benefits coefficient vectors. The generic formula used for the separate breakdowns of each crop type (expressed as person-days per m^3 or ton) was as follows:

$$t_{ijk} \times \mathbf{c}_{\mathrm{l}} = \mathbf{r}_{\mathrm{ijkl}}$$

Where,

t_{ijk} = the total number of person-days for the *i*th crop type, in the *j*th type of involvement within the *k*th segment of the value chain;

$\mathbf{c}_l$ = the row vector of coefficients for the *l*th type of breakdown;

$\mathbf{r}_{ijkl}$ = the results (column) vector of the *i*th crop type, in the *j*th type of involvement within the *k*th segment of the value chain for the *i*th crop type expressed in terms of the *l*th type of breakdown;

i = {forestry, sugarcane, avocados, bananas, grapefruit, mangoes, oranges}

j = {labour}

k = value chain as determined per crop type

l = {type of employment, skills levels, location, gender, race}.

The second set of summary tables (expressed as total employment) was derived using the following formula:

$$r_{ijkl} \times P_j = R_{ijkl}$$

where,

P_j = the scalar of product flow in the value chain, expressed in m^3 or tons,

R_{ijkl} = the vector of jobs created in Mpumalanga in terms of equivalent person-years for all value chain activities.

6.3 THE RECEIVERS OF SOCIAL BENEFITS AND COSTS

The so-called receivers of social benefits and costs investigated in this study can broadly be described as the resident society in Mpumalanga and, to a lesser extent, tourists visiting the area. Within these two groups it was recognised that poverty is a key variable in the sustainable development of the region's economy and social adaptive capacity.

It is commonly known that poverty is largely associated with rural areas, and that poverty alleviation strategies in South Africa are largely aimed at the alleviation of rural poverty, rural land uses such as those under discussion have large roles to play in the livelihoods and social sustainability of poor households. Rural livelihoods are sustainable if adequate stocks and flows of food and cash is available to a household to meet its basic needs and social reproduction requirements. Social sustainability refers to the ability of a household, internally, as well as in its interaction with other households, to maintain the ability to create wealth, and to foster social integration and cohesion (DWAF, 2002b). To these ends, forestry and irrigated agriculture not only provide employment, but also create opportunities for households to acquire land and capital assets through outgrower and contractor schemes. In addition, the forestry and irrigated agriculture industries contribute to livelihoods through corporate social investment programmes.

Water and poverty are intimately linked to such an extent, that access to water is often used as a poverty indicator. Although this linkage is mostly associated with access to safe drinking water and sufficient supply of water for other basic needs, water also has a large role to play in poverty reduction through economic productivity. The implementation of basic water supply services to RDP standards to rural households has facilitated an increase in vegetable, small livestock and other subsistence farming (Kruger, 2002). Conversely, forestry and irrigation agriculture may compete for water and land with rural communities, leading to social conflict over ownership and access (DWAF, 2002b).

6.4 RESULTS OF SOCIAL IMPACT ANALYSIS

6.4.1 Employment benefit distribution

The analysis of person days per m^3 or ton of product in the forward linkages have to be assessed carefully, as this unit of measurement excludes many important variables such as salary and wage rate and the weighting effect of product flow. Direct comparisons of the three value chains represented in Table 6.1 (Appendix 8) should therefore not be done, based on employment in person-days per m^3 or ton.

Plantation forestry created ***direct employment*** opportunities of which 85% were in rural areas, 72% were for males and 70% were for Blacks. Insignificant part-time, seasonal or casual employment was created. ***Indirect employment*** opportunities in the solid wood processing sectors involved mostly

Blacks (84% in solid wood processing, 67% in board manufacturing, 47% in pulp and paper manufacturing and 61% in furniture production). Skills level increased from plantations (mostly unskilled), through solid wood processing (mostly semi-skilled) to pulp and paper manufacturing (39% skilled). The largest part-time and casual employment was in charcoal (11%) and board manufacturing (10%) respectively (Table 6.2, Appendix 8).

The ***direct employment*** opportunities from ***sugarcane and sub-tropical fruit*** production display similar proportional breakdowns, as both were agricultural activities of similar nature. In addition, many farmers grow both crops on the same management unit, and therefore employ the same workforce during its production. As in forestry, employment opportunities were male dominated (72%), and most labour opportunities were for Blacks (68%) in rural areas (87%). Seasonal employment plays a large role, especially in the sub-tropical fruit sector (Bekker, 2001). Unfortunately, no published data could be obtained for this. ***Indirect employment*** opportunities in forward linkages were dominated by semi-skilled jobs, and Blacks; with a 25%-30% casual and part-time employment component (Tables 6.3 & 6.4, Appendix 8).

Male employment dominated the ***indirect benefits*** in ***all industries*** (60%-66%). Sub-tropical fruit had significantly higher part-time and seasonal labour components, of nearly 25% of total jobs created. Forestry employed the highest skills levels, with 5% more skilled employees than the other two value chains. Between 50 and 56% of all jobs fell in the semi-skilled category. The urban/rural distribution was equal at nearly 50% each. The highest proportions of Blacks were employed in sugar, followed by forestry (Table 6.1, Appendix 8).

It was recognised that ***income distribution of employment benefits*** would yield a different picture to the above in terms of all the household categories. However, not enough data was available to accurately simulate income distribution. As an example, the bulk of Black households benefitting from direct employment benefits received farm worker wages. Average wages paid to unskilled workers in these sectors are categorised by the Department of Labour into four groups, based on magisterial districts. The magisterial of the Crocodile catchment that is of relevance fall in Group 2 at R 695,00 per month (Waterval Boven), Group 3 at R588,00 per month (Nelspruit), and Group 4 at R450 per month (Baberton, Witrivier) (Government, 2001).

Tables 6.5, 6.6 & 6.7 (Appendix 8) show the total employment (equivalent person-years) created in Mpumalanga per crop type. Plantation forestry generated 10 195 equivalent person-years of direct employment and 19 309 equivalent person-years of indirect employment. Most employment opportunities (85%) in the sugar industry resulted from the direct benefits of sugarcane production (12 485 equivalent person-years). In the sub-tropical fruit industry, 8 923 equivalent person-years of employment was created, of which 74% was direct employment.

Plantation forestry and irrigated sugarcane farming provides the most direct employment, largely because of the proportion of land used is far greater than that used for sub-tropical fruit production. Indirect employment is dominated by forestry.

6.4.2 Descriptive analysis

6.4.2.1 Small grower schemes

Mpumalanga has smallholders doing sugarcane and sub-tropical fruit irrigation agriculture (WRC, 2000). There are no forestry small growers in Mpumalanga (Mayers, et al, 2001).

Approximately 15% of ***sugarcane*** in South Africa is grown on communally held land. Sugarcane provides what the small growers want: a good/safe entry crop; good returns and low risk; ready markets; institutional and technical back-up, and a reliable service. Sugarcane provides the best entry crop for new farmers given the institutional back-up and technical, financial and associated support they receive from the sugarcane industry. No other private and/or government institution can provide the same service (Scott Wilson, 1998). The small growers and the sugar industry cooperate on many levels to create a win-win situation for both. Land-redistribution initiatives by sugar millers and commercial cane growers (mostly White) were introduced in the 1990's to settle Black cane growers (60-90 ha plots), yielding 41 tons/ha/a. The cooperative effort involves centralised industry sourcing and management of credit. To these ends, contract farming systems are in place, which allow small growers advances for annual tasks, which are later deducted from milling proceeds. Markets are guaranteed and millers act as agents and extension services. The sugar industry also created a fund, Umthombo AgriFinance, to finance cane development against the security of a cession on the income from the crop. The sugar industry also facilitates government support to small farmers through tariff protection and infrstructure support (Maloa, 2001; Mayers, et al, 2001; SASA, 2002). There is much evidence to suggest that many sugar production related jobs and entrepreneurial opportunities have arisen, primarily in the Natal sugar belt, but this has not taken off to the same extent in Mpumalanga where farming units are larger (7 - 10 ha under irrigation) and the haulage distance to the sugar mills is longer (in excess of 30 km) (Conningarth, 1998a).

The Fruit crops require higher initial investment and there is no industry infrastructure similar to the sugar refining activity of the sugar industry to coordinate small farmer assistance (Scott Wilson, 1998).

Both the ***forestry and sugar industries*** support small contractor programmes aimed at developing viable black contracting businesses which can provide efficient services to commercial forests and the small cane grower sector respectively (Maloa, 2001).

6.4.2.2 Spatial analysis

Figure 6.1: Location of vulnerable households in the Crocodile River catchment.

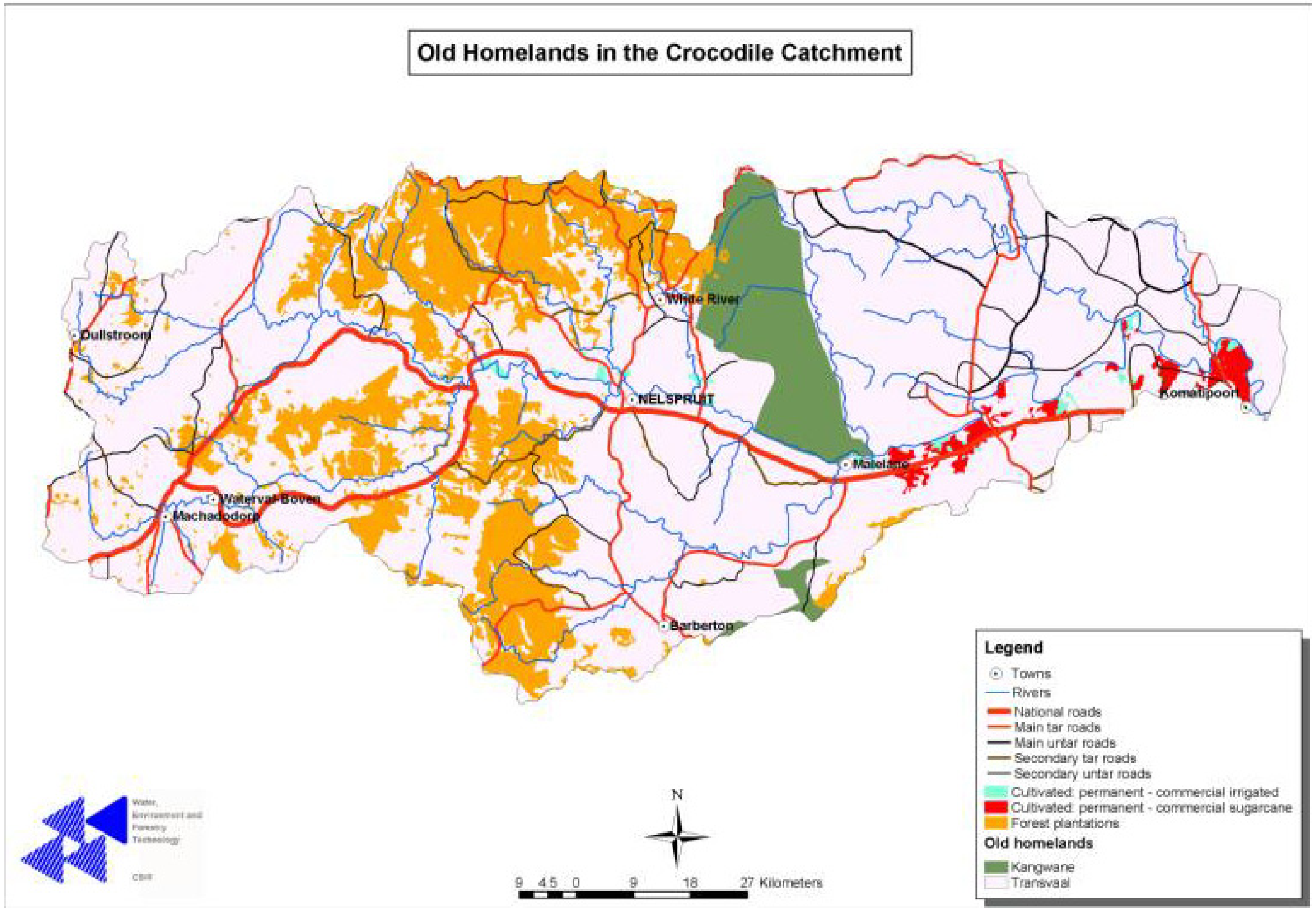
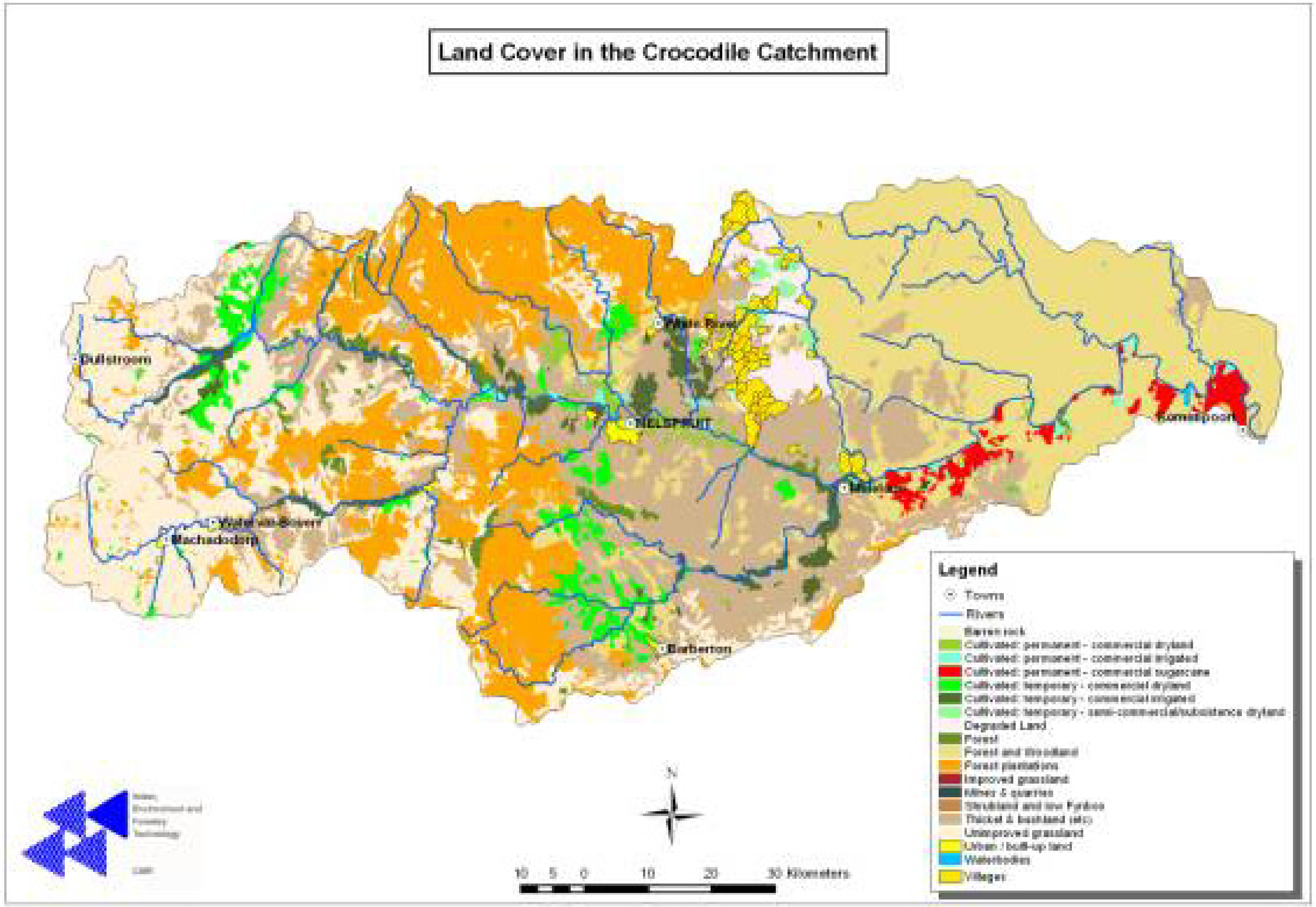


Figure 6.1 shows the location of the former homeland of Kangwane, where the highest probability of poverty prevalence household vulnerability exists. Figure 6.2 shows the location of the major villages within Crocodile River catchment, which corresponds mostly with the former homeland area.

Figure 6.2: Land cover in the Crocodile River catchment.



From Figure 6.2 it is clear that the forestry and irrigation activities are not located close to the vulnerable households, eliminating to a large extent the potential for conflicts over land access. It can be expected however, that employment benefits may filter to these households, through migrant labour.

Figure 6.3: **Location of farming management units in the Crocodile River catchment.**

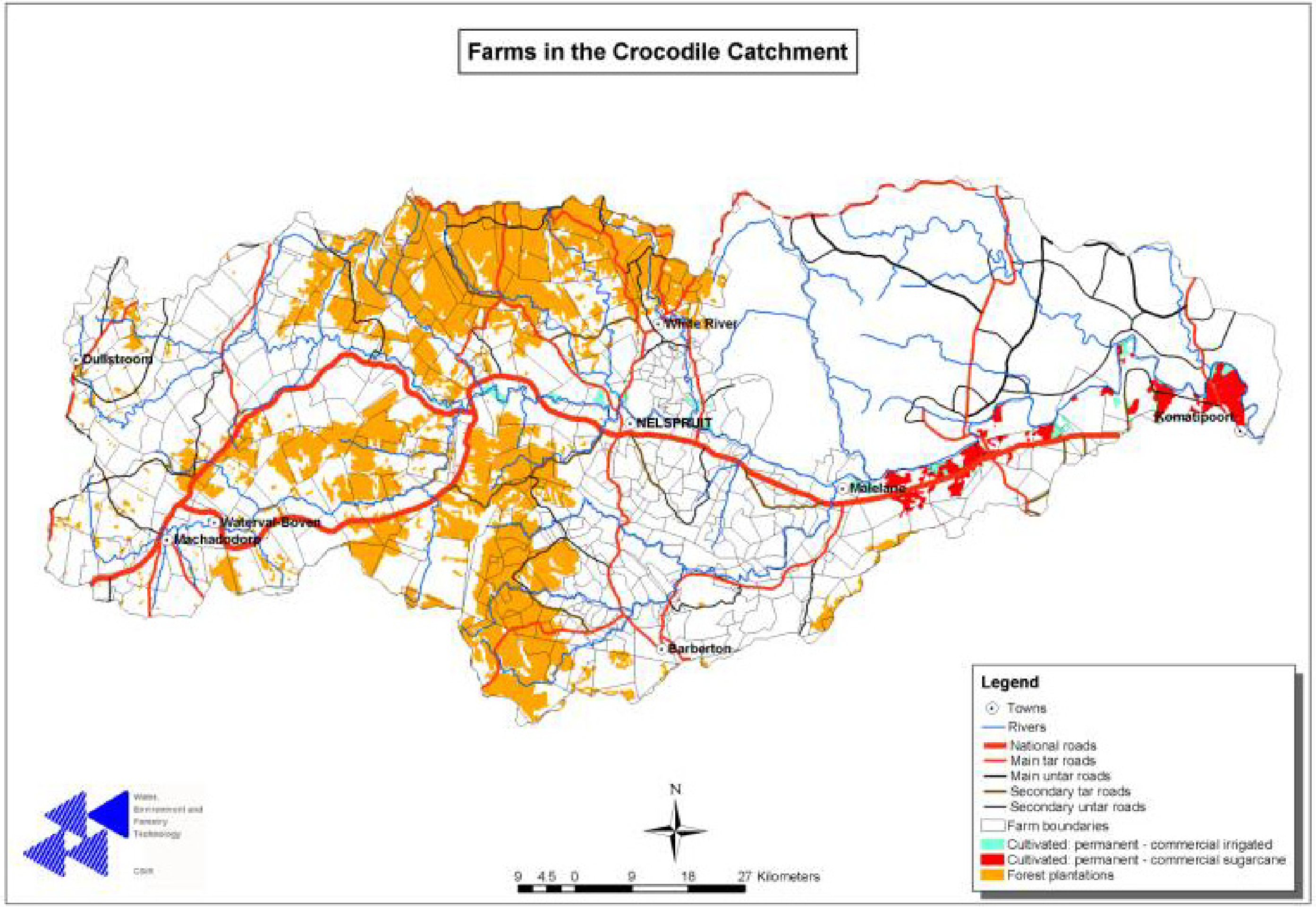
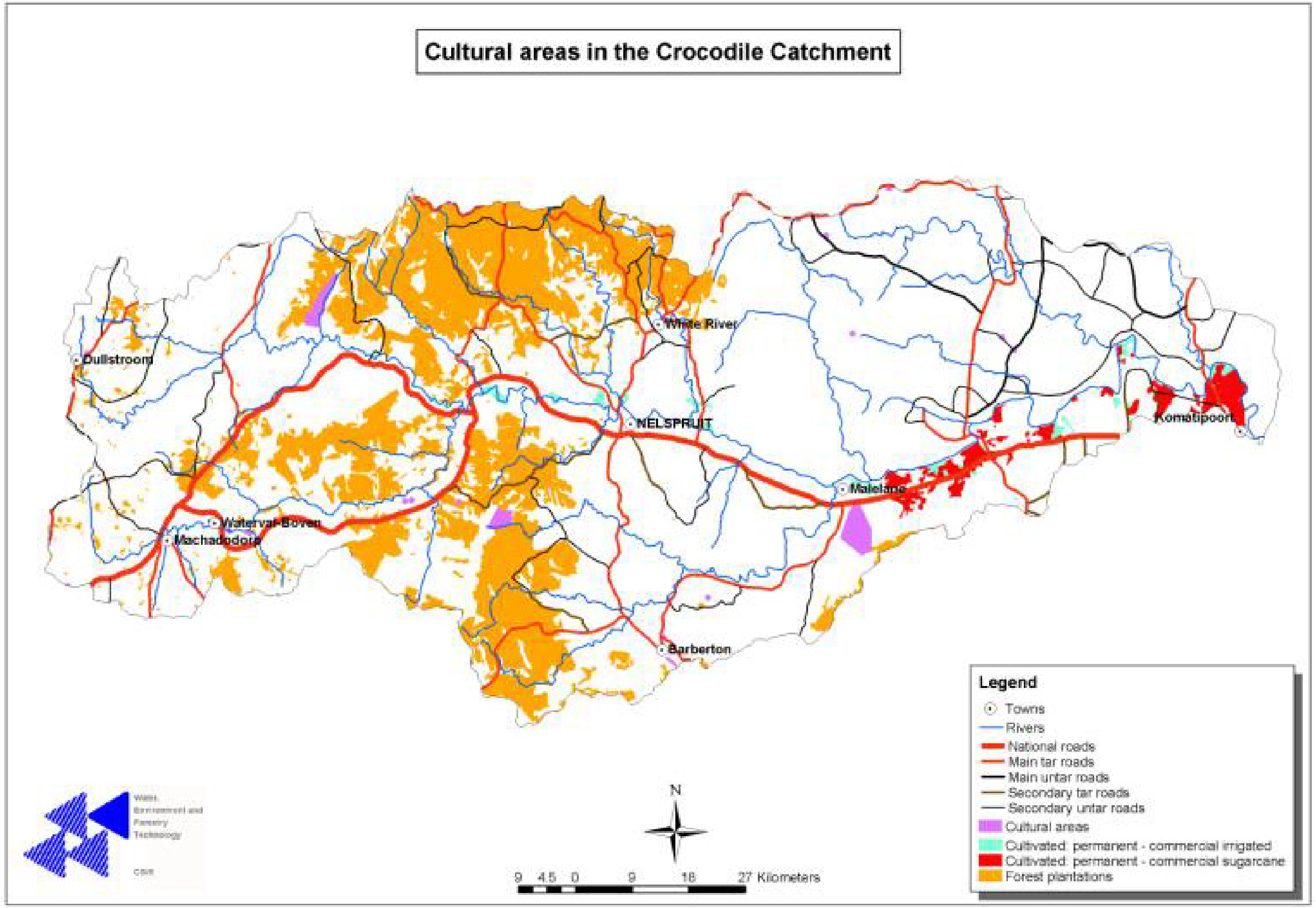


Figure 6.3 shows the farm boundaries for each catchment. It shows the relative size of the forestry and irrigation farming management units and extent of communal land in the former Kangwane.

Figure 6.4: Location of cultural areas in the Crocodile River catchment.



Three areas of large cultural significance exist in the study area of which two are located between Forestry plantations.

6.4.2.3 Social corporate investment

The forestry and irrigated agriculture industries contribute to physical and social infrastructure by maintaining roads and housing, small business development, and through corporate social initiatives investing in clinics, hospitals and education for its employees and their families (Sappi, 2002; Verryn, 2002; SASA , 2002; Maloa, 2001).

6.4.3 Contributions to livelihoods

Approximately seventy percent of all agricultural farm workers in the study area are male. They are relatively young, their household size is relatively small and they are mostly SA citizens (Government, 2001).

Generally speaking, the expansion of forestry and irrigation activities in rural areas in South Africa has the potential to create conflict between rural communities and foresters or farmers. In the Crocodile River catchment, however, where water is already a scarce resource and the potential for expansion of these land use activities are limited, there is a lesser risk for such conflict. In areas where water scarcity is not as prevalent, the expansion of forestry and irrigation activities are subject to comprehensive biophysical and social impact assessment processes. The owner of the property on which new plantations or irrigation is planned, has to apply to the Department of Water Affairs and Forestry and the Department of Agriculture respectively; after which the respective Departments run intradepartmental processes. Depending on the outcome of these processes, the relevant Department may request an EIA to be completed, which includes a social impact assessment (Stemmet, 2002). Whereas expansion of these activities was a threat to rural communities' livelihoods, through forced relocation, in the previous political dispensation, the legislation described above is now preventing such threats.

Household management of the financial returns of labour, land and capital resulting from the value chain activities of the three crops are diverse. Salaries and wages earned from labour are usually spent on the daily activities of purchasing food and transport services, and some may be sent to families residing in the communal areas of the former Kangwane. The proceeds from land and capital by outgrowers or small contractors are usually spent on essentials such as school fees, buildings, building improvements, marriage payments or paying off or purchasing vehicles (Mayer et al, 2001).

CHAPTER 7:

COMPARATIVE ANALYSIS OF THE ECONOMIC EFFICIENCY OF WATER USE

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7.1 INTRODUCTION

Based on the results of the preceding analyses, total economic benefits generated by the different value chains are compared in this section. Although the comparison is based on per unit water used, it is important to remember that this comparative analysis is not meant to determine the marginal value of water used by the compared activities or provide information on water pricing. The numbers generated here do not by any means provide a measure of the marginal value or price of water. The purpose of this analysis is rather to reveal how much total social and economic value is generated from using water in the compared alternative economic activities.

7.2 COMPARATIVE ANALYSIS

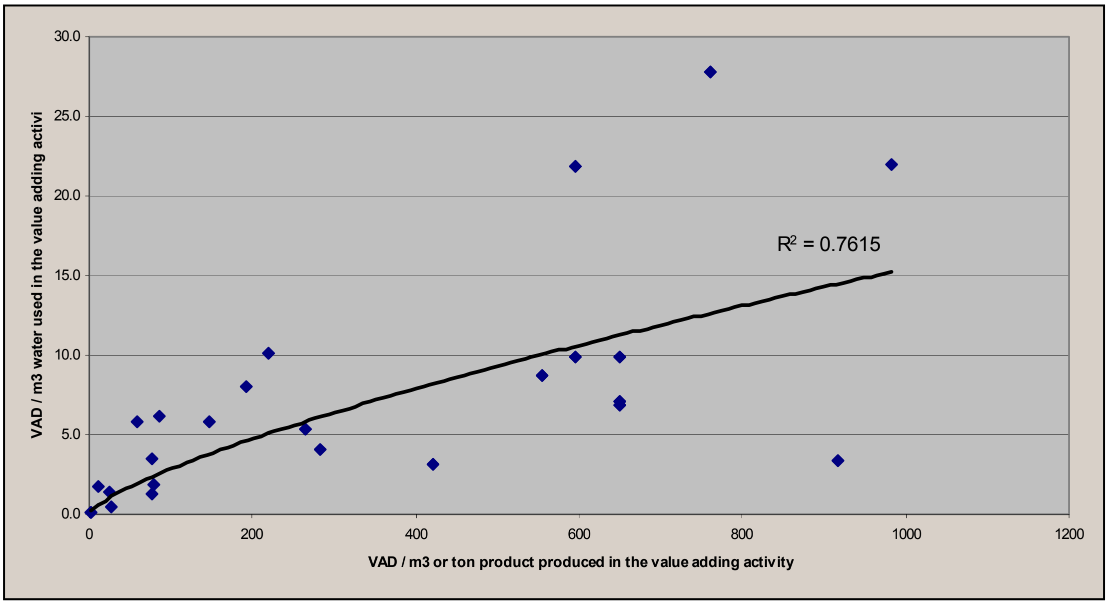
7.2.1 Direct and Indirect effects

As described earlier, total economic benefits associated with the use of water in the alternative value chains compared in this section, represent ***benefits directly realized*** in the sectors under investigation, and in addition the ***benefits indirectly accruing*** to sectors supplying inputs (backward linkages) or processing outputs (forward linkages). Total economic benefits are measured as total value added (VAD) and employment (full-time jobs equivalent) per unit water used by the compared economic activities. The results of the comparative analysis are presented in Table 7.2.

According to the VAD measure of economic benefits ***directly*** generated by the sector in question, irrigated mangos and oranges dominated other productive activities followed in a distant second place by production of pine roundwood. However, when ***indirect*** benefits in terms of VAD realised in upstream and downstream sectors forming the backward and forward linkages were taken into account, the comparative position of the various sectors changed significantly (Table 7.2). Production of pine roundwood generated highest total benefits in terms of direct and indirect VAD per cubic meter of water used, followed by eucalypt roundwood. As discussed earlier, the ranking of pine over eucalypt is attributed to the high value addition in processing pine timber in Mpumalanga for furniture and wood products (F&WP) compared with the high share of processing eucalypt roundwood for mining timber, which earned much lower VAD than F&WP. The position of sub-tropical fruits changed drastically compared to irrigated sugarcane farming and forest plantations when indirect benefits were accounted for. While mangos are ranked slightly behind sugarcane, the gap was much wider in the case of the other fruits. The fact that sub-tropical fruits undergo very little processing beyond the farm gate compared to the various chains of timber and sugar processing downstream is the main cause of this result. While almost 100% of the fruit crops are sold in the fresh produce market or exported fresh, most of the harvested timber and sugarcane go through a number of phases of further processing before sold as final products, whether locally or in external markets.

Figure 7.1 shows the progressive increase in VAD/m^3 of water used for the pooled data of the three value chains. The lower bounds of these data represent the lower VAD multiplier fruit value chains, while the upper data points represent forestry value chain activities. On the whole, this graph shows the importance of incorporating the forward linkages (and indirect effects) of land uses that depend heavily on water into analyses of water apportionment.

Figure 7.1: Increase of VAD/m^3 water used with increased value production in the value chain.



Source: Data extracted from Tables 4.2, 4.4 and 4.6

Sub-tropical fruits, especially mangos and oranges, ranked better in terms of ***direct*** employment benefits compared to timber plantations and irrigated sugar (Table 7.2). Similar to the case of total VAD measure of economic benefits, sub-tropical fruits were ranked lowest when ***indirect*** employment benefits were taken into account. More full-time jobs were realised in the production of timber from pine and eucalypt trees than the rest. Production of sugarcane under irrigation in Mpumalanga also dominated sub-tropical fruits in terms of total employment benefits.

The distribution of employment benefits showed that increased skills levels were required towards the consumer end of the value chains for all the crops, indicating that these VAD activities benefited households with stronger educational structures (see Chapter 6). Whereas the primary crop production benefited far more non-urban that urban households, all three value chains located their higher end value adding activities towards urban areas.

The environmental coefficients analysis in Table 7.1 shows that longer values chains have higher indirect environmental impact multiplier effects. To produce a ton of sub-tropical fruit for instance, required nearly 40% more energy than to produce a ton of roundwood. However, after accounting for the ***indirect*** energy multiplier effect, a ton of timber entering the forestry value chain used 95% more energy than a ton of fruit that entered and passed through the fruit value chain. In the sugarcane value chain, the net energy multiplier was rather low, in spite of the long value chain; this was due to the extensive use of bagasse as a boiler fuel. All three value chains had air emissions (pollutants and greenhouse gases) due to transport activities and releases from soil, but the forestry value chain had by far the largest indirect air emissions, due to its high energy use in the pulp and paper; board manufacturing and charcoal manufacturing sectors. In general, the shorter sub-tropical fruits value chain had the lowest environmental sink requirements per ton of product produced.

7.2.2 Value chain comparisons

Based on the economic impact analysis (Table 7.2.1), ***pine forestry***, with its associated longer value chain, added the most economic value to an **incremental** cubic meter of water used, and produced the largest ration of employment opportunities (R21.27/m^3). However, when using **evpotranspiration** as a basis for comparison, forestry activities had the lowest economic beneficiation values, with pine forestry marginally more productive than eucalypt forestry at R1.52/m^3 water (Table 7.2.2). The value adding activities in this value chain also produced the largest environmental pressure per cubic meter of water used: requiring the second-most energy (after Eucalypt), producing the largest contributions to water pollution (BOD and TSS), and emitting the largest quantities of air pollutants and greenhouse gases. At a first glance, this implies that the larger economic benefits yielded were associated with increased environmental costs that are borne by society as a whole (or externalities). However, pine forestry is closely associated with two important environmental services, which yield benefit to society. Carbon uptake forms part of the photosynthesis process that occurs during tree growth. If the xylem (wood) remains intact in a solid wood form (mostly timber) for a period of longer than 25 years, the carbon is considered sequestered (Van der Merwe, 2002). Modelling of carbon sequestration in the value chains showed that it was 1,97 kg/m^3 water (used in the value chain), which was higher than the total, equivalent carbon, greenhouse gas emission of the value chain of 1,82 kg/m^3 (Table 7.2) In addition, large areas of forestry estates comprise managed indigenous forests and riparian zones. Based on an estimate of 20% of the total forestry estate in Mpumalanga, this comprised 50 000ha. As

South African forestry is increasingly moving towards full certification of its forests, it is reasonable to assume that these areas are managed sustainable, which may provide biodiversity benefits to society.

The ***eucalypt*** value chain follows a similar pattern to that of the pine (Table 7.2.1 and 7.2.2). After pines, it was the second largest producer of value and employment to a unit of water that flowed into the chain. It had the highest energy requirements per cubic meter of water of all the value chains, due to its use in charcoal production. However, its carbon sequestration capacity was by far the largest of all the value chains, was nearly double that of the pine value chain, and four times its greenhouse gas production. This was due to the relatively large volume of mining timber produced from eucalyptus roundwood, with zero net carbon emissions. The biodiversity management benefit discussed above for forestry estates also holds for Eucalypt forestry. The two forestry value chains have the highest ration of water recycling, this is attributed to pulp and paper industry with its large emphasis on closed water systems.

Sugarcane appears to be the "middle of the road" value chain when incremental water use is used as a basis for comparison (R9.91/m^3) (Table 7.2.1). After forestry, it produced the second highest total (direct + indirect) economic value added and employment to a cubic meter of incremental water used, but it also placed a smaller demand on the environment as a sink and energy source (Table 7.2.1). When using evapotranspiration as a basis for comparison, sugarcane was the most water efficient crop at R7.69/m3 (Table 7.2.2). The total and direct air pollutant emissions for sugar were the highest of the values chains. This could be attributed to burning on the cane fields and the burning of bagasse for boiler fuel. On the other hand, sugarcane was also the most energy efficient of all the value chains, because of the fact that bagasse is a waste material from the sugar milling process, and therefore also a low cost form of energy, both from a private (firm) and an externality (society) point of view. The biodiversity management benefit discussed above for forestry estates, also holds for sugarcane farming.

The ***sub-tropical fruit crops*** were at the lower end of value addition to water use scale (Table 7.2.1) when incremental water use was used as a basis for comparison. Mangos (R8,91/m^3) produced total VAD of slightly lower than sugarcane (R9,91/m^3), followed by oranges, grapefruit, avocadoes and bananas. When considering evapotranspiration as a basis for comparison (Table 7.2.2), fruit crops were placed midway between sugar cane and forestry as a water efficient crop (R2.06/m^3 – R4.53/m^3). These crops also had by far the least significant environmental impacts per unit of water used of all the value chains. These crops were the largest users of fertiliser, which, in the long term, may increase the risk of soil salinisation and non-point source water pollution if irrigation and other on-farm systems are not managed optimally. The biodiversity management benefit discussed above for forestry estates and sugarcane farming, also holds for fruit farming.

Table 7.1: Comparative direct and indirect Emission coefficients E_{ij} for the Forestry, Sugar and Fruit value chains.

Emission and resource use		Units / m^3 or ton roundwood	Forestry			Sugarcane			Subtropical fruit		
			Direct	Indirect	Multiplier	Direct	Indirect	Multiplier	Direct	Indirect	Multiplier
Incremental water use[a]		M^3	55			82			234		
Evapotranspiration		M^3	643			106			398		
Intake (Water supply system)[a]		M^3		1.40771276			0.86483564			3.23	
Recycled/reused water[a]		M^3		3.80919773			1.28379405			3.23	
Fertiliser use [b]		MT	0.00359232	-		0.00553473	-		0.01557987	-	
Electricity [b]		M kW-hr	0.00000872	0.00028419	33.6	0.00000403	0.00002038	6.1	0.00001485	0.00003444	3.32
Energy [b]		TJ	0.00008132	0.0046791	58.5	0.00009081	0.00058704	7.5	0.00013837	0.00021651	2.56
Waste [b]		MT	-	0.00007901		-	0.00000501		-	-	
Water pollution [b]	BOD	MT	0.00000155	0.00021484	139.2	0.0000004	0.00012555	312.5	0.00000264	0.00000893	4.37
	TSS	MT	-	0.00073134		0.00007843	0.00032828		0.00051457	0.00001408	1.03
Air emissions [b]	SO2	MT	0.00000263	0.00099496	379.9	0.00000063	0.00020414	323.2	0.00000447	0.00001476	4.3
	CO	MT	0.00000014	0.00142777	10,169.4	0.00025112	0.00040077	2.6	0.00000024	-	
	NO2	MT	0.00000133	0.00074956	565.1	0.00028053	0.00024747	1.9	0.00000226	0.00000984	5.35
	VOC	MT	0.00000086	0.00031628	370.9	0.00004425	0.00007919	2.8	0.00000145	0.00000492	4.38
	Lead	MT	-	-		-	-		-	-	
	PM10	MT	0.00000154	0.00013555	89.1	-	0.0000503		0.00000262	0.00000492	2.88
	CO2	$MTCO_2E$	0.00479142	0.08255369	18.2	0.00565621	0.0454785	9	0.00815307	0.01487491	2.82
	CH4	$MTCO_2E$	0.00002104	0.00003639	2.7	0.00001703	0.00003513	3.1	0.0000358	0.00000984	1.27
	N2O	$MTCO_2E$	0.00000385	0.00217041	564.5	0.00081352	0.00071716	1.9	0.00000655	0.00003444	6.26
	CFCs	$MTCO_2E$	-	-		-	0.00035483		-	-	
Services [a]	Carbon sequestration	$MTCO_2E$	-	0.13479108		-	0.00150237		-	-	

Sources: Surveys, 2000 [a]; Eiolca 2002 [b]

Table 7.2.1: Direct and total VAD and employment benefits from forest plantations, sugar farming and sub-tropical fruits per m^3 incremental water use in the primary sector (Mpumalanga 1998).

	Units	Forestry Plantations		Sugarcane	Sub-tropical Fruits				
		Pines	Eucalypts		Mangos	Oranges	Grapefruit	Avocados	Bananas
Direct VAD	**R/ m^3 water**	1.18	1.51	0.92	2.76	1.92	1.48	1.74	1.28
Total VAD	**R/ m^3 water**	21.27	13.3	9.91	8.91	6.55	4.94	3.4	3.2
Direct employment	**MD/m^3 water**	0.006	0.012	0.002	0.02	0.018	0.013	0.005	0.007
Total employment	**MD/ m^3 water**	0.114	0.078	0.044	0.037	0.039	0.028	0.007	0.012
Recycled/Reused	m3/ **m^3 water**	0.08	0.036	0.015	-	0.019	0.022	0.016	-
Direct Fertiliser	kg/ **m^3 water**	0.055	0.037	0.067	0.073	0.116	0.081	0.063	0.054
Total Fertiliser	kg/ **m^3 water**	0.053	0.036	0.067	0.073	0.114	0.079	0.061	0.054
Direct Electricity	kW-hr/ **m^3 water**	0.135	0.088	0.05	0.055	0.135	0.082	0.059	0.051
Total Electricity	kW-hr/ **m^3 water**	4.574	6.87	0.29	0.05	0.34	0.32	0.23	0.05
Direct Energy	MJ/ **m^3 water**	1.26	0.82	1.15	0.51	1.26	0.76	0.55	0.48
Total Energy	MJ/ **m^3 water**	72.266	118.25	8.16	0.51	2.52	2.25	1.64	0.48
Direct Waste	kg/ **m^3 water**	-	-	-	-	-	-	-	-
Total Waste	kg/ **m^3 water**	0.0003	0.0043	0.0001	-	-	-	-	-
Direct BOD	kg/ **m^3 water**	0.000024	0.0000156	0.0000049	0.0000098	0.0000241	0.0000145	0.0000105	0.0000092
Total BOD	kg/ **m^3 water**	0.0045	0.002	0.0015	0	0.0001	0.0001	0.0001	0
Direct TSS	kg/ **m^3 water**	-	-	0.001	0.0019	0.0047	0.0028	0.002	0.0018
Total TSS	kg/ **m^3 water**	0.0153	0.0069	0.0049	0.0019	0.0047	0.0029	0.0021	0.0018
Direct Air emissions	kg/ **m^3 water**	0.000077	0.00005	0.007014	0.000031	0.000077	0.000046	0.000033	0.000029
Total Air emissions	kg/ **m^3 water**	0.070617	0.040076	0.018156	0.000031	0.000251	0.000251	0.000183	0.000029
Direct PM10	kg/ **m^3 water**	0.000024	0.000015	-	0.00001	0.000024	0.000014	0.00001	0.000009
Total PM10	kg/ **m^3 water**	0.002931	0.00112	0.000606	0.00001	0.000053	0.000048	0.000035	0.000009
Direct Greenhouse Gasses	kg/ **m^3 water**	0.074	0.048	0.079	0.03	0.075	0.045	0.033	-
Total Greenhouse Gasses	kg/ **m^3 water**	1.818	0.933	0.639	0.03	0.162	0.148	0.108	-
Direct Carbon sequestration	kg/ **m^3 water**	-	-	-	-	-	-	-	-
Total Carbon sequestration	kg/ **m^3 water**	1.965	3.604	0.018	-	-	-	-	-

Source: Modelling done as part of this study

Table 7.2.2: Direct and total VAD and employment benefits from forest plantations, sugar farming and sub-tropical fruits per m^3 evapotranspiration used in the primary sector (Mpumalanga 1998).

	Units	Forestry Plantations		Sugarcane	Sub-tropical Fruits				
		Pines	Eucalypts		Mangos	Oranges	Grapefruit	Avocados	Bananas
Direct VAD	**R/ m^3 water**	0.08	0.14	0.71	1.40	0.86	0.66	1.17	0.82
Total VAD	**R/ m^3 water**	1.52	1.23	7.69	4.53	2.93	2.21	2.28	2.06
Direct employment	**MD/m^3 water**	0.0004	0.0011	0.0016	0.0102	0.0080	0.0058	0.0033	0.0045
Total employment	**MD/ m^3 water**	0.01	0.01	0.03	0.02	0.02	0.01	0.00	0.01
Recycled/Reused	m3/ **m^3 water**	0.01	0.00	0.01	-	0.01	0.01	0.01	-
Direct Fertiliser	kg/ **m^3 water**	0.00	0.00	0.05	0.04	0.05	0.04	0.04	0.03
Total Fertiliser	kg/ **m^3 water**	0.00	0.00	0.05	0.04	0.05	0.04	0.04	0.03
Direct Electricity	kW-hr/ **m^3 water**	0.01	0.01	0.04	0.03	0.06	0.04	0.04	0.03
Total Electricity	kW-hr/ **m^3 water**	0.33	0.64	0.22	0.03	0.15	0.14	0.15	0.03
Direct Energy	MJ/ **m^3 water**	0.09	0.08	0.89	0.26	0.56	0.34	0.37	0.31
Total Energy	MJ/ **m^3 water**	5.15	10.97	6.33	0.26	1.13	1.00	1.10	0.31
Direct Waste	kg/ **m^3 water**	-	-	-	-	-	-	-	-
Total Waste	kg/ **m^3 water**	0.00	0.00	0.00	-	-	-	-	-
Direct BOD	kg/ **m^3 water**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total BOD	kg/ **m^3 water**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Direct TSS	kg/ **m^3 water**	-	-	0.00	0.00	0.00	0.00	0.00	0.00
Total TSS	kg/ **m^3 water**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Direct Air emissions	kg/ **m^3 water**	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Total Air emissions	kg/ **m^3 water**	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Direct PM10	kg/ **m^3 water**	0.00	0.00	-	0.00	0.00	0.00	0.00	0.00
Total PM10	kg/ **m^3 water**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Direct Greenhouse Gasses	kg/ **m^3 water**	0.01	0.00	0.06	0.02	0.03	0.02	0.02	-
Total Greenhouse Gasses	kg/ **m^3 water**	0.13	0.09	0.50	0.02	0.07	0.07	0.07	-
Direct Carbon sequestration	kg/ **m^3 water**	-	-	-	-	-	-	-	-
Total Carbon sequestration	kg/ **m^3 water**	0.14	0.33	0.01	-	-	-	-	-

Source: Modelling done as part of this study

7.3 TEMPORAL ASPECTS

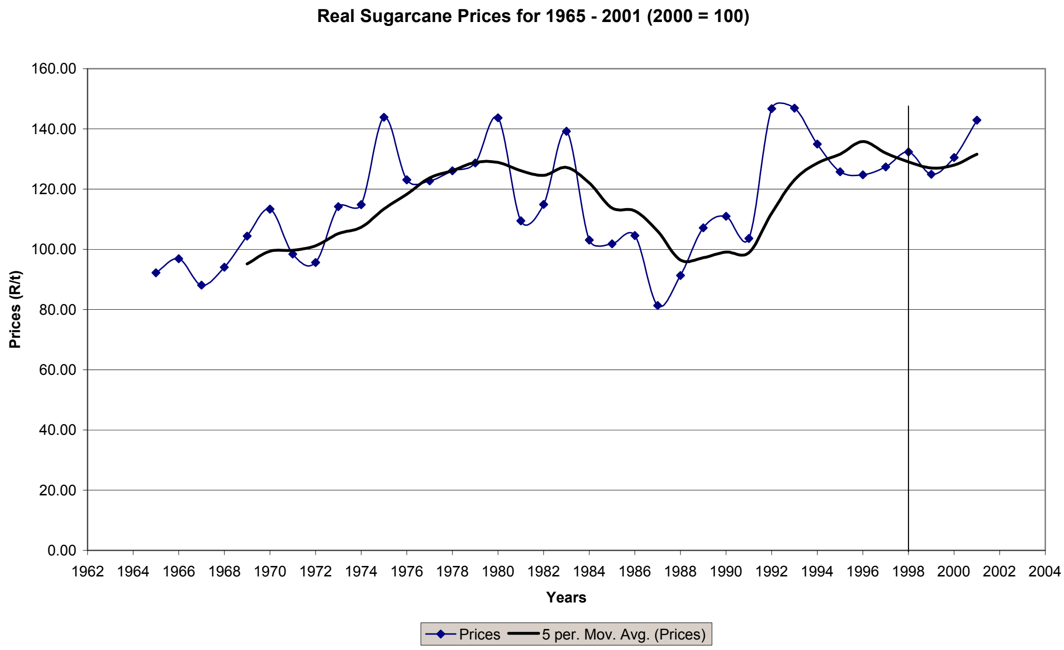
The results of the analyses in this report was based on data for the accounting year 1998. This requires an objective qualification in terms of possible patterns and trends in product and input price changes over time as well as other assumptions of the analysis.

Figure 7.2: Pine and Eucalypt, weighted average real (base year = 2000) prices roundwood, received at roadside, in Mpumalanga (Rands/m^3).

Source: Forest Economic Services, 1991-1997; DWAF, 1998-2000

Roundwood is a commodity with a stable long-term supply from long rotation plantations, and a steady demand from value chains with high economies of scale, which also depend on long term supply contracts from forests. This situation results in fairly stable market price conditions, and subsequently little price variations from year to year. The new political dispensation in South Africa brought about changes in forestry pricing policies, resulting in less protection for secondary roundwood processors. The effect of these new policies is evident in Figure 7.2, where a sharp increase in real roundwood prices were observed between 1994 and 1996. It does appear that, by 1998, prices had stabilised into a slowly increasing long-term trend, and this that 1998 could therefore be considered a normal year for roundwood.

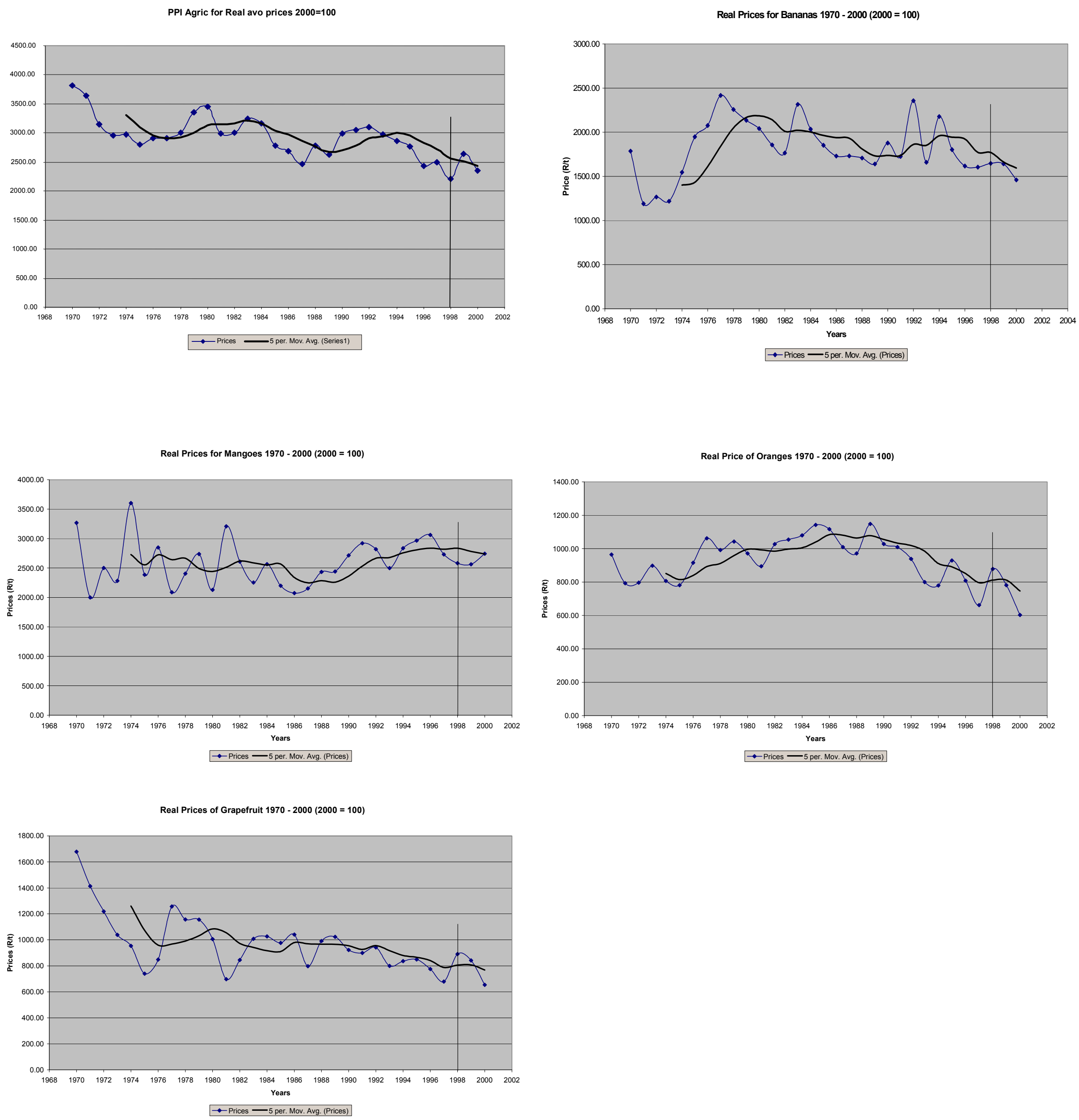
Figure 7.3: Sugarcane real (base year = 2000) prices.



Source: SASA, 2000a.

Sugarcane is a commodity that is much more sensitive, on an annual basis, to global sugar prices than roundwood. Two price cycles are evident from the 5-year moving average in Figure 7.3, with the first stretching from 1965-1988 (peaking during the late 1970's), and the second starting in the early 1990's. It appears therefore that sugarcane in 1998 received prices typical of the early stages of a price cycle increase. In 1998, the real sugarcane price was virtually the same as the 5-year moving average.

Figure 7.4: Sub-tropical fruit real (base year = 2000) prices.



Source: Department of Agriculture, 2000

Sub-tropical fruit prices, with their short value chains, are much more sensitive to changing consumer demand, than roundwood or sugarcane. This explains the large annual price variations. The 5-year moving averages in Figure 7.4 show that all the crops, except mangos, were on a steady long-term real price decline in 1998. This is probably due to steadily increasing global fruit production. However, the mango price was about R200 below the 5 year moving average. This was also true for avocados and bananas. The citrus prices were about R100 above the 5-year moving average.

From the above analyses it can be concluded that roundwood and sugarcane prices had stable years in 1998, and that both of these commodities were on a steady real price increase cycle. Analyses of direct VAD/m^3 of water for these two crops can therefore be expected to increase for as long as the real prices increase. The VAD/m^3 of water results reported on here for mangos, avocados and bananas could be considered to slightly underestimate the 5-year moving average conditions, while the citrus fruits were a slight overestimation. All the fruits were however, on a real price decline, which may indicate that VAD/m^3 of water values may decrease over the long term.

CHAPTER 8:

CONCLUSIONS, POLICY IMPLICATIONS, LIMITATIONS AND RECOMMENDATIONS

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8.1 CONCLUSIONS

Water is scarce and precipitation is extremely variable in South Africa. South Africa is also a country with great welfare needs where challenging economic development targets need to be achieved within the constraints of limited and unreliable water supply. These development targets are underpinned by the growth in economic activities such as agriculture, mining, energy production and many small, medium and micro enterprises, which constitute some of the largest water using sectors in the economy. Within these industries, increased competition place pressure on water users to keep supplying their markets with competitively priced goods, while rising costs of new water supplies puts pressure on water users to achieve higher efficiency in water use. These market forces, and the relative scarcity of water as a critical production factor, impact on financial viability and imply that the economic efficiency of water use becomes increasingly important.

In response to this situation, a new National Water Act (NWA) has been instituted in SA in 1998, which signified a radical departure from previous water use policies in the country (NWA, 1998). The NWA accordingly has important implications for future management, allocation and use of water resources in SA. The NWA revolves around the principles of equity, social justice, economic efficiency and environmental sustainability. Major features of the Act include among others:

- Abolishment of private rights to water,
- Application of economic efficiency principles to allocation of water for productive economic uses,
- Priority to correction of inequalities of the past in terms of access to water and water services for poverty reduction, and
- Protection of the people and the environment against the hazards of production and consumption activities that deplete stocks and degrade the quality of water and watershed services.

Pursuance of the above principles in the implementation of the NWA impacts on the design of different policy instruments and strategies for the management and use of water. For instance, the *equity and* *poverty reduction* goals will lead to increased demand for water for domestic purposes as millions of people, previously excluded from this service, are catered for. The stated *efficiency principle* requires removal of subsidies, which could in the short term negatively influence returns on capital invested during periods of high water subsidies. Efficiency also requires the implementation of water demand management strategies, a major component of which is related to water allocation based on economic efficiency principles, and would therefore have to be carefully designed to ensure that sustainability and equity principles are achieved. *Environmental sustainability* requires water to be managed with a long-term view of sustaining the natural system, while maintaining an adequate supply of good quality water.

Investigations done as part of this study used the above principles as a point of departure. It attempted to quantify and compare the economic, environmental and other social aspects of water usage in a catchment.

Water apportionment decisions remain, for the largest part, dependent on accurate water use information. This study has shown how estimates of forestry water use figures changed with the adoption of a more refined water use model. The measurement of irrigation water use remains an important issue in the determination of actual on farm water use, and prediction models for this are not adequate. Comparative analysis of forestry and irrigation water use must be done carefully, as the terminology and definitions used in forest hydrology and irrigation planning are different. Incorrect application of these may result in incorrect comparative analysis.

The ratio of the indirect to direct water use per ton of product shows indirect water use to be virtually insignificant direct water use for forestry, sugarcane and subtropical fruit production. These ratios were 2.5, 1.0 and 0.8 respectively.

This study revealed the importance of considering the indirect economic benefits in comparing the social worthiness of alternative productive uses of water and other economic resources. This was especially evident from the VAD and employment multiplier effects, which were between 2 and 20-fold larger than the direct benefits. The multiplier effects were more pronounced for the longer value chains, i.e. those that comprised of more intermediate value adding activities between the farm and the final consumer. This means that water use productivity in water scarce areas will benefit more from more value addition. Managing water solely for the export of products with high water use requirements and low indirect value addition therefore amounts to exporting water at likely low value or economic returns, and subsidising the purchaser of those products with virtual water.

The comparative analysis of the water use efficiency of the different land uses can be based either on the incremental water use or the total evapotranspiration of the crops compared. Evapotranspiration indicates the total water use of the crop, whereas incremental water use is the difference between the evapotranspiration of the crop and the evapotranspiration of the natural vegetation replaced by the crop. Incremental water use also estimates the impact of a land use on stream flow and is often referred to as the stream flow reduction impact. The selection of an appropriate water use definition for comparative analysis is crucial as the study showed that the forestry value chain makes more efficient use of water when incremental water use is the basis for comparison. When evapotranspiration is used as a basis for comparison, sugar cane is the most efficient land use, with forestry being the least efficient.

It is important to keep price cycles and the long-term outlook for each industry in mind when doing comparative analyses. Incorrect conclusions may be drawn if this is not done. Related to these price variations is the fact that landowners make land use decisions based on strategies to optimally hedge their price risk. A case in point is the dual cropping of sugarcane and sub-tropical fruit on the same management units (farms). A farmer will consider all the resources to his/her disposal and will attempt to allocate them optimally for the highest returns. Comparative analyses should bear this in mind.

The study also clearly showed the trade-offs between economic production and environmental emission and resource use pressures. In this case, higher VAD and employment multipliers usually go hand in hand with higher energy use and larger emission factors. Environmental source and sink functions are used as inputs in the production process, without an evaluation on the sustainability of their use to ecosystems. Such production factors are not normally captured in economic accounting systems, and are classified as negative externalities. It is apparent that these externalities should be considered in policy impact analyses of this nature, where water apportionment decisions may have large indirect effects.

Nevertheless, some positive environmental externalities also occur. All the value chains producing the larger environmental emissions and sinks, in this case pine and eucalypt forestry and sugarcane, also produced potentially significant environmental benefits. In the case of forestry, its carbon sequestration ability significantly outweighed the level of greenhouse gas emissions. In the case of sugar, the use of bagasse as a major energy source reduced net energy requirements considerably. All three the land uses also has the potential to produce benefits to society through effective management of natural ecosystems on their estates or management units.

The environmental benefits yielded from value chains creates opportunities for the whole industry, from the land owner through to all producers in the forward linkages, and suppliers in the backward linkages, to offset potential environmental costs related to the value chain. This approach is rooted in the concept of weak sustainability, which recognises that, in order for a society to create wealth, some consumptive use of land (including the environment) has to be made. This consumptive use is associated with environmental costs, borne by society, and should be offset against investments ploughed back into society.

It is also within this concept that social adaptive capacity is defined. The broader social impacts of the value chains were much more challenging to quantify than the economic, employment and environmental impacts. Within the terms of reference of the study, vulnerable households were the key social group that was focussed on. Vulnerable households were regarded as poor, mostly black, rural households with low education levels. It was concluded that the three land uses under discussion had large impacts on these households as the bulk of employment opportunities (expressed in man-days per ton) was supplied to them. The effect of these employment opportunities on household income and social adaptive capacity remains an important variable, but was not researched due to data constraints. Large, institutionally organised industry sectors, such as forestry and sugar, and large fruit farmers, have in partnership with poor rural communities, implemented small grower and small contractor schemes, which benefits rural livelihoods.

The study also showed the value of transfer studies when policy decisions have to be made in the absence of comprehensive primary data.

8.2 POLICY IMPLICATIONS

From the above discussion, the following policy implications for water apportionment are evident:

- Land uses that perform best in terms of economic value added (VAD) to water use, are not necessarily the most efficient water user once its forward and backward linkages are assessed. Furthermore, value chains that perform best in terms of economic and employment benefits per amount of water used; are not necessarily the most efficient once its environmental and social externalities are added. The indirect environmental impacts of the value chains must therefore also be taken into account for a comprehensive evaluation of the economic and social worthiness of alternative land uses. Water allocation decisions therefore require multi-criteria decision-making tools.
- The use of incremental water use values will provide different crop water use efficiencies than in the cases where evapotranspiration are used.
- Water apportionment policies seek to build on the strengths that exist within different land uses: it's not an economically bad thing to use more water than other land users, in fact, it is rather more important to achieve optimal allocation of resources within the ***thresholds*** of the whole catchment, in order to ensure maximum societal returns. The question is how such optimal allocation of resources can be achieved. Possible ways included the following:
  - Through regulation, involving specific target setting based on ecological ***thresholds*** for different land uses. Such regulations should encourage water users to focus internally on their production processes - on aspects such as technology and management improvements.
  - Through markets, either through the allocation of tradeble water and/or environmental use permits for the catchment or river system, or the introduction of

water and/or environmental use charges and taxes. In the former case land users can decide whether to buy or sell such permits and/or change production processes while in the former case this choice is more restricted. Internationally, the focus is on the development of optimal policy response mixes and more study is required on the feasibility of policy responses in various settings (e.g. catchments)

    - Through a combination of regulation and markets. Regulation should at least internalise equity and ecological aspects.

- Water apportionment decisions based on the total economic value concepts, which includes environmental and social impacts, are data intensive, and require reliable (preferably) primary data. Policy makers virtually never have the luxury of having adequate data at their disposal to make policy decisions. Investing in a small number of well designed studies that produce reliable primary data for South African conditions, will prove invaluable in informing policy decisions for the whole country and would provide the backbone of a case-sensitive environmental economic predictive model.
- Water apportionment policies should consider its effect on other government policy initiatives. Two examples exist in the sugarcane and forestry value chains, where fiscal incentives (sugarcane outgrowers) and government investments (furniture manufacturing) exist, for the purposes of job creation.
- The above listed policy implications indicates that although water allocations regulation should be planned from a national office, it should be implemented through mechanisms that devolves the decision-making process to as decentralised a level as possible.

In general, the following policy implications for integrated land use and water management are evident:

- When evaluated from a societal perspective, the evaluation of alternative land uses would be served by a holistic approach – taking all impacts into account, but also an objective approach in weighing these costs and benefits in a well-defined and scientifically robust framework. This is imperative for making the correct choices on the use of our scarce natural resources.

8.3 LIMITATIONS

The main limitation of the study lay in the absence of data for the quantification of environmental and social impacts. The transfer study relied to a large extent on USA emissions and resource use data, which were done based on USA production processes and technologies. In addition, information on dose response functions was not available for local conditions, which is critical for the determination of the seriousness of the environmental impacts. Household data used were very generic and the only reliable manner to obtain household income and livelihoods data, which are very site specific, is through intensive field studies. Current EIA and SIA methodologies are mostly processed based, and therefore no formalised data frameworks exist for doing model-based quantification, such as was done in this study. Social data especially, tended to be more qualitative in nature.

The technical scope of the study required the intensive input from experts in five fields: forest hydrology, irrigation, economics, environmental science and sociology. Within the financial scope of the study however, it was not possible to involve these experts as permanent team members.

8.4 FUTURE WORK

Two avenues of future work has been identified:

- The environmental and social externalities identified here can be linked to a Social Accounting Matrix in order to model the effects of various water policy decisions.
- Research is required on selected pilot study areas in order to generate a comprehensive data base from which benefit transfer studies may be done to inform water policy decision-making.

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APPENDIX 1: Questionnaire Format

Total Sales Products Volume Price ………… …….. ……
Intermediate Consumption Products Volume Price ………… …….. ……
Value Added + Salaries & Wages + Profit + Interest paid + Dividends paid + Tax paid
Water use

APPENDIX 2: Input-Output Models' Structure and Use

Introduction

I-O models describe a multi-sector economy with a basic focus on disaggregating the supply side into several processing industries only using intermediate inputs and supply the rest of its production to a single final demand sector (the Open Leontief model). Fixed coefficients are used to allocate sectoral output between intermediate use by other sectors and final consumption (the fixed coefficient Leontief technology). Later versions of the model incorporated the final demand sector into the intermediate processing structure as a supplier of primary factors and user of part of the generated output (the Closed Leontief model). Other versions further dis-aggregate final demand into various household and government groups, introduced imports and exports, capital accounts, etc. Regionally disaggregated (spatial) as well as dynamic (intertemporal) I-O tables-based models are solved for various analytical purposes.

The Leontief I-O Model Structure

I-O data-based models are represented in a compact matrix notation by:

$$X = AX + d \qquad (1)$$

Where X is a vector of total outputs of the various economic sectors, A is the I-O coefficient matrix, AX calculates intermediate inputs required by the various members of X (producing sectors) and d is the vector of final demands (VAD). This formulation describes the general situation that total output X is allocated between intermediate use by other sectors for further production (intermediate demand) and the remainder is absorbed in final demand (final consumption and investment demand) or exported.

I-O models are concerned with solving for sectoral output levels (X) that satisfy final demands for those outputs (d) given the inter-industry structure of production (A). In other words, model 1 can determine the production plan that is consistent with a desired final demand vector (d) given the inter-sectoral transaction matrix (A), i.e. generating direct intermediate demands necessary to generate the target net output (d). Making use of matrix algebra, model 1 can be solved to determine X as follows:

$$X - AX = d$$

$$(I-A)\,X = d \qquad (2)$$

$$X = (I-A)^{-1}\,d$$

Where I is a nxn identity matrix. As the inverse matrix $(I-A)^{-1}$ is defined one can solve for X given d. The matrix A is known as the direct input requirements matrix (Leontief inter-industry transactions' coefficient matrix). The elements of A (a_{ij}) define the value or amount of input required from all sectors to produce one unit of output of a given sector j:

$$[\,a_{ij}\,] \quad = \quad \begin{vmatrix} a_{11} & a_{12} & . & . & a_{1n} \\ a_{21} & a_{22} & . & . & a_{2n} \\ . & . & . & . & . \\ . & . & . & . & . \\ a_{n1} & a_{n2} & . & . & a_{nn} \end{vmatrix} \qquad 3)$$

Where a_{ij} is the amount of product i required as an input to produce one unit of j.

On the other hand, the inverse matrix $(I\text{-}A)^{-1}$ gives the total (direct and indirect) output requirements per unit of output to be generated in sector j. This is known as the total input requirements matrix, which is used to calculate production or supply-side multipliers. This matrix is used to derive various types of multipliers the most common of which are the output and income multipliers. With additional information on employment by various sectors, it is also used for calculating job multipliers[19].

[19] For further details on the I-O framework and multipliers see Miller and Blair (1985) among many others.

APPENDIX 3: Selected estimates of agricultural multipliers in the international literature

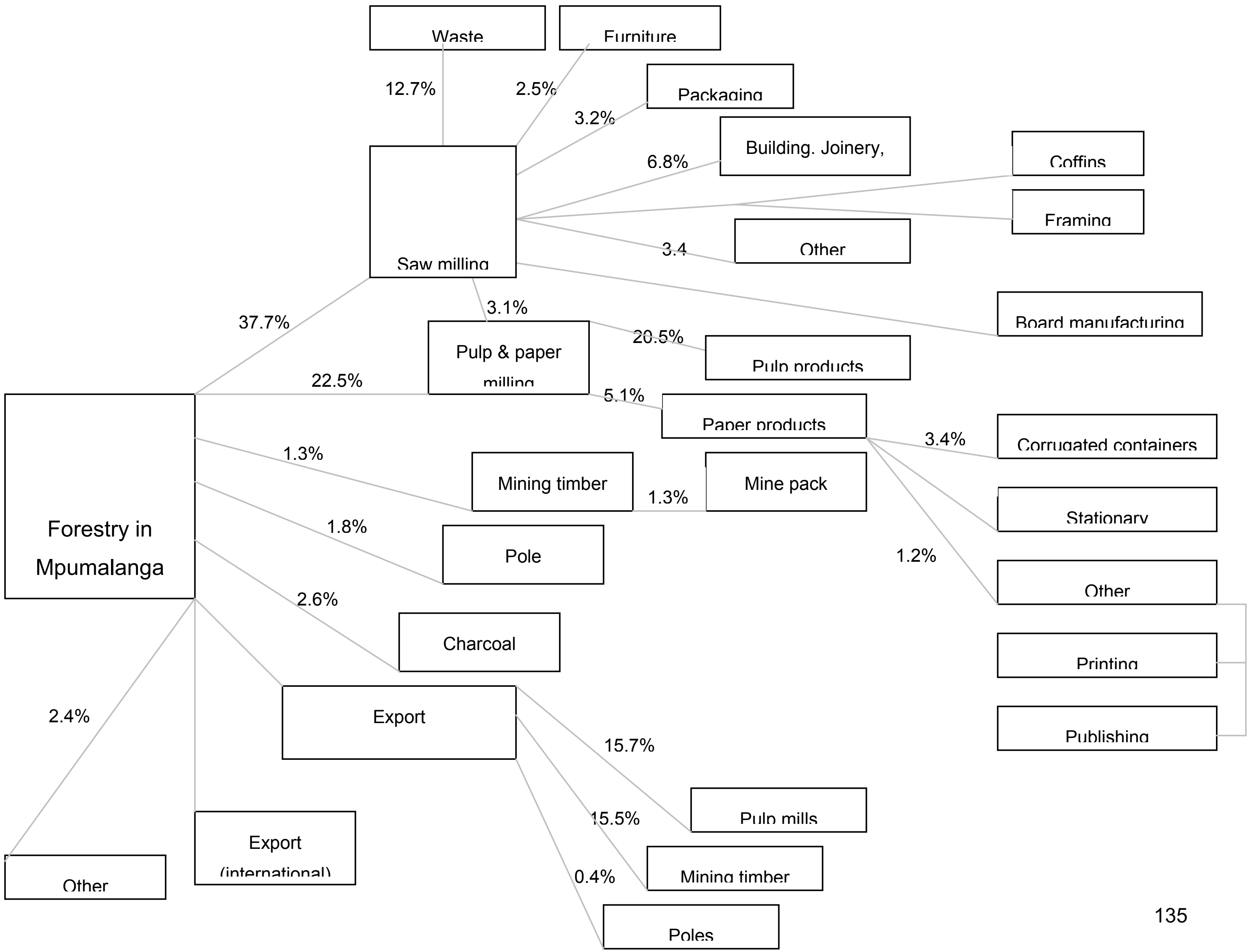
Country	Multiplier estimate[1]	Study
Europe[3]	**<u>1.12 – 1.8</u>**	
Scotland, Forestry	1.16 - 1.61	Johnson and Leat (1987)
Scotland, Agriculture	1.8	Mitchell (1996)
Scotland		Thomson and Psaltopoulos (1996)
Forest planting	1.16 – 1.4	
Forest harvesting	1.12 – 1.57	
England		Harrison-Mayfield (1996)
Agriculture	1.26	
Forestry	1.12	
Food processing	1.72	
Wood products	1.42	
Paper	1.53	
Africa[2]	**<u>1.32 – 2.88</u>**	
Burkina Faso	2.88	Delgado et al. (1998)
Niger	1.96	Delgado et al. (1998)
Senegal	2.48	Delgado et al. (1998)
Zambia	2.48	Delgado et al. (1998)
Sierra Leone	1.5	Haggblade et al. (1987)
Nigeria	2.81	Haggblade et al. (1987)
Malawi	1.66	Simler (1994)
Madagascar	2 – 2.7	Dorosch and Haggblade (1993)
Gambia[3]		Leat and Chalmers (1991)
Primary agriculture	1.48 - 2.22	
Agric. Machinery	1.32 - 1.58	
Food processing	1.33 - 1.98	
Asia[2]	**<u>1.64 - 1.82</u>**	
India	1.7	Ranagarajan (1982)
India	1.64	Hazell and Haggblade (1990)
Malaysia	1.82	Hazell (1984)
<u>Average</u>	**<u>1.12 – 2.88</u>**	

1. Impact of 1% increase in agricultural income on total value added or income of the entire economy (both agriculture and non-agriculture sectors).

2. Except for the Ranagarajan (1982) study, which was based on a macro-econometric model and the Gambia I-O based study, all estimates were based on variants of the semi I-O model with demand segments of the SAM structure of economic systems incorporated.

3. All I-O based estimates (e.g. only production multipliers).

APPENDIX 4: Forestry value chain in Mpumalanga: Wood flow in forward linkages



APPENDIX 5: Forestry value chain in Mpumalanga: Input supply from backward sectors

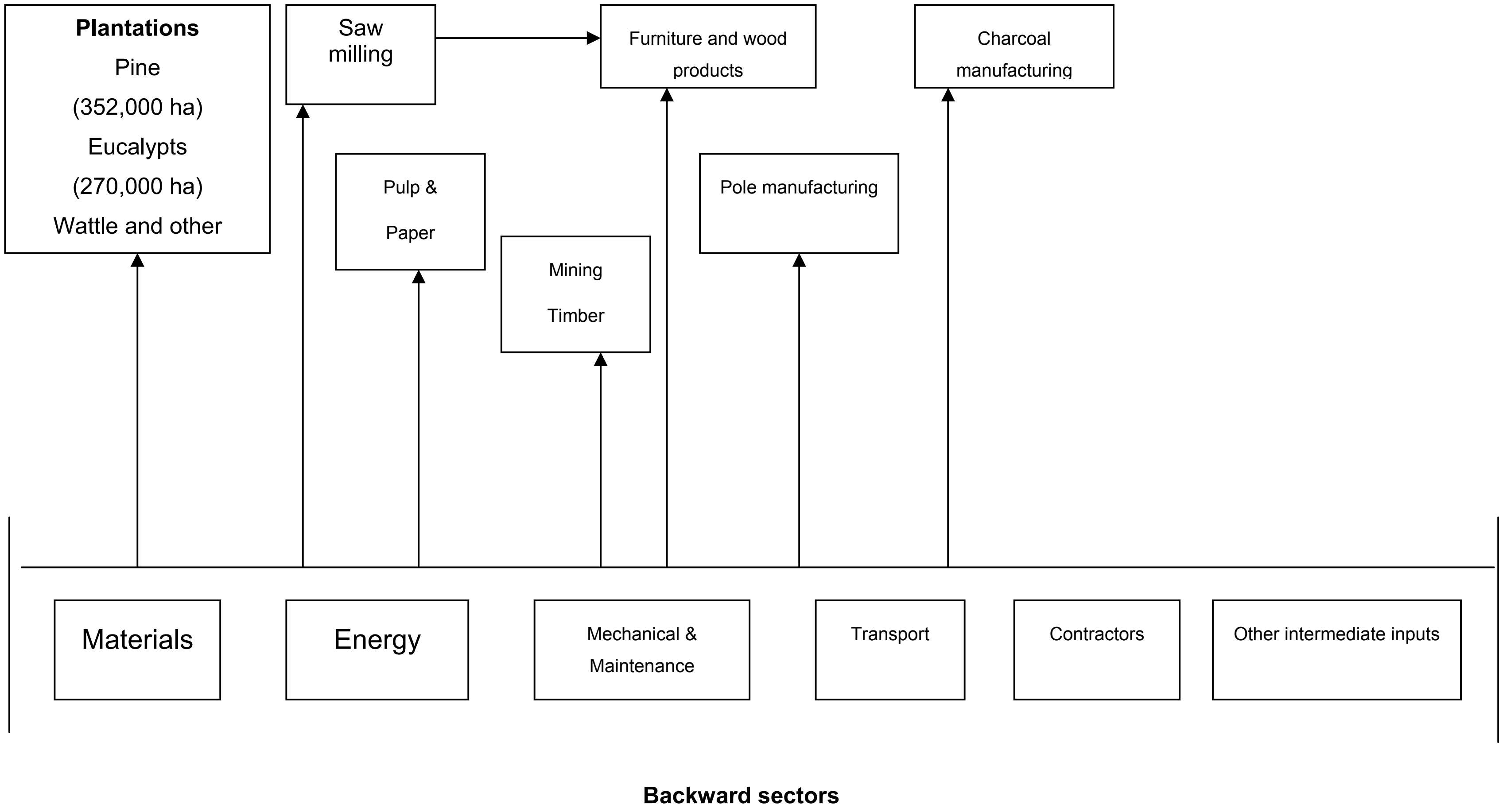
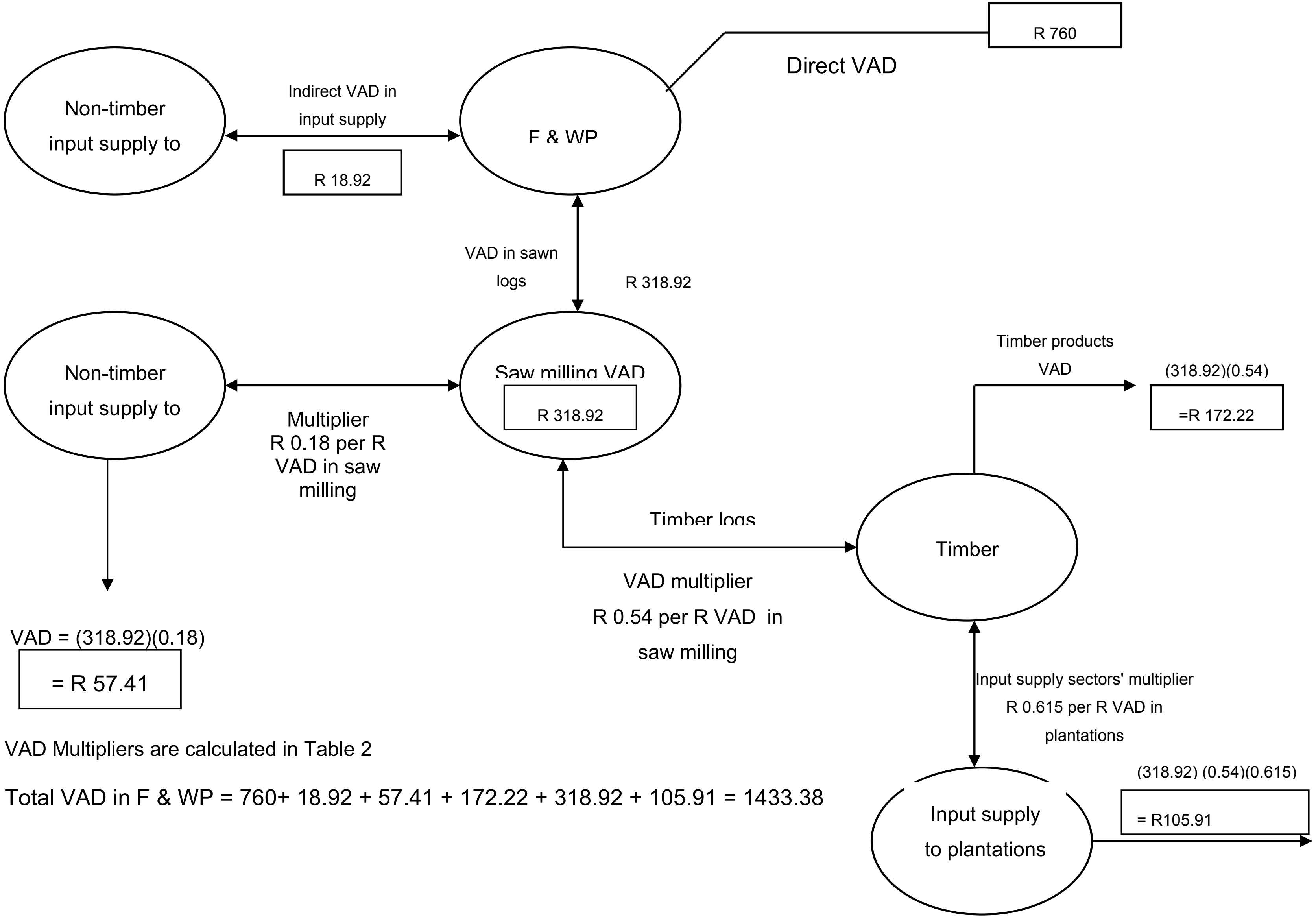


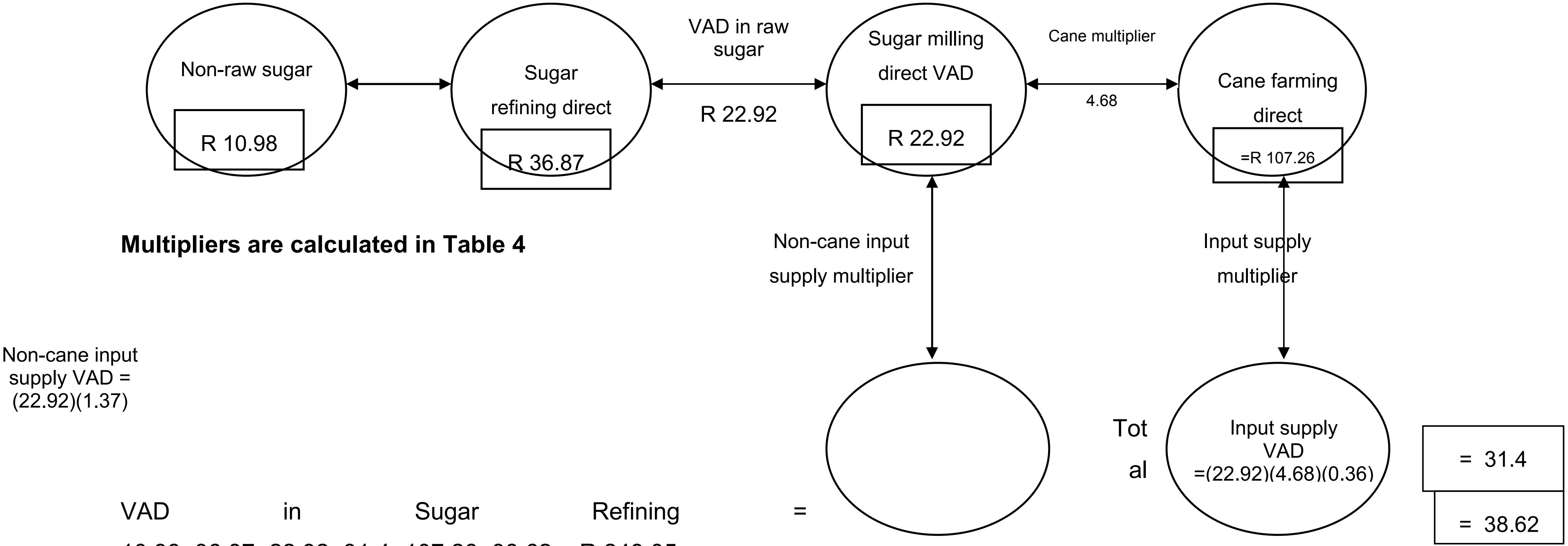
Figure 1: Value added chain in Furniture and Wood Products (F & WP), Mpumalanga (R/m^3logs 1998 prices)



VAD Multipliers are calculated in Table 2

Total VAD in F & WP = 760+ 18.92 + 57.41 + 172.22 + 318.92 + 105.91 = 1433.38

Figure 2: Total VAD in Sugar Refining in Mpumalanga (R/ton cane 1998 prices)

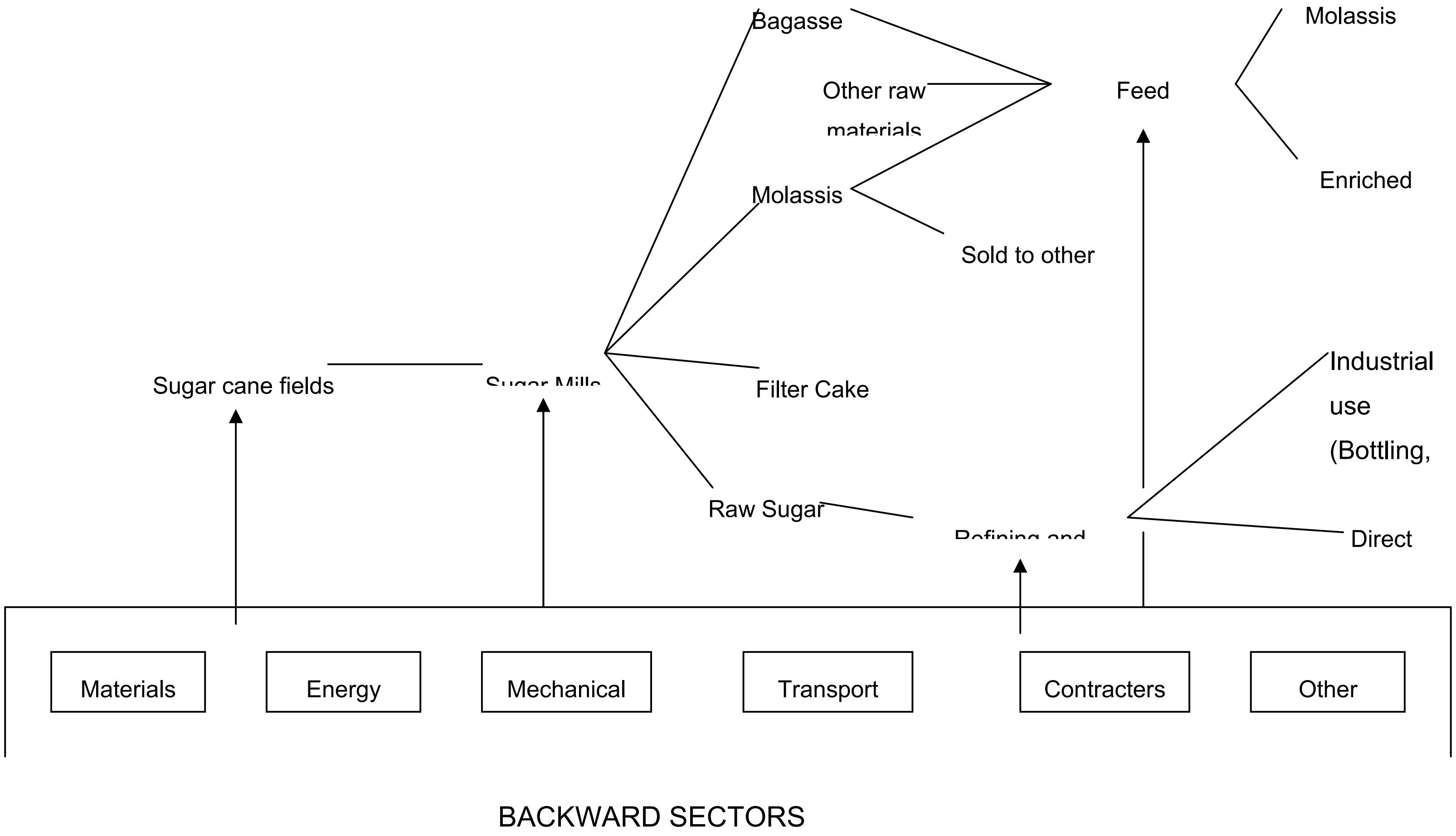


Multipliers are calculated in Table 4

VAD in Sugar Refining = 10.98+36.87+22.92+31.4+107.26+38.62 = R 248.05

Note that the total sugar industry multiplier in Table 4 includes sugar transport, feed and board manufacturing and industrial processing components of the whole chain of value addition.

APPENDIX 6: Sugar value chain in Mpumalanga



APPENDIX 7: ECONOMIC IMPACT ASSESSMENT Data Sources

Surveyed data sources in the forestry and forest products industry

The following sources have been tapped for information on forest plantations and forest products

- **Forest Plantations Data:** Forest Economics Services (FES, 1996). The main source of all information on actual production costs and other data on the economics of pine and gum plantations in South Africa.
- **Forest Products Data: D**epartment of Water Affairs and Forestry (DWAF, 1997/98 & 1998/9). Commercial timber resources and round wood processing in SA: 1997/98 & 1998/9. DWA&F, Pretoria
- Additional information was gathered from personal communications and questionnaires sent to the following *companies*:

  Mondi Timber Head Office, Sappi Novaboard Head OfficeCrickmay, Erasmus & Associates, Lion Match Head Office, South African Wood Preservers Association **(**SAWPA), Silicon Smelters, Pietersburg, Forestry SA, South African Lumber Millers Association **(**SALMA), PG Bison Mpumalanga, Buckman Laboratories, Mondi Forests Mpumalanga, Mondi Paper, Technical Head Office Durban, Woodline Head Office, Sasol Head Office, Sappi Head Office, Forestry Services & Facilitators, Rhoe Pollenc Head Office, Industrial Development Corporation.

Surveyed Data Sources in the sugarcane farming and processing sectors

- South African Cane Growers Association (SACGA, 1999). Data on the costs of and benefits from cane farming in Mpumalanga in 1998 have been provided by the SACGA.
- South African Sugar Association (SASA, 2000a). General information about production figures (area, cane and sugar yields, employment and distribution of product between final consumption and industrial use over the past decade.
- Transvaal Suiker Beperk (TSB, 1999). All information on milling, refining and further processing.
- Molatek Animal Feeds (1999). All data on feed manufacturing.

Surveyed Data Sources in the sub-tropical fruits production and processing sectors

- National Department of Agriculture (NDA, 2000). Abstract of Agricultural Statistics. NDA, Pretoria

- Department of Agriculture, Mpumalanga (DA-Mpumalanga, 1999). COMBUD: Enterprise budgets for 1998 in Mpumalanga Province, DA, Nelspruit
- Farmers and growers' associations surveys in 2000 in Mpumalanga Province, Department of Agricultural Economics, University of Pretoria
- Dickon Hall Processors (2000).
- AgriSA

General data sources

- Statistics South Africa (SSA, 1993). Census of manufacturing 1993. SSA, Pretoria.
- Statistics South Africa (SSA, 1996). Agricultural Surveys 1994-1996. SSA, Pretoria.
- Statistics South Africa (SSA, 1999). Gross Domestic Product. SSA, Pretoria.
- Statistics South Africa (SSA, Various Issues). Input-output and Socail accounting Matrices for SA. SSA, Pretoria.

APPENDIX 8: SOCIAL IMPACT ANALYSIS PRINCIPLES

The nine principles that SIA's should comply to, as listed in the *Guidelines and Principles for Social Impact Assessment* (U.S. Department of Commerce 1994) follow:

- The SIA must identify and include all affected parties through participation with the diverse public.
- It should analyse who wins and who loses (impact equity), especially concerning minority groups.
- SIAs must focus the assessment on the important issues rather than just those that are easy to quantify.
- The methods and assumptions used need to be reported and described.
- The significance of the social variables or impacts chosen needs to be defined.
- Feedback must be provided to project planners of possible problem areas as well as opportunities. The ideal is that project planners could introduce changes to their proposed actions to avoid or minimise adverse impacts on the community.
- SIA practitioners who use professional social science methods and have experience in the field should be employed to provide the best results.
- Monitoring and mitigation programs need to be put in place as a joint agency and community responsibility.

APPENDIX 9: DATA OUTPUT

This Appendix contains the data output generated by the models built for the purposes of this study:

Tables 5.10-5.11 contain the environmental data, summarised and discussed in Chapter 5.

Tables 6.1-6.8 contain the social data, summarised and discussed in Chapter 5.

The data are the result of a modelling process and therefore the use of decimals in these Tables do not reflect scientific precision.

Table 5.10: Emission coefficients E_{ij} for the forestry value chain.

Source	Unit	Pine Forestry	Gum Forestry	Saw milling	Mining timber	Poles	Charcoal	Pulp and Paper	Furniture products	Board products	Transport
Soil											
Nitrogenous	tons	0.0000031	0.0000032	-	-	-	-	-	-	-	-
Ammonium nitrate	tons	0.00032	0.00033	-	-	-	-	-	-	-	-
Ammonium sulfate	tons	0.00046	0.00047	-	-	-	-	-	-	-	-
Organic	tons	0.00074	0.00076	-	-	-	-	-	-	-	-
Phosphatic	tons	0.0000093	0.0000096	-	-	-	-	-	-	-	-
Super phosphates	tons	0.00089	0.00091	-	-	-	-	-	-	-	-
Mixed	tons	0.0011	0.0012	-	-	-	-	-	-	-	-
Electricity	MkW-h	0.0000087	0.0000087	0.000067	0.000028	0.0000068	0.000030	0.0000062	0.00029	0.00025	0.00025
Energy	TJ	0.000081	0.000081	0.00032	0.000028	0.00014	0.00045	0.00013	0.00076	0.00093	0.0045
Water											
Precipitation	m^3	1,028.84	573.26	-	-	-	-	-	-	-	-
Incremental	m^3	66.53	50.60	-	-	-	-	-	-	-	-
Intake	m^3	-	-	0.33	0.0049	0.43	0.23	9.73	0.92	0.13	-
Recycled/Reused	m^3	n.a.	n.a.	0.50	0.0074	0.65	-	27.16	1.38	0.20	-
Discharged	m^3	n.a.	n.a.	0.33	0.0049	0.43	0.23	9.73	0.92	0.13	-

n.a. = not applicable

Source: Modelling done as part of this study

Table 5.10 (continued): Emission coefficients E_{ij} for the forestry value chain.

Sink	Unit	Pine Forestry	Gum Forestry	Saw milling	Mining timber	Poles	Charcoal	Pulp and Paper	Furniture products	Board products	Transport
Waste											
Generated	MT	-	-	0.00000095	-	0.0072142	0.0000427	0.00010	0.00011	0.0000092	0.0000011
Managed	MT	-	-	-	-	0.0001680	-	-	-	-	0.000000039
Shipped	MT	-	-	0.00000095	-	0.0030333	0.0000427	0.000019	0.00011	0.0000061	0.0000012
Water pollution											
BOD	MT	0.0000016	0.0000016	0.0000066	-	-	-	0.0015717	-	-	-
TSS	MT	-	-	0.000031	-	-	-	0.005338	-	-	-
Air emissions											
SO_2	MT	0.0000026	0.00000263	0.0000468	0.0000844	0.0000195	0.0002107	0.0071	0.0007495	0.000107	0.0000027
CO	MT	0.00000014	0.00000014	0.0004070	0.0000094	0.0000950	0.0024216	0.0083	0.0000008	0.000825	0.0001164
NO_2	MT	0.00000133	0.00000133	0.0001320	0.0000094	0.0000057	0.0000427	0.0048	0.0000034	0.000471	0.0000493
VOC	MT	0.00000086	0.00000086	0.0001426	0.0001125	0.0000337	0.0001100	0.0015	0.0000651	0.000920	0.0000219
Lead	MT	-	-	-	-	-	-	-	-	-	-
PM10	$MTCO_2E$	0.00000154	0.00000154	0.0000888	-	0.0000076	0.0000554	0.0007	0.0000005	0.000348	-
GWP	$MTCO_2E$	0.00481631	0.00481631	0.0177810	-	0.0192942	0.0219460	0.5312	0.1369976	0.049150	0.0054178
CO_2	$MTCO_2E$	0.00479142	0.00479142	0.0173731	-	0.0192366	0.0218060	0.5159	0.1368079	0.047735	0.0052663
CH_4	$MTCO_2E$	0.00002104	0.00002104	0.0000254	-	0.0000388	0.0000177	0.0001	0.0001799	0.000052	0.0000085
N_2O	$MTCO_2E$	0.00000385	0.00000385	0.0003827	-	0.0000189	0.0001235	0.0138	0.0000098	0.001366	0.0001430
CFCs	$MTCO_2E$	-	-	-	-	-	-	-	-	-	-

Service	Unit	Pine Forestry	Gum Forestry	Saw milling	Mining timber	Poles	Charcoal	Pulp and Paper	Furniture products	Board products	Transport
Carbon sequestration	$MTCO_2E$	-	-	221,214	217,042	13,467	-	39,063	4,186	125,000	-
Area under conservation	Ha	57,376	43,991	-	-	-	-	-	-	-	-

Source: Modelling done as part of this study

Table 5.11: Emission coefficients E_{ij} for the sugar cane value chain.

Source	Unit	Sugar cane	Sugar milling	Boiler Fuel	Sugar refining	Food & Beverages	Feed Processing	Board Manufacturing	Transport
Soil									
Nitrogenous	tons	-	-	-	-	-	-	-	-
Ammonium nitrate	tons	-	-	-	-	-	-	-	-
Ammonium	tons	0.00170285	-	-	-	-	-	-	-
Organic	tons	0.00042526	-	-	-	-	-	-	-
Phosphatic	tons	-	-	-	-	-	-	-	-
Super phosphates	tons	-	-	-	-	-	-	-	-
Mixed	tons	0.00340662	-	-	-	-	-	-	-
Electricity	MkW-h	0.00000403	0.000028	0.000006	0.000041	0.000090	0.000030	0.000114	0.000000
Energy	TJ	0.00009081	0.001544	0.000052	0.002265	0.000832	0.000229	0.001412	0.000074
Water									
Precipitation	m^3	90.42000000	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Incremental	m^3	82.20000000	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Intake	m^3	-	0.0307	-	0.17	7.30	0.21	9.73	-
Recycled/Reused	m^3	Not applicable	0.0307	-	0.1743	7.30	0.21	27.16	-
Discharged	m^3	Not applicable	0.0307	-	0.1743	7.30	0.21	27.16	-

Source: Modelling done as part of this study

Table 5.11 (continued): Emission coefficients E_{ij} for the sugar cane value chain.

Sink	Unit	Sugar cane	Sugar milling	Boiler Fuel	Sugar refining	Food & Beverages	Feed Processing	Board Manufacturing	Transport
Waste									
Generated	MT	-	-	-	0.000024	-	0.00000014	0.000072	0.00000110
Managed	MT	-	-	-	-	-	-	0.0000046	0.000000038
Shipped	MT	-	-	-	-	-	0.00000014	0.000065	0.00000125
Water pollution									
BOD	MT	0.00000040	0.00020	-	0.00029	0.00000033	0.000000083	0.0031	-
TSS	MT	0.000078	0.00028	-	0.00042	0.00000013	0.00000012	0.0107	-
Air emissions									
SO_2	MT	0.0000006	0.0007240	-	0.0010619	0.0002197	0.0000156	0.0000131	0.0000027
CO	MT	0.0002511	0.0010176	0.0000524	0.0014925	0.0002346	0.0000015	0.0000013	0.0001164
NO_2	MT	0.0002805	0.0007722	-	0.0011327	0.0000363	0.0000088	0.0000157	0.0000493
VOC	MT	0.0000443	0.0001569	0.0000150	0.0002301	0.0000946	0.0000230	0.0002553	0.0000219
Lead	MT	-	-	-	-	-	-	-	-
PM10	$MTCO_2E$	-	0.0001931	-	0.0002832	-	0.0000284	0.0000013	-
GWP	$MTCO_2E$	0.0064868	0.1277830	0.0024093	0.1874253	0.0625269	0.0158831	0.1050283	0.0054160
CO_2	$MTCO_2E$	0.0056562	0.1254825	0.0024018	0.1840509	0.0580287	0.0158440	0.1049025	0.0052646
CH_4	$MTCO_2E$	0.0000170	0.0000684	0.0000075	0.0001003	0.0000657	0.0000136	0.0000804	0.0000085
N_2O	$MTCO_2E$	0.0008135	0.0022362	-	0.0032800	0.0001090	0.0000256	0.0000454	0.0001429
CFCs	$MTCO_2E$	-	-	-	-	0.0043235	-	-	-

Service	Unit	Sugar cane	Sugar milling	Boiler Fuel	Sugar refining	Food & Beverages	Feed Processing	Board Manufacturing	Transport
Carbon sequestration	$MTCO_2E$	-	-	-	-	-	-	0.00150237	-
Area under conservation	ha	0.20000000	-	-	-	-	-	-	-

Source: Modelling done as part of this study

Table 5.12: Emission coefficients E_{ij} for the sub-tropical fruit value chain.

Source	Unit	Avocados	Mangos	Mango Processing	Oranges	Orange Processing	Grapefruit	Grapefruit Processing	Bananas	Transport
Soil										
Nitrogenous	tons	0.0000336	0.0000203	-	0.0000097	-	0.0000103	-	0.0000154	-
Ammonium nitrate	tons	0.0034320	0.0020706	-	0.0009891	-	0.0010556	-	0.0015733	-
Ammonium sulfate	tons	0.0050050	0.0030196	-	0.0014424	-	0.0015394	-	0.0022945	-
Organic	tons	0.0080584	0.0048618	-	0.0023223	-	0.0024786	-	0.0036943	-
Phosphatic	tons	0.0001009	0.0000609	-	0.0000291	-	0.0000310	-	0.0000463	-
Super phosphates	tons	0.0096398	0.0058158	-	0.0027781	-	0.0029650	-	0.0044192	-
Mixed	tons	0.0122475	0.0073891	-	0.0035296	-	0.0037670	-	0.0056147	-
Electricity	MkW-h	0.0000289	0.0000271	0.00042105	0.0000112	0.00042105	0.0000112	0.00042105	0.0000170	0.0000004
Energy	TJ	0.0002696	0.0002529	0.00264662	0.0001047	0.00264662	0.0001047	0.00264662	0.0001581	0.0000737
Water										
Precipitation	m^3	11.7017646	4.4454744	-	3.0522490	-	4.2144515	-	7.3094497	#VALUE!
Incremental	m^3	528.3000000	200.7	-	137.8000000	-	190.2700000	-	330.0000000	#VALUE!
Intake	m^3	-	-	39.47		39.47		39.47	-	-
Recycled/Reused	m^3	-	-	39.47	-	39.47	-	39.47	-	-
Discharged	m^3	-	-	39.47	-	39.47	-	39.47	-	-

Source: Modelling done as part of this study

Table 5.12 (continued): Emission coefficients E_{ij} for the sub-tropical fruit value chain.

Sink	Unit	Avocados	Mangos	Mango Processing	Oranges	Orange Processing	Grapefruit	Grapefruit Processing	Bananas	Transport
Waste										
Generated	MT	-	-	-	-	-	-	-	-	0.0000011
Managed	MT	-	-	-	-	-	-	-	-	0.0000000
Shipped	MT	-	-	-	-	-	-	-	-	0.0000012
Water pollution										-
BOD	MT	0.00000515	0.00000483	0.00010910	0.00000200	0.00010910	0.00000200	0.00010910	0.00000302	-
TSS	MT	0.00100249	0.00094059	0.00017211	0.00038928	0.00017211	0.00038928	0.00017211	0.00058794	-
Air emissions										
SO_2	MT	0.0000087	0.0000082	0.0001805	0.0000034	0.0001805	0.0000034	0.0001805	0.0000051	0.000003
CO	MT	0.0000005	0.0000004	-	0.00000018	-	0.00000018	-	0.00000027	0.000116
NO_2	MT	0.0000044	0.0000041	0.0001203	0.0000017	0.0001203	0.0000017	0.0001203	0.0000026	0.000049
VOC	MT	0.0000028	0.0000027	0.0000602	0.0000011	0.0000602	0.0000011	0.0000602	0.0000017	0.000022
Lead	MT	-	-	-	-	-	-	-	-	-
PM10	$MTCO_2E$	0.0000051	0.0000048	0.0000602	0.0000020	0.0000602	0.0000020	0.0000602	0.0000030	-
GWP	$MTCO_2E$	0.0159664	0.0149804	0.1823158	0.0061999	0.1823158	0.0061999	0.1823158	0.0093639	0.005418
CO_2	$MTCO_2E$	0.0158839	0.0149030	0.1818346	0.0061679	0.1818346	0.0061679	0.1818346	0.0093156	0.005266
CH_4	$MTCO_2E$	0.0000697	0.0000654	0.0001203	0.0000271	0.0001203	0.0000271	0.0001203	0.0000409	0.000009
N_2O	$MTCO_2E$	0.0000128	0.0000120	0.0004211	0.0000050	0.0004211	0.0000050	0.0004211	0.0000075	0.000143
CFCs	$MTCO_2E$	-	-	-	-	-	-	-	-	-

Service	Unit	Avocados	Mangos	Mango Processing	Oranges	Orange Processing	Grapefruit	Grapefruit Processing	Bananas	Transport
Carbon sequestration	$MTCO_2E$	-	-	-	-	-	-	-	-	-
Area under conservation	Ha	0.2000000	0.2000000	-	0.2000000	-	0.2000000	-	0.2000000	-

Source: Modelling done as part of this study

Table 5.13: Dose impacts D_{ij} for the forestry value chain.

Source	Unit	Pine Forestry	Gum Forestry	Saw milling	Mining timber	Poles	Charcoal	Pulp and Paper	Furniture products	Board products	Transport
Soil											
Nitrogenous	Tons	8.76	5.67	-	-	-	-	-	-	-	-
Ammonium nitrate	Tons	893.78	578.45	-	-	-	-	-	-	-	-
Ammonium sulfate	Tons	1,303.43	843.57	-	-	-	-	-	-	-	-
Organic	Tons	2,098.63	1,358.22	-	-	-	-	-	-	-	-
Phosphatic	Tons	26.29	17.01	-	-	-	-	-	-	-	-
Super phosphates	Tons	2,510.47	1,624.76	-	-	-	-	-	-	-	-
Mixed	Tons	3,189.56	2,064.27	-	-	-	-	-	-	-	-
Electricity	MkW-h	24.61	15.51	59	16	0	4	4	5	63	1,156
Energy	TJ	229.42	144.59	279	16	5	55	79	13	232	20,842
Water											
Precipitation	m^3	2,902,726,981	1,019,345,499	-	-	-	-	-	-	-	-
Incremental	m^3	187,704,615	89,974,289	-	-	-	-	-	-	-	-
Intake	m^3	-	-	292,980	2,899	17,179	28,573	6,084,071	15,460	33,615	-
Recycled/Reused	m^3	Not applicable	Not applicable	439,470	4,348	25,768	-	16,977,210	23,189	50,423	-
Discharged	m^3	Not applicable	Not applicable	292,980	2,899	17,179	28,573	6,084,071	15,460	33,615	-

Source: Modelling done as part of this study

Table 5.13 (continued): Dose impacts D_{ij} for the forestry value chain.

Sink	Unit	Pine Forestry	Gum Forestry	Saw milling	Mining timber	Poles	Charcoal	Pulp and Paper	Furniture products	Board products	Transport
Waste											
Generated	MT	-	-	1	-	286	5	62	2	2	5
Managed	MT	-	-	-	-	7	-	-	-	-	0
Shipped	MT	-	-	1	-	120	5	12	2	2	6
Water pollution											
BOD	MT	4	3	6	-	-	-	982	-	-	-
TSS	MT	4	3	28	-	-	-	3,336	-	-	-
Air emissions											
SO_2	MT	7.41	4.67	41.38	49.50	0.77	25.80	4,407.14	12.55	26.75	12.44
CO	MT	0.40	0.25	360.09	5.50	3.76	296.53	5,159.38	0.01	206.35	535.37
NO_2	MT	3.75	2.36	116.77	5.50	0.22	5.23	2,975.36	0.06	117.69	226.74
VOC	MT	2.41	1.52	126.18	66.00	1.33	13.47	915.96	1.09	230.04	100.67
Lead	MT	-	-	-	-	-	-	-	-	-	-
PM10	$MTCO_2E$	4.34	2.74	78.53	-	0.30	6.79	450.69	0.01	87.12	-
GWP	$MTCO_2E$	13,589	8,564	15,734	-	764	2,687	331,976	2,294	12,288	24,919
CO_2	$MTCO_2E$	13,518	8,520	15,373	-	762	2,670	322,454	2,291	11,934	24,223
CH_4	$MTCO_2E$	59	37	22.44	-	1.54	2.17	86.07	3.01	12.99	39.16
N2O	$MTCO_2E$	10.87	6.85	339	-	0.75	15.13	8,629	0.16	341.62	657.54
CFCs	$MTCO_2E$	-	-	-	-	-	-	-	-	-	-

Service	Unit	Pine Forestry	Gum Forestry	Saw milling	Mining timber	Poles	Charcoal	Pulp and Paper	Furniture products	Board products	Transport
Carbon sequestration	$MTCO_2E$	-	-	221,214	217,042	13,467	-	39,063	4,186	125,000	-
Area under conservation	ha	57,376	43,991	-	-	-	-	-	-	-	-

Source: Modelling done as part of this study

Table 5.14: Dose impacts D_{ij} for the sugar value chain.

Source	Unit	Sugar cane	Sugar milling	Boiler Fuel	Sugar refining	Food & Beverages	Feed Processing	Board Manufacturing	Transport
Soil									
Nitrogenous	tons	-	-	-	-	-	-	-	-
Ammonium nitrate	tons	-	-	-	-	-	-	-	-
Ammonium sulfate	tons	5,160.28	-	-	-	-	-	-	-
Organic	tons	1,288.69	-	-	-	-	-	-	-
Phosphatic	tons	-	-	-	-	-	-	-	-
Super phosphates	tons	-	-	-	-	-	-	-	-
Mixed	tons	10,323.33	-	-	-	-	-	-	-
Electricity	MkW-h	12.20	10.21	3.14	11.26	22.35	5.35	8.29	1.18
Energy	TJ	275.18	560.07	26.99	617.59	206.84	41.25	102.88	223.32
Water									
Precipitation	m^3	274,006,236	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Incremental	m^3	249,096,578	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Intake	m^3	-	11,122.56	-	47,516.05	1,815,164.48	37,869.70	709,100.93	-
Recycled/Reused	m^3	Not applicable	11,122.56	-	47,516.05	1,815,164.48	37,869.70	1,978,700.76	-
Discharged	m^3	Not applicable	11,122.56	-	47,516.05	1,815,164.48	37,869.70	1,978,700.76	-

Source: Modelling done as part of this study

Table 5.14 (continued): Dose impacts D_{ij} for the sugar value chain.

Sink	Unit	Sugar cane	Sugar milling	Boiler Fuel	Sugar refining	Food & Beverages	Feed Processing	Board Manufacturing	Transport
Waste									
Generated	MT	-	-	-	6.6034	-	0.0249	5.2395	3.3209
Managed	MT	-	-	-	-	-	-	0.3334	0.1166
Shipped	MT	-	-	-	-	-	0.0249	4.7394	3.7751
Water pollution									
BOD	MT	1.23	71.999046	-	79.392542	0.081491	0.015001	228.976212	-
TSS	MT	237.68	103.229845	-	113.830394	0.032300	0.021726	777.690161	-
Air emissions									
SO_2	MT	1.920219	262.534126	-	289.493442	54.639023	2.809359	0.952638	8.194341
CO	MT	760.979949	369.006300	27.241903	406.899116	58.356924	0.273477	0.095264	352.614710
NO_2	MT	850.10	280.04	-	308.79	9.04	1.59	1.14	149.34
VOC	MT	134.11	56.88	7.78	62.72	23.53	4.15	18.60	66.31
Lead	MT	-	-	-	-	-	-	-	-
PM10	$MTCO_2E$	-	70.01	-	77.20	-	5.12	0.10	-
GWP	$MTCO_2E$	19,657.31	46,338.73	1,253.13	51,097.20	15,550.66	2,865.65	7,650.69	16,412.64
CO_2	$MTCO_2E$	17,140.43	45,504.46	1,249.24	50,177.25	14,431.95	2,858.58	7,641.52	15,953.77
CH_4	$MTCO_2E$	51.60	24.79	3.89	27.34	16.33	2.46	5.86	25.79
N2O	$MTCO_2E$	2,465.28	810.94	-	894.21	27.11	4.62	3.31	433.08
CFCs	$MTCO_2E$	-	-	-	-	1,075.27	-	-	-

Service	Unit	Sugar cane	Sugar milling	Boiler Fuel	Sugar refining	Food & Beverages	Feed Processing	Board Manufacturing	Transport
Carbon sequestration	$MTCO_2E$	-	-	-	-	-	-	4,552.75	-
Area under conservation	Ha	8,361.95	-	-	-	-	-	-	-

Source: Modelling done as part of this study

Table 5.15: Dose impacts D_{ij} for the sub-tropical fruit value chain.

Source	Unit	Avocados	Mangos	Mango Processing	Oranges	Orange Processing	Grapefruit	Grapefruit Processing	Bananas	Transport
Soil										
Nitrogenous	tons	1.56	0.56	-	2.98	-	0.96	-	3.32	-
Ammonium nitrate	tons	159.58	56.71	-	303.90	-	98.04	-	338.39	-
Ammonium sulfate	tons	232.72	82.70	-	443.18	-	142.98	-	493.48	-
Organic	tons	374.69	133.16	-	713.56	-	230.21	-	794.55	-
Phosphatic	tons	4.69	1.67	-	8.94	-	2.88	-	9.95	-
Super phosphates	tons	448.22	159.29	-	853.60	-	275.39	-	950.47	-
Mixed	tons	569.47	202.37	-	1,084.50	-	349.88	-	1,207.58	-
Electricity	MkW-h	1.34	0.74	1.15	3.45	10.39	1.04	3.14	3.65	0.27
Energy	TJ	12.53	6.93	7.20	32.16	65.31	9.72	19.74	34.00	50.80
Water										
Precipitation	m^3	544,097	121,754	-	937,839	-	391,438	-	1,572,080	na
Incremental	m^3	24,564,365	5,496,852	-	42,340,635	-	17,672,278	-	70,974,750	-
Intake	m^3	-	-	107,441	-	974,116	-	294,459	-	-
Recycled/Reused	m^3	-	-	107,441	-	974,116	-	294,459	-	-
Discharged	m^3	-	-	107,441	-	974,116	-	294,459	-	-

Source: Modelling done as part of this study

Table 5.15 (continued): Dose impacts D_{ij} for the sub-tropical fruit value chain.

Sink	Unit	Avocados	Mangos	Mango Processing	Oranges	Orange Processing	Grapefruit	Grapefruit Processing	Bananas	Transport
Waste										
Generated	MT	-	-	-	-	-	-	-	-	0.76
Managed	MT	-	-	-	-	-	-	-	-	0.03
Shipped	MT	-	-	-	-	-	-	-	-	0.86
Water pollution										-
BOD	MT	0.2396	0.1324	0.2970	0.6147	2.6924	0.1858	0.8139	0.6499	-
TSS	MT	46.6	25.8	0.4685	119.6	4.2	36.2	1.3	126.5	
Air emissions										
SO_2	MT	0.405	0.224	0.491	1.039	4.453	0.314	1.346	1.098	
CO	MT	0.022	0.012	-	0.056	-	0.017	-	0.059	1.864
NO_2	MT	0.205	0.113	0.327	0.526	2.969	0.159	0.897	0.556	80.210
VOC	MT	0.132	0.073	0.164	0.338	1.484	0.102	0.449	0.358	33.970
Lead	MT	-	-	-	-	-	-	-	-	15.083
PM10	$MTCO_2E$	0.237	0.131	0.164	0.608	1.484	0.184	0.449	0.643	-
GWP	$MTCO_2E$	742.390	410.290	496.242	1,905.003	4,499.192	575.850	1,360.030	2,013.950	-
CO_2	$MTCO_2E$	738.554	408.169	494.933	1,895.158	4,487.317	572.874	1,356.441	2,003.542	3,733.428
CH_4	$MTCO_2E$	3.243	1.792	0.327	8.321	2.969	2.515	0.897	8.797	3,629.047
N2O	$MTCO_2E$	0.594	0.328	1.146	1.524	10.391	0.461	3.141	1.611	5.867
CFCs	$MTCO_2E$	-	-	-	-	-	-	-	-	98.513

Service	Unit	Avocados	Mangos	Mango Processing	Oranges	Orange Processing	Grapefruit	Grapefruit Processing	Bananas	Transport
Carbon sequestration	$MTCO_2E$	-	-	-	-	-	-	-	-	-
Area under conservation	Ha	845	366	-	1,351	-	432	-	1,229	-

Source: Modelling done as part of this study

Table 6.1: Indirect employment distribution benefits in the Forestry, Sugarcane and Fruit value chains (person-days per m^3 or ton).

		Forestry value chain		Sugarcane value chain		Sub-tropical fruit value chain	
Total Employment		8.93		3.30		4.88	
Type	Regular	8.48	95.0%	2.82	85.4%	3.55	72.7%
	Part-time / Seasonal	0.25	2.8%	2.55	7.6%	1.20	24.6%
	Casual	0.20	2.2%	2.91	7.2%	0.13	2.7%
Skills Level	Managerial	0.45	5.1%	0.16	4.8%	0.24	4.8%
	Skilled	1.37	15.3%	0.35	10.7%	0.52	10.7%
	Semi-skilled	4.69	52.6%	1.87	56.5%	2.76	56.5%
	Unskilled	1.58	17.7%	0.48	14.5%	0.71	14.5%
	Unspecified	0.84	9.4%	0.44	13.4%	0.65	13.4%
Location	Urban	4.37	49.0%	1.62	49.0%	2.39	49.0%
	Non-urban	4.56	51.0%	1.68	51.0%	2.49	51.0%
Gender	Male	5.36	60.0%	2.19	66.4%	2.39	66.3%
	Female	3.56	39.9%	1.11	33.6%	1.64	33.7%
Race	Africans / Blacks	6.08	68.1%	2.36	71.5%	2.43	49.7%
	Coloureds	1.05	11.8%	0.20	6.1%	1.17	24.1%
	Indians / Asians	0.66	7.4%	0.32	9.7%	0.03	0.6%
	Whites	1.13	12.7%	0.42	12.7%	1.06	21.7%

Source: Modelling done as part of this study

Table 6.2: Direct and indirect employment distribution benefits in the Forestry value chain (person-days per m^3 or ton).

		Direct		Indirect						
		Pine plantations	Gum plantations	Saw milling	Mining timber milling	Pole manufactu-ring	Charcoal manufactu-ring	Board Manufactu-ring	Pulp and paper milling	Furniture and wood products
		m^3	m^3	m^3	m^3	m^3	tons	m^3	tons	m^3
Total Employment		**0.45**	**0.62**	**1.05**	**0.75**	**1.15**	**0.39**	**1.46**	**1.63**	**2.50**
Type	**Regular**	0.45	0.62	1.00	0.71	1.09	0.35	1.32	1.59	2.43
	Part-time / Seasonal	-	-	0.05	0.03	0.05	-	0.04	0.03	0.04
	Casual	-	-	0.01	0.01	0.01	0.04	0.10	0.00	0.03
Skills Level	**Managerial**	0.01	0.01	0.02	0.04	0.06	0.02	0.07	0.13	0.12
	Skilled	0.02	0.03	0.06	0.08	0.12	0.04	0.16	0.64	0.27
	Semi-skilled	0.13	0.18	0.35	0.42	0.65	0.22	0.83	0.82	1.41
	Unskilled	0.29	0.40	0.62	0.11	0.17	0.06	0.21	0.05	0.36
	Unspecified	-	-	-	0.10	0.15	0.05	0.20	-	0.33
Loca -tion	**Urban**	0.07	0.09	0.51	0.37	0.56	0.19	0.72	0.80	1.22
	Non-urban	0.38	0.53	0.54	0.38	0.59	0.20	0.74	0.83	1.28
Gen-der	**Male**	0.33	0.45	0.63	0.45	0.69	0.23	0.88	0.98	1.50
	Female	0.12	0.17	0.42	0.30	0.46	0.16	0.58	0.65	1.00
Race	**Africans / Blacks**	0.30	0.42	0.88	0.63	0.96	0.35	0.98	0.77	1.52
	Coloureds	0.10	0.14	0.10	0.07	0.11	0.00	0.19	0.09	0.50
	Indians / Asians	0.00	0.00	0.01	0.00	0.01	0.01	0.08	0.37	0.19
	Whites	0.04	0.06	0.07	0.05	0.08	0.03	0.21	0.41	0.29

Source: Modelling done as part of this study

Table 6.3: Direct and indirect employment distribution benefits in the Sugarcane value chain (person-days per m^3 or ton).

		Direct	Indirect				
		Sugarcane Farming	Sugar Milling	Sugar Refining	Feed Manufacturing	Board Manufacturing	Food and Beverages
Total Employment		**1.03**	**0.08**	**0.05**	**0.03**	**0.04**	**3.10**
Type	**Regular**	0.97	0.06	0.03	0.03	0.04	2.66
	Part-time / Seasonal	-	0.01	0.01	0.00	-	0.23
	Casual	0.06	0.01	0.01	0.00	0.00	0.22
Skills Level	**Managerial**	0.01	0.00	0.00	0.00	0.00	0.15
	Skilled	0.31	0.01	0.00	0.00	0.00	0.33
	Semi-skilled	0.10	0.05	0.03	0.02	0.02	1.75
	Unskilled	0.57	0.01	0.01	0.00	0.01	0.45
	Unspecified	0.04	0.01	0.01	0.00	0.00	0.41
Location	**Urban**	0.13	0.04	0.02	0.01	0.02	1.52
	Non-urban	0.90	0.04	0.02	0.01	0.02	1.58
Gender	**Male**	0.75	0.05	0.03	0.02	0.02	2.06
	Female	0.28	0.03	0.02	0.01	0.01	1.04
Race	**Africans / blacks**	0.70	0.06	0.04	0.02	0.02	2.21
	Coloureds	0.23	0.00	0.00	0.00	0.00	0.19
	Indians / Asians	0.00	0.01	0.00	0.00	0.00	0.31
	Whites	0.09	0.01	0.00	0.01	0.01	0.39
	Unspecified	0.01	-	-	-	-	-

Source: Modelling done as part of this study

Table 6.4: Direct and indirect employment distribution benefits in the sub-tropical Fruit value chain (person-days per m^3 or ton).

		Direct	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct
		Avocados	Mangos	Mango Processing	Oranges	Orange Processing	Grapefruit	Grapefruit Processing	Bananas
	Total Employment	**2.67**	**4.04**	**4.88**	**2.42**	**4.88**	**2.37**	**4.88**	**2.14**
Type	Regular	2.52	3.81	3.55	2.28	3.55	2.24	3.55	2.02
	Part-time / Seasonal	-	-	1.20	-	1.20	-	1.20	-
	Casual	0.15	0.23	0.13	0.14	0.13	0.13	0.13	0.12
Skills Level	Managerial	0.03	0.05	0.24	0.03	0.24	0.03	0.24	0.03
	Skilled	0.80	1.21	0.52	0.72	0.52	0.71	0.52	0.64
	Semi-skilled	0.25	0.38	2.76	0.23	2.76	0.22	2.76	0.20
	Unskilled	1.48	2.24	0.71	1.34	0.71	1.31	0.71	1.19
	Unspecified	0.11	0.16	0.65	0.10	0.65	0.10	0.65	0.09
Location	Urban	0.34	0.51	2.39	0.30	2.39	0.30	2.39	0.27
	Non-urban	2.33	3.53	2.49	2.12	2.49	2.07	2.49	1.87
Gender	Male	1.93	2.92	3.24	1.75	3.24	1.71	3.24	1.55
	Female	0.74	1.12	1.64	0.67	1.64	0.66	1.64	0.59
Race	Africans / blacks	1.81	2.74	2.43	1.64	2.43	1.61	2.43	1.45
	Coloureds	0.59	0.90	1.17	0.54	1.17	0.53	1.17	0.47
	Indians / Asians	0.01	0.01	0.03	0.01	0.03	0.01	0.03	0.01
	Whites	0.25	0.37	1.06	0.22	1.06	0.22	1.06	0.20

Source: Modelling done as part of this study

Table 6.5 Direct and indirect jobs created in the Forestry value chain (equivalent person-years)

		Direct		Indirect						
		Pine plantations	Gum plantations	Saw milling	Mining timber milling	Pole manufactu-ring	Charcoal manufactu-ring	Board Manufactu-ring	Pulp and paper milling	Furniture and wood products
		m^3	m^3	m^3	m^3	m^3	tons	m^3	tons	m^3
Total Employment		6,997	3,201	5,830	1,816	182	281	1,798	9,223	180
Type	**Regular**	6,997	3,201	5,529	1,722	173	249	1,622	9,022	175
	Part-time / Seasonal	-	-	251	78	8	-	55	186	3
	Casual	-	-	50	16	2	32	121	15	2
Skills Level	**Managerial**	140	64	117	88	9	14	87	738	9
	Skilled	350	160	350	195	20	30	193	3,597	19
	Semi-skilled	2,029	928	1,924	1,026	103	159	1,016	4,611	102
	Unskilled	4,478	2,048	3,439	264	26	41	261	277	26
	Unspecified	-	-	-	243	24	38	241	-	24
Location	**Urban**	1,065	487	2,856	890	89	138	881	4,518	88
	Non-urban	5,932	2,714	2,974	926	93	143	917	4,705	92
Gender										
	Male	5,062	2,316	3,496	1,089	109	168	1,078	5,531	108
	Female	1,935	885	2,325	724	73	112	717	3,678	72
Race	**Africans / Blacks**	4,741	2,169	4,879	1,520	152	251	1,202	4,352	110
	Coloureds	1,553	710	533	166	17	3	238	491	36
	Indians / Asians	25	11	34	11	1	4	101	2,080	13
	Whites	644	295	384	119	12	23	257	2,299	21
	Unspecified	35	16	-	-	-	-	-	-	-

Source: Modelling done as part of this study

Table 6.6 Direct and indirect jobs created in the Sugarcane value chain (equivalent person-years)

		Direct	Indirect				
		Sugarcane Farming	Sugar Milling	Sugar Refining	Feed Manufacturing	Board Manufacturing	Food and Beverages
Total Employment		12,485.13	981.84	66.73	16.56	13.28	1,080.96
Type	Regular	11,787.57	687.94	46.75	15.57	12.76	926.60
	Part-time / Seasonal	-	151.15	18.09	0.50	-	78.95
	Casual	697.56	142.75	9.70	0.48	0.52	75.41
Skills Level	Managerial	158.48	47.52	3.23	0.80	0.64	52.32
	Skilled	3,739.94	105.42	7.16	1.78	1.43	116.06
	Semi-skilled	1,164.01	554.84	37.71	9.36	7.50	610.85
	Unskilled	6,921.36	142.69	9.70	2.41	1.93	157.10
	Unspecified	501.35	131.37	8.93	2.22	1.78	144.63
Location	Urban	1,569.46	480.99	32.69	8.11	6.50	529.55
	Non-urban	10,915.67	500.85	34.04	8.45	6.77	551.41
Gender	Male	9,033.22	651.27	44.26	10.99	8.81	717.02
	Female	3,451.92	330.57	22.47	5.58	4.47	363.94
Race	Africans / blacks	8,459.80	781.67	53.12	11.58	8.73	770.66
	Coloureds	2,770.41	7.51	0.51	1.37	1.48	67.20
	Indians / Asians	43.84	94.82	6.44	0.51	0.28	106.89
	Whites	1,149.25	97.84	6.65	3.10	2.79	136.21
	Unspecified	61.83	-	-	-	-	-

Source: Modelling done as part of this study

Table 6.7 Direct and indirect jobs created in the sub-tropical Fruit value chain (equivalent person-years)

		Direct Avocados	Direct Mangos	Indirect Mango	Direct Oranges	Indirect Orange	Direct Grapefruit	Indirect Grapefruit	Direct Bananas
Total Employment		496.59	442.60	178.61	2,974.29	1,619.39	880.50	489.51	1,841.04
Type	**Regular**	468.84	417.87	129.83	2,808.11	1,177.08	831.31	355.81	1,738.18
	Part-time / Seasonal	-	-	44.02	-	399.14	-	120.65	-
	Casual	27.75	24.73	4.76	166.18	43.17	49.19	13.05	102.86
Skills Level	**Managerial**	6.30	5.62	8.65	37.75	78.38	11.18	23.69	23.37
	Skilled	148.75	132.58	19.18	890.95	173.87	263.76	52.56	551.49
	Semi-skilled	46.30	41.26	100.93	277.30	915.12	82.09	276.63	171.64
	Unskilled	275.29	245.36	25.96	1,648.85	235.35	488.12	71.14	1,020.61
	Unspecified	19.94	17.77	23.90	119.44	216.68	35.36	65.50	73.93
Location	**Urban**	62.42	55.64	87.50	373.89	793.31	110.68	239.81	231.43
	Non-urban	434.16	386.96	91.11	2,600.40	826.08	769.82	249.71	1,609.61
Gender	**Male**	359.29	320.23	87.50	2,151.95	1,074.17	637.06	324.70	1,332.03
	Female	137.30	122.37	60.14	822.34	545.22	243.44	164.81	509.02
Race	**Africans / blacks**	336.48	299.90	88.78	2,015.35	804.93	596.62	243.32	1,247.47
	Coloureds	110.19	98.21	42.99	659.98	389.80	195.38	117.83	408.52
	Indians / Asians	1.74	1.55	1.11	10.44	10.04	3.09	3.04	6.47
	Whites	45.71	40.74	38.68	273.78	350.66	81.05	106.00	169.47
	Unspecified	2.46	2.19	-	14.73	-	4.36	-	9.12

Source: Modelling done as part of this study

Table 6.8 Direct and indirect jobs created in the Forestry, irrigated Sugarcane and sub-tropical Fruit chains (equivalent person-years)

		Forestry			Sugar			Sub-tropical fruit		
		Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect
Total Employment		29,507	10,198	19,309	14,778	12,485	2,293	8,923	6,635	2,288
Type	Regular	28,689	10,198	18,492	13,611	11,788	1,823	7,927	6,264	1,663
	Part-time / Seasonal	580	-	580	249	-	249	564	-	564
	Casual	237	-	237	926	698	229	432	371	61
Skills Level	Managerial	1,264	204	1,060	270	158	111	195	84	111
	Skilled	4,914	510	4,404	3,987	3,740	247	2,233	1,988	246
	Semi-skilled	11,898	2,957	8,941	2,473	1,164	1,309	1,911	619	1,293
	Unskilled	10,861	6,526	4,335	7,246	6,921	325	4,011	3,678	332
	Unspecified	570	-	570	802	501	301	573	266	306
Location	Urban	11,011	1,552	9,459	2,693	1,569	1,123	1,955	834	1,121
	Non-urban	18,496	8,646	9,850	12,085	10,916	1,170	6,968	5,801	1,167
Gender	Male	18,958	7,378	11,580	10,579	9,033	1,546	6,287	4,801	1,486
	Female	10,521	2,819	7,701	4,198	3,452	747	2,605	1,834	770
Race	Africans / blacks	19,375	6,910	12,465	10,175	8,460	1,715	5,633	4,496	1,137
	Coloureds	3,748	2,263	1,485	2,866	2,770	96	2,023	1,472	551
	Indians / Asians	2,281	36	2,245	259	44	215	37	23	14
	Whites	4,053	939	3,114	1,417	1,149	267	1,106	611	495
	Unspecified	50	50	-	62	62	-	33	33	-

Source: Modelling done as part of this study