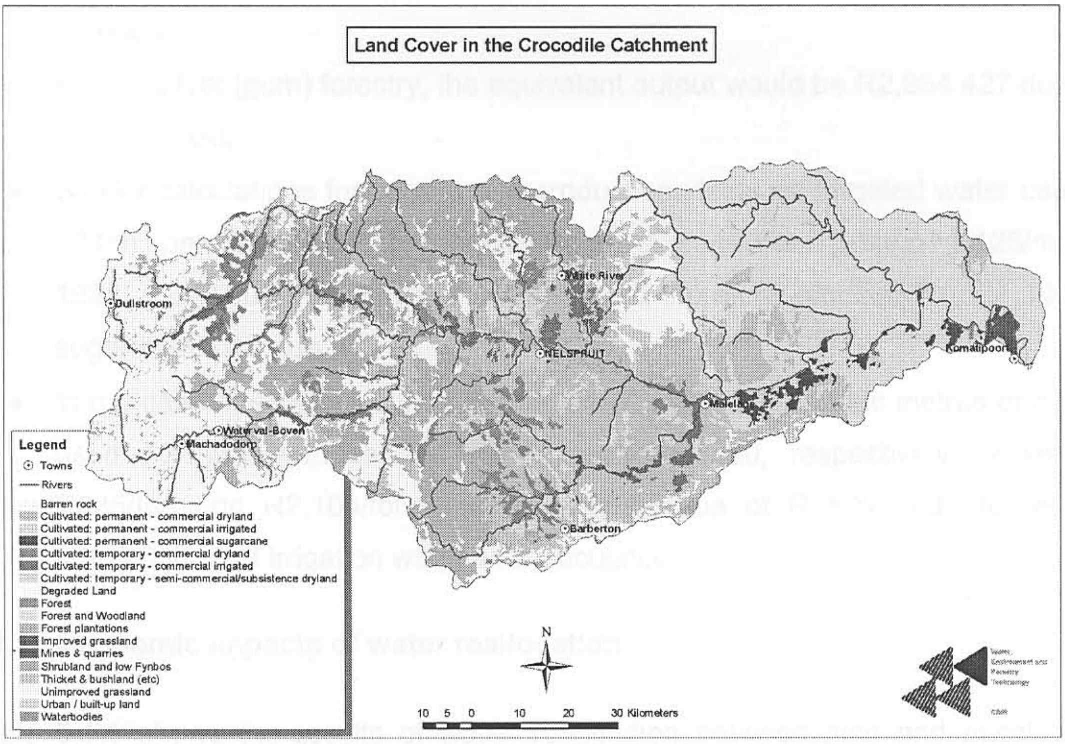
Chapter 5: Results & Discussion

In this Chapter, the results of the various scenarios simulating the impacts of changes in certain selected policy measures are presented and discussed in detail. Unless otherwise indicated, the prices used were for 1998. In all instances, scenarios were generated by first determining the change in Output (ΔX) based on specific assumptions, and thereafter calculating the resultant change in Final Demand (ΔFD) by applying the ***FD/X*** ratio calculated from the original Conningarth SAM (2000).

5.1 Scenario 1: Reallocation of water between major users

In the Crocodile River Catchment, water transfers among major water users in the agriculture sector could take place between forestry, irrigated horticultural crops and irrigated sugar cane farming. Figure 5.1 shows the distribution and extent of land use by these activities.

Figure 5.1: Land use patterns in the Crocodile River Catchment.



Transfer of water between forestry in the upper part of the catchment and the irrigated crops in the lower parts would be complex due to the large distance between their locations, and the subsequent hydrological complexities involved. It is much more probable that reallocation may occur between and within the fruit and sugar farming activities in the lower lying regions of the catchment. However, at a macro level, it is possible to simulate the effect of substituting plantations with sugar cane and sub-tropical fruit farming or vice versa.

In these policy experiments, substitution scenarios of 1,000,000m^3 of water between forestry, sugar and fruit growers were simulated. Changes in final demand due to these substitutions were calculated based on the following assumptions:

- Pine forestry, at an average mean annual increment (MAI) of 15m^3/ha/a, and an average incremental water use of 100mm (equivalent to 1000m^3 of water per hectare), has a water usage of 66.5m^3 per cubic metre of round wood produced. At an average round wood price of R126/m^3 at roadside in 1998, 1,000,000m^3 of water would therefore produce R1,894,737 in round wood revenue.
- For Eucalypt (gum) forestry, the equivalent output would be R2,964,427 due to a higher MAI.
- Similar calculations for sugar cane production yields an irrigated water use of 82.0m^3 per ton of cane produced. At an average cane price of R125/m^3 in 1998, 1,000,000m^3 of irrigation water would therefore produce R1,524,390 in sugar cane revenue.
- In the case of subtropical fruit farming (137.8 and 528.3 cubic metres of water used per ton oranges and avocadoes produced, respectively, prices of R835/ton and R2,108/ton, and an output value of R 8,583,691 for every 1,000,000m^3 of irrigation water was calculated.

5.1.1 Economic impacts of water reallocation

Table 5.1.1 shows the results of water substitution between pine and eucalyptus forestry and sugar cane production. In the case of the pine-sugar cane substitution, an economy-wide reduction in total output of -0.005% is observed for every 1 million m^3 of water reallocated from pine forestry to sugar cane. The main contributors to this effect are the direct impacts of increased Sugar Cane production (0.013%) and reduced Round wood production (-0.617%); and the indirect impacts of Other Commodities (-0.001%), Labour (-0.003%), Large Commercial Farmers (0.006%) and Forestry Enterprises (-0.032%). Large Commercial Farmers' enterprises show increased returns, as sugar is a commodity in which they invest. Forestry Enterprises show decreased returns due to decreased forestry activities. These results indicate that Forestry is a more efficient user of water than sugar cane, in the Crocodile catchment. In the case of eucalypt-cane substitution, similar multiplier effects are observed in the value chain activities discussed above, but due to the higher MAI of eucalyptus compared to pines, the economy-wide effect is even more pronounced, yielding a decreased output of -0.008% for every 1 million m^3 of water reallocated from eucalypt forestry to sugar cane.

Table 5.1.1: The economy-wide effect (ΔX) of water reallocation (1,000,000m^3) between forestry and sugar

Water use efficiency (m^3 water/ton sugar or m^3 roundwood): sugar = 82.0; pine = 66.5; eucalypt = 50.6

	Sectors	Pine forestry substituted by sugar	Eucalypt forestry substituted by sugar
5	Sugar Cane	0.013%	0.013%
21	Roundwood	-0.617%	-0.966%
35	Other Commodities	-0.001%	-0.002%
39	Labour	-0.003%	-0.006%
41	Large Commercial Farmers	0.006%	0.005%
45	Forestry Enterprises	-0.032%	-0.050%
Total (excluding Activities where duplicate commodity exists)		-0.005%	-0.008%

Table 5.1.2 shows the same experiments in a situation of different crop water usages. In the pine-sugar cane case, it was assumed that sugar water use productivity increased by 10% to 73.8m^3 water per ton of cane produced, due to favourable climatic conditions; while in the eucalypt-sugar cane case eucalypt water use efficiency was improved to 38.6m^3 per cubic metre round wood produced, based on modelling by the CSIR (Gush et al. 2002).

Table 5.1.2: The economy-wide effect of water reallocation (1,000,000m^3) between forestry and sugar

Water use efficiency (m^3 water/ton sugar or m^3 round wood): sugar = 73.8; pine = 66.5 in the pine-sugar scenario; sugar = 82.0 and eucalypt = 38.6 in the eucalypt-sugar scenario

	Sectors	Pine forestry substituted by sugar	Eucalypt forestry substituted by sugar
5	Sugar Cane	0.015%	0.013%
18	Other food & beverages	0.000%	0.000%
21	Roundwood	-0.617%	-1.266%
35	Other Commodities	-0.001%	-0.002%
39	Labour	-0.003%	-0.007%
41	Large Commercial Farmers	0.006%	0.005%
45	Forestry Enterprises	-0.032%	-0.066%
Total (excluding Activities where duplicate commodity exists)		-0.005%	-0.011%

These results show that the effect of favourable climatic conditions on sugar cane, that increased sugar cane yield by 10% per cubic metre water used, improved Sugar Cane output increase to 0.015% from 0.013% (Table 5.1.1) for a 1,000,000m^3 water reallocation from pine to sugar cane, but did not significantly affect the total economic impact (0.005%) when compared to the results of Table 5.5.1. Further sensitivity analysis showed that the Total economic effect reduced to -0.004% only at an increased sugar cane yield of 30% per cubic metre water used.

In the case of Eucalypt forestry, new research, producing new estimates of eucalypt water use (Gush et al. 2002); changed water use efficiency of Eucalypt from 50.6 cubic metres water used per cubic metre timber harvested to 38.6. This meant that the total economic effect of a 0.008% reduction in Output (Table 5.1.1) was underestimated by 0.003% and is in fact -0.011% (Table 5.1.2). This result demonstrates the danger of basing decisions with far reaching economic effects on inaccurate water use estimates.

The main conclusion from Tables 5.1.1 and 5.1.2 is that non-market water allocation decisions between major water users need to be treated with great care. Although these results confirm previous work by Hassan (2002) and Crafford et al (2003) where value chain analyses of major water users in Mpumalanga have shown forestry to have larger direct and indirect economic impacts than the sugar value chain, the economic effects on other sectors such as labour and enterprises are also demonstrated here. However, both the forestry and sugar cane land uses support extended value chains, beyond the boundaries of the catchment, in which large multi-national companies play a large role. Water allocation decisions within a small catchment area may have economic multiplier effects that are only noticeable outside the catchment area. Water allocation to producers according to its scarcity value, as suggested by the National Water Pricing Strategy, therefore has to be done through a market driven process where the marginal value is determined by transactions between the producers.

It is also interesting to note that the production of additional sugar does not have a positive impact on the Other Food & Beverages sector. This counter-intuitive result is probably due to the fact that the bulk of the produced sugar gets exported to value adding facilities outside the catchment area, and is another strong argument for policy makers to take great care when making non-market related water allocation decisions.

Table 5.1.3 shows the economy-wide effect of water transactions of 100,000m^3 within irrigated land uses.

Table 5.1.3: The economy-wide effect of water reallocation (100,000m^3) between sugar and oranges; and oranges and bananas

Water use efficiency (m^3 water/ton sugar or m^3 round wood): sugar = 82.0; oranges = 137.8 and avocadoes = 330.3

	Sectors	Sugarcane substituted by oranges	Bananas substituted by oranges
3	Fuel	0.010%	0.002%
5	Sugar Cane	-0.001%	0.000%
12	Avoes	0.006%	0.001%
14	Citrus	0.268%	0.266%
31	Paper products	0.003%	0.001%
35	Other Commodities	0.001%	0.000%
39	Labour	0.002%	0.000%
41	Large Commercial Farmers	0.029%	0.005%
44	Agro-Industries	0.000%	0.000%
Total (excluding Activities where duplicate commodity exists)		0.007%	0.002%

The results show that in both cases it appears more beneficial to allocate water to the production of oranges. However, these analyses do not account for risk and investment factors taken into account by farmers when they decide which crops to produce. A drop in the price of oranges may completely change the outcome of this analysis. Both sugar cane and sub-tropical fruit producers may plant different fruit types and sugar cane in order to hedge against price fluctuations. For example, if the price of bananas were to increase by 10% and the price of oranges to drop to R708/ton, the net total economic benefit of allocation of water from oranges to avocadoes would be zero (assuming zero transaction costs). Once again, this emphasizes the care that needs to be taken in water allocation decisions.

This is a very important result, which, at a first glance, appears to contradict findings in earlier studies by Hassan (2002) and Crafford (2002). These studies found the value chain of sugar cane to outperform that of sub-tropical fruit if measured in terms of value added produced per unit water consumed. On closer examination, the reason for this apparent contradiction is found in the definition of the catchment area investigated and the structure of the economy in that catchment area. The Hassan (2002) and Crafford (2003) studies defined and traced the value chains for the three land uses forestry, sub-tropical fruit and sugar cane production at a provincial (Mpumalanga) level, whereas the Conningarth (2000) study, on which the present analysis is based, investigated the economic structure of the Nkomazi and part of the Barberton magisterial districts, a small component of Mpumalanga, where the local economies are largely agriculture-reliant, and relatively few manufacturing and commerce activities take place. It can therefore be expected that the amount of value adding as well as the total economic output would be less in the smaller, more rural area. Although insufficient structural economic data (multipliers) exist to demonstrate this, analysis of the total output of the various geographical areas support it: the SAM model shows the total output in the Inkomati area of Mpumalanga (Nkomazi and a part of Baberton magisterial districts) to be R8,8bn while for the rural parts of the Crocodile River Catchment area (this excludes the urban part of Nelspruit) the total output is R11,7bn (in 1998). Estimates of GGP for

1998, based on the 1994 DBSA GGP data, gives a total output of R19,2 for the Lowveld area and R111,1bn for Mpumalanga.

The model developed in this study combined the multipliers and typical output of a small, regional, rural, agricultural economy with the multipliers of its extended value chains.

5.1.2 Environmental indicators and impacts

Table 5.1.4 shows the environmental impacts of the water re-allocation between pine and sugar cane. Re-allocation of 1,000,000m^3 of water by substituting pine plantations with sugar cane results in a reduction in water use of 101,000m^3 in the rest of the economy. This result must not be interpreted as a water "saving", as it goes hand in hand with a reduction in total economic activity of 0.005% (section 5.1.1). In the eucalypt to sugar cane case, the change in water use is a larger negative (-175,000m^3) – because Eucalypt has a higher efficiency than Pine, the re-allocation of water from Eucalypt to Sugar cane has a higher indirect water use impact than in the case of Pine, as there are fewer round wood to process, especially in the higher water use pulpwood industry. The indirect water use impact can therefore also be very significant, and water allocation decisions should not be made in isolation of this impact.

Energy use does not increase significantly, neither does the global warming potential (GWP) calculated by the sum of the CO_2-equivalent emissions. Only small reductions in air pollution and fertiliser requirements are observed.

For most of the environmental impacts it becomes clear that more analysis is required to quantify the impact of the source or sink activity on humans and the ecology. Analyses of SO_2, CO, NO_2, VOC and Lead emissions for instance, are meaningless if the dose-response relationship between the emissions and human and/or ecological health is not understood. The indicators of soil source use and fertiliser consumption, only become meaningful when their site-specific impacts, such as soil salinisation (due to over-fertilisation and water pollution) and reduced soil fertility (due to under-fertilisation) are captured. Soil erosion is a form of Sink impact, and cannot be captured in this type of analysis due to its close association with poor land management practices. This leads to an important conclusion: the analysis of environmental impacts as part of an economy-wide framework (such as a SAM) is limited to indicators and impacts that can be quantitatively linked to economic activities as part of a mass balance. For instance, transport of goods will require the use of a minimum amount of fuel, which can be expressed as a coefficient of the transport economic activity. These environmental impacts also have in common the fact that they can be measured at a specified entry or exit point into or out of the economic activity (e.g. a conveyor belt, pipe or exhaust). In the literature, these are referred to as point-source/sink indicators or impacts. On the other hand, the non-point source environmental indicators and impacts are difficult to measure and mostly have to be modelled according to site-specific conditions. Examples of non-point source/sink environmental *indicators* are fertiliser application, soil erosion, non-point source water pollution (mostly due to over-fertilisation) and over-grazing, all of which have in common a large "poor" management variable. Examples of non-point source/sink environmental *impacts* are the ill-health effects suffered by humans and the environment due to for instance water and air pollution. These effects are site specific and are influenced by many factors such as concentration of the impact, proximity and the relative vulnerability of the community(ies) or ecology and the dose-response relationship. It therefore becomes clear that the framework used in this study to analyse environmental impacts also (as in the case of the economic impacts) is insufficient for fully quantifying environmental impacts. It is however possible to draw strategic conclusions on the expected change in magnitude of some of the impacts. In further discussion only the relevant environmental impacts will be analysed.

Table 5.1.4: Environmental impacts of substituting pine and eucalypt with sugar cane.

Environmental indicators / impacts			Unit	Pine subst by sugar		Eucalypt subst by sugar	
				ΔE	ΔE	ΔE	ΔE
Source	Water	Intake	1000 m3	-101	-0.016%	-175	-0.028%
	Energy	Electricity	Mkw-hr	-0.0048	-0.002%	-0.0089	-0.004%
		Energy	TJ	-0.0143	0.000%	-0.0687	-0.001%
		Bitum	mt	0.3673	0.000%	-0.2066	0.000%
		Anth	mt	0.0002	0.000%	-0.0001	0.000%
		NatGas	mt	0.0110	0.000%	-0.0075	0.000%
		LNG	mt	0.0078	0.001%	0.0048	0.000%
		LPG	mt	0.1548	0.003%	0.1428	0.002%
		MotGas	mt	-0.4321	-0.005%	-0.9331	-0.011%
		LFO	mt	0.1100	0.001%	0.0840	0.001%
		HFO	mt	0.0037	0.000%	-0.0222	0.000%
	Soil	Nitrogenous	Rmill	-0.0000	-0.084%	-0.0000	-0.131%
		Ammonium Nitrate	Rmill	-0.0006	-0.084%	-0.0010	-0.131%
		Ammonium Sulfate	Rmill	-0.0009	-0.073%	-0.0014	-0.115%
		Organic	Rmill	-0.0014	-0.082%	-0.0023	-0.129%
		Phosphatic	Rmill	-0.0000	-0.084%	-0.0000	-0.131%
		Super Phosphates	Rmill	-0.0017	-0.084%	-0.0027	-0.131%
		Mixed	Rmill	-0.0022	-0.075%	-0.0034	-0.118%
Sink	Air	SO2	mt	0.0020	0.000%	-0.0087	0.000%
		CO	mt	0.0881	0.005%	0.0839	0.005%
		NO2	mt	0.0971	0.005%	0.0916	0.005%
		VOC	mt	0.0146	0.003%	0.0127	0.002%
		Lead	mt	0.0000	0.000%	-0.0000	0.000%
		PM10	mt	-0.0006	0.000%	-0.0016	-0.001%
		CO2	MTCO2E	-0.4249	0.000%	-4.1271	-0.001%
		CH4	MTCO2E	-0.0090	-0.005%	-0.0182	-0.010%
		N2O	MTCO2E	0.2816	0.005%	0.2657	0.005%
		CFCs	MTCO2E	-0.0173	-0.002%	-0.0278	-0.004%
	Soil	Waste Shipped	mt	0.0144	0.000%	-0.0281	0.000%

Abbreviations used:

Bitum = Bituminous Coal
Anth = Anthracite Coal
Nat Gas = Natural Gas
LNG = Liquified Natural Gas
MotGas = Motorcar Fuel
LFO = Light Fuel Oil
HFO = Heavy Fuel Oil
SO2 = Sulfur Dioxide
CO = Carbon Monoxide
NO2 = Nitrogen Dioxide
VOC = Volatile Organic Compounds
Lead = Lead particulate emissions (air)
PM10 = Particulate Matter (less than 10 microns in diameter)
MTCO2E = metric tons of CO2 equivalent

mt = metric tons
Mkw-hr = Millions of kilowatt hours
MTCO2E = metric tons of CO2 equivalent
TJ = Terajoules of Energy (1 TJ = 1,000,000,000,000 Joules)

The environmental impact data used in the modelling were largely based on United States sourced data (CMUGDI, 2001). As the direct benefits transfer method was used, the environmental impacts coefficients generated by the modelling will therefore not accurately reflect Crocodile River catchment conditions. This is mainly due to two reasons: resource sourcing and technology application in the US will differ from those within the study catchment area. Electricity generation in South Africa for instance, will be much more dependent on coal use (Bitum and Anth in the model results) than on other energy sources (e.g. NatGas, LNG, LPG). This highlights the need for a South African database for environmental indicators and impacts.

Table 5.1.4 shows that most of the environmental impacts decreases with the substitution of forestry with sugar cane. This confirms results of the WRC study (Crafford et al. 2002), where the primary land use activities with the longer value chain and higher value addition multiplier, also had larger environmental impacts. The most significant exception to this trend is in the air pollution emissions, where the burning of sugar cane appears to result in a larger negative impact on air quality.

Table 5.1.5 shows the environmental impacts of substituting 100,000m^3 water for oranges with sugar cane and avocadoes, respectively. In both instances the indirect water use, resulting from additional water use in the value chains, are relatively small or negligible. These results once again show that the value chain with the larger value addition multiplier effect (see Table 5.1.3), also has larger environmental impacts.

Table 5.1.5: **Environmental impacts of substituting sugar cane and bananas with oranges.**

Environmental indicators / impacts			Unit	Sugar subst by oranges		Bananas substituted by oranges	
				ΔE	ΔE	ΔE	ΔE
Source	Water	Intake	1000 m3	47	0.008%	-9	-0.001%
	Energy	Electricity	Mkw-hr	0.01	0.006%	0.00	0.001%
		Energy	TJ	0.2	0.005%	0.0	0.001%
		Bitum	mt	4	0.003%	1	0.001%
		Anth	mt	0.00	0.003%	0.00	0.000%
		NatGas	mt	0.1	0.003%	0.0	0.000%
		MotGas	mt	1	0.014%	0	0.003%
	Soil	Nitrogenous	Rmill	0	0.100%	0	0.025%
		Ammonium Nitrate	Rmill	0	0.100%	0	0.025%
		Ammonium Sulfate	Rmill	0	0.089%	0	0.022%
		Organic	Rmill	0.0017	0.098%	0.0004	0.025%
		Phosphatic	Rmill	0.0000	0.100%	0.0000	0.025%
		Super Phosphates	Rmill	0.0021	0.100%	0.0005	0.025%
		Mixed	Rmill	0.0026	0.091%	0.0007	0.023%
Sink	Air	SO2	mt	0.0677	0.003%	0.0122	0.001%
		CO	mt	0.0366	0.002%	0.0080	0.000%
		NO2	mt	0.0315	0.002%	0.0074	0.000%
		VOC	mt	0.0	0.002%	0.0	0.000%
		Lead	mt	0.0	0.003%	0.0	0.000%
		PM10	mt	0.0	0.004%	0.0	0.001%
		CO2	MTCO2E	16.6	0.004%	3.3	0.001%
		CH4	MTCO2E	0.0219	0.012%	0.0053	0.003%
		N2O	MTCO2E	0.0915	0.002%	0.0214	0.000%
		CFCs	MTCO2E	0.1009	0.013%	0.0175	0.002%
	Soil	Waste Shipped	mt	1	0.009%	0	0.002%

5.2 Scenario 2: Impacts of Pricing Policies

5.2.1 Reduction of water subsidies

As discussed in section 2.2.5, water for agricultural use was heavily subsidised under the legislation preceding the NWA. The NWA and its National Water Pricing Strategy aims at full recovery of water supply costs. Subsidies for agriculture are being phased out in accordance with agreements between the AgriSA and DWAF. In the case study area, four irrigation water prices exist. Above the Krokodilpoort, the full quota for irrigation was (in 1998) 8,000m^3/ha, and the basic water price R26.67/ha (0.35 cent/m^3) with a stepped tariff of R75.27/ha (0.94 cent/m^3) for additional water use. Below the Krokodilpoort, the full quota for irrigation was (in 1998) 13,000m^3/ha, and the basic water price R26.67/ha (0.21 cent/m^3) with a stepped tariff of R122.43/ha (0.94 cent/m^3) for additional water use (DWAF, 2000b). According to the agreement between the SAAU and DWAF, the basic prices would be increased by

50% from 1998/9 to 1999/2000, resulting in basic prices of R41.51/ha (0.52 cent/m^3) above the Krokodilpoort and R41.51/ha (0.32 cent/m^3) below the Krokodilpoort. The effects of these subsidy reductions on the economy are evaluated in this section. Two scenarios were simulated. In the first, the economy-wide impact of the reduction in water subsidies on irrigation agriculture is evaluated. Based on the number of hectares irrigated in the catchment, and the above-mentioned subsidy reductions, sugar cane irrigators and sub-tropical fruit irrigators paid an additional R44 000 and R131 000, respectively, for water. The change in final demand is calculated taking into account the price responsiveness of the water users – the change in subsidy is therefore multiplied by the price elasticity of water demand. A price elasticity of demand for water in SA of –0.6 was used (Hassan, 1998) and an additional simulation was done using an elasticity of –0.4, which indicates a smaller demand sensitivity of water users to price changes.

The results show that the additional water tariff amounts paid by the irrigation sector had an economy-wide impact of –0.002% under an elasticity scenario of -0.6 and -0.001% under an elasticity scenario of -0.4. As expected, a higher responsiveness of agriculture to water tariffs (i.e. higher (negative) elasticity) would lead to a corresponding higher decrease in water use and a corresponding reduction in crop output. The irrigated fruit crops are also much more affected by the subsidy reduction than sugar cane. The reason for this is the higher increase in subsidies paid by sub-tropical fruit irrigators.

Table 5.2.1: Economic impacts (ΔX) of reductions in water subsidies to irrigation agriculture

Sectors		Reduction of subsidies Elasticity = -0.6	Reduction of subsidies Elasticity = -0.4
5	Sugar Cane	0.000%	0.000%
12	Avoes	-0.009%	-0.006%
13	Mangoes	-0.025%	-0.016%
14	Citrus	-0.035%	-0.023%
15	Bananas	-0.042%	-0.028%
35	Other Commodities	0.000%	0.000%
41	Large Commercial Farmers	-0.009%	-0.006%
Total (excluding Activities where duplicate commodity exists)		-0.002%	-0.001%

Table 5.2.1E shows that the effect of these subsidy reductions has a very small effect on total water use. The reduction in water use varies between 12,300m^3 and 18,400m^3 depending on the elasticity (-0.4 and -0.6, respectively). This is equivalent to more or less one hectare under irrigation (8,000m^3/ha above the Crocodile Gorge, and 13,000m^3/ha below the Gorge).

Table 5.2.1E: Water use impacts of reductions in water subsidies to irrigation agriculture

Environmental indicators / impacts			Unit	Red. of subsidies	
				ΔE	
Source	Water	Intake	1000 m3	-12.3	Elasticity = -0.4
	Water	Intake	1000 m3	-18.4	Elasticity = -0.6

5.2.2 Introduction of a catchment management charge (CMC)

Under the NWA, the National Water Pricing Strategy makes allowance for a catchment management charge (CMC) to be levied on all water users. This charge is built into the water tariff paid by agriculture and industrial, urban and rural households. Forestry has traditionally not been expected to pay this levy. The introduction of a charge of R2/ha on an afforested area of 287 000ha, results in a direct reduction in output in pine and eucalypt forestry of R574k and a change in Final Demand of R128k (using the ***FD/X*** ratio from the Conningarth SAM). The price elasticity of demand used was – 1.0: as tree water use is a biological process, the only scope for reducing forestry water use would be to liquidate (reduce) afforested area in the long run. Liquidation of afforested areas is however a long-term process due to the long rotation-cycles of crops. An economy wide decrease in output of 0.002% resulted (Table 5.2.2). Table 5.2.2E shows a reduction in water use of 40,100m^3, which, based on water use efficiency ratios (66.5 and 38.6 m^3 water/m^3 round wood for Pine and Eucalypt, respectively) and MAI's (15 and 25 m^3 /ha /year), equals a reduction of 40-42 hectares of plantation area in the long run.

Table 5.2.2: Economic impacts (ΔX) of introducing a catchment management charge (CMC) on pine and eucalypt forestry

Sectors		Introduction of CMC
21	Roundwood	-0.187%
35	Other Commodities	0.000%
39	Labour	-0.001%
45	Forestry Enterprises	-0.010%
Total		-0.002%

Table 5.2.2E: Water use impacts of an introduction of a catchment management charge (CMC) to forestry

Environmental indicators / impacts			Unit	Introduction of CMC	
				ΔE	
Source	Water	Intake	1000 m3	-40.1	Elasticity = -1.0

5.2.3 Changes in Industrial water tariffs

Table 5.2.3 shows the results of increases in municipal water tariffs to industrial water users. In this experiment the typical sectoral output/water use ratios published in the StatsSA 1998 Supply and Use Tables (StatsSA, 2000) were multiplied by the output per sector in the study area to determine sectoral water use. A 10% increase in water tariff from a respective baseline price of R1.50/m^3 for urban industrial users and R0.69/m^3 for other industrial users were assumed (Bate et al. 2002). These increases were multiplied with the sectoral water use figures. A price elasticity of water demand of –0.6 was applied. The total economic impact was a reduction of 0.065% (Table 5.2.3). The industries most impacted here are those in the forest products value chain, especially the saw milling and pulp and paper industries. The impact on water use was a decrease of 117,000m^3 (Table 5.2.3E).

Table 5.2.3: Economic impacts (ΔX) of changes in Industrial water tariffs ***(Elasticity = -0.6)***

Sectors		Change in Industrial Water Tariffs
2	Agrochemicals & other	-0.063%
3	Fuel	-0.018%
18	Other food & beverages	-0.012%
21	Roundwood	-0.260%
27	Wood products & Building Board	-0.462%
29	Furniture	-0.146%
30	Pulp&Paper	-0.081%
32	Freight transport	-0.024%
33	Trade	-0.024%
35	Other Commodities	-0.022%
38	Electricity Commodity	-0.031%
39	Labour	-0.032%
41	Large Commercial Farmers	-0.008%
45	Forestry Enterprises	-0.455%
46	Other Capital (urban & other)	-0.048%
Total		-0.065%

Table 5.2.3E: Water use impacts of an increase in Industrial Water Tariffs

Environmental indicators / impacts			Unit	Change in Industrial Water Tariffs	
				ΔE	
Source	Water	Intake	1000 m3	-117.0	Elasticity = -0.6

5.2.4 Comparative Analysis of changes in water tariffs on forestry, irrigation and industry

The economic and water use impacts of changes in water tariffs for forestry, irrigation and industry that results from WDM policy interventions show that an inflation-based increase (10%) in water tariffs have by far the largest impact on urban users (Table 5.2.4). Table 5.2.4 demonstrates the importance of the three variables water use proportion, water use responsiveness (elasticity) and water tariff level, in using water tariffs as a tool for water demand management. The change in water tariff was calculated by multiplying the elasticity of demand, the water tariff and the water tariff increase. Firstly, the proportionate share of water use should be considered to ensure that a water tariff strategy targets the correct sector. Secondly, the price elasticity of water demand has been based on assumptions of -1.0 for forestry and -

0.6 for the other water users. An elasticity of -0.6 effectively means that the water tariff effect is “diluted” by a factor of 60%. It is therefore very important to have accurate elasticity data as every 0.1 error in elasticity value can cause a 10% error in water tariff, which will have economy-wide effects. Finally, water tariffs at such low levels as those of forestry and irrigation crops require different (probably much higher) levels of tariff increases to influence water demand.

Table 5.2.4: The comparative impact on water use sectors of a 10% increase in water tariffs across all sectors.

	Forestry		Agriculture		Industry
	Pine	Eucalypt	Sugarcane	Fruit species	Urban
Proportionate water use	27%	18%	34%	14%	7%
Elasticity of demand	-1.0	-1.0	-0.6	-0.6	-0.6
Water tariff (cents/m^3)	0.0013	0.0008	0.21	0.35	150
Water tariff increase	10%	10%	10%	10%	10%
Change in water tariff (cents/m^3)	0.00013	0.00008	0.01	0.02	9.00

5.3 Scenario 3: The potential impact of environmental externalities on water use

Indicators of environmental the impacts of economic activity in the Crocodile River catchment in 1998 are shown in Table 5.3.1. These quantities were calculated using the SAM economic activity levels at 1998 prices and the environmental impacts vector E. The data indicate that the total water use in the catchment was 623 million m^3 in 1998. This was just under 50% of the mean annual runoff of 1,263 million m^3. Electricity use was 0.2 MkW-hr (million kilowatt hours), and total energy use 5.0 TJ (terra joules). The impact on soil as a source of essential elements required for plant growth was measured by the use of fertiliser expressed in Rands. The model estimated fertiliser use in the Catchment to be R35 million. This indicator does not provide useful information and qualitative data are required to better describe the Source impact on Soil. Such data would include salinisation, erosion and other factors that lead to a lower soil productivity. The contribution to greenhouse effect of CO_2, CH_4, N_2O and CFCs were approximately 401 $MtCO_2$ (metric tons CO_2) equivalent. A very important externality to investigate for its impact on water use would be water pollution. Unfortunately no suitable water pollution data were available for incorporation into the model, due to the fact the model relies on point-source data, whereas water pollution is often non-point source in nature.

Table 5.3.1: Selected environmental indicators and impacts in the Crocodile River Catchment (1998)

Environmental indicators / impacts			Unit	E
Source	Water	Intake	million m^3	623
	Energy	Electricity	Mkw-hr	0.2
		Energy	TJ	5.0
		Bitum	mt	118
		Anth	mt	0.1
		NatGas	mt	3.3
		MotGas	mt	8.3
	Soil	Fertiliser Use	Rmill	35.8
Sink	Air	SO2	mt	2.2
		CO	mt	1.9
		NO2	mt	2.0
		VOC	mt	0.6
		Lead	mt	0.0
		PM10	mt	0.2
		CO2	MTCO2E	395
		CH4	MTCO2E	0.2
		N2O	MTCO2E	5.8
		CFCs	MTCO2E	0.8
	Soil	Waste Shipped	mt	12

Policy interventions that strive to minimise environmental impacts may affect water demand. The environmental-SAM could be used to model this. For instance, if it were decided to reduce carbon emissions in the catchment, what would the effect of a carbon tax be on water demand? In other words, what are the water demand management implications of environmental taxes? Table 5.3.2 shows such effect reflecting an environmental (carbon) tax policy experiment.

The first column shows the CO_2 equivalent emission (**e**) factors for each sector. The total CO_2 equivalent emission was calculated by multiplying the emission factors (**e**) with the total output (**X_t**). A carbon tax of R20/ton was imposed on the prices of all carbon producing activities. A –0.54 price elasticity of carbon supply was assumed (McRae, 2000), and multiplied by the Connigarth SAM (2000) ***FD/X*** ratio, yielding the changed final demand (**ΔFD**). The resultant impact on the total economy of a carbon tax bill of R8,028k (k = x1000), resulted in a change in final demand of –R1,377k and an economy-wide impact of –R2,611k. Although the main purpose of this tax would be to achieve a reduction in CO_2 equivalent emissions amounting to 0,8% (total $MtCO_2$ equivalent emissions, see Table 5.3.3), it also has an indirect economic impact of -0.026% (ΔX) and a subsequent 1,215,000 m^3 reduction in water use. This experiment demonstrates the importance of considering the economy-wide effects of non-water policy decisions on water demand management.

A major limitation of this model is the fact that it does not incorporate carbon sequestration activities. The model does not include the effect of carbon sinks as in the case of Forestry. 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). The carbon sequestration effect in the Forestry value chain is mainly due to the application of timber in a solid wood form, in underground mine packs. Modelling of carbon sequestration in forestry value chains by Crafford and co-workers (2002) showed a 1,97kg and 3.60kg equivalent CO_2 **sequestration** per cubic metre water used in Pine and Eucalypt forestry respectively. The study further showed that carbon **emissions** from these value chains were 1,82 kg and 0.93kg /m^3 equivalent CO_2 sequestered per cubic metre water used in Pine and Eucalypt forestry. As the emission values were lower than the sequestration values, Forestry has negative net carbon emissions. More research is required to determine the carbon sequestration coefficients of the economic sectors evaluated in this study.

Another limitation lies in the fact that the model uses the same elasticity of supply for all sectors. Different economic sectors respond differently to changes in input prices.

Table 5.3.2: The economic impact (ΔX) of a carbon tax on industries in the Crocodile River catchment

All values given in R'000		Carbon tax = R20 / mt CO2 Eq					
Sectors		mtCO2Eq / R'M Output	Tons CO2	Carbon tax paid (R)	ΔFD	ΔXt	ΔXt
1	Fertilizer	0.254	9.1	181.8	-3.3	-4.7	-0.01%
3	Fuel	0.118	15.6	312.6	-52.6	-58.6	-0.06%
5	Sugar Cane	0.041	16.8	336.5	-6.0	-6.6	0.00%
8	Sugar	0.079	4.1	81.2	-41.3	-45.4	-0.01%
12	Avoes	0.008	0.6	12.0	-0.4	-1.0	0.00%
13	Mangoes	0.008	0.2	4.3	-0.2	-0.8	0.00%
14	Citrus	0.008	1.5	29.8	-13.2	-16.4	-0.01%
15	Bananas	0.008	1.3	25.5	-11.3	-12.2	-0.01%
16	Juice Factories	0.029	2.1	41.5	0.0	-9.2	-0.03%
18	Other food & beverages	0.010	6.8	136.1	-59.7	-64.1	-0.03%
21	Roundwood	0.008	0.6	11.3	-1.4	-24.9	-0.04%
22	Saw Milling	0.015	6.2	124.2	0.0	-167.9	-0.10%
23	Mining Timber	0.015	2.4	48.3	0.0	-2.3	-0.01%
26	Boards	0.037	6.2	123.4	0.0	-5.4	-0.01%
31	Paper products	0.171	69.0	1381.0	-372.9	-379.3	-1.26%
32	Freight transport	0.021	4.8	95.1	-0.3	-13.2	-0.01%
33	Trade	0.031	6.4	127.5	-17.6	-26.5	-0.02%
38	Electricity Commodity	1.973	243.0	4860.6	-775.4	-798.9	-0.84%
	Rest of Sectors		4.8	96.1	-21.8	-973.9	2.40%
	Total (excluding Activities where duplicate commodity exists)		401.4	8 028.7	-1 377.3	-2 611.4	-0.026%

Table 5.3.3: The environmental impact (ΔE) of a carbon tax on the Crocodile River catchment

Environmental indicators / impacts			Unit	Carbon tax = R20/mtCO2Eq	
				ΔE	ΔE
Source	Water	Intake	1000 m3	-1215	-0.2%
	Energy	Electricity	Mkw-hr	0.000	0.0%
		Energy	TJ	-0.019	-0.4%
	Soil	Fertiliser Use	Rmill	0.000	0.0%
Sink	Air	SO2	mt	-0.010	-0.5%
		CO	mt	-0.001	0.0%
		NO2	mt	-0.005	-0.2%
		VOC	mt	0.000	0.0%
		Lead	mt	0.000	-0.6%
		PM10	mt	0.000	-0.1%
		CO2	MTCO2E	-1.645	-0.42%
		CH4	MTCO2E	0.000	-0.13%
		N2O	MTCO2E	-0.014	-0.24%
		CFCs	MTCO2E	0.000	-0.02%
	Soil	Waste Shipped	mt	-0.005	0.0%

5.4 Scenario 4: Projecting Absolute Water Scarcity

Absolute water scarcity is a situation where water demand exceeds water supply. Within the next 20 years, many water scarce countries and catchments can expect to reach this situation. The onset of this situation will also require the second phase of

WDM, as defined by the NWPS, to be implemented: allocation according to scarcity value, or water markets.

Table 5.4.1 shows the relationship between economic growth and water supply. The economic output as modelled by the SAM for 1998 was used as a baseline, and a constant 2,5% economic growth rate was assumed. The annual economic output ($\mathbf{X_{tn}}$) for the years indicated ($\mathbf{n}$ = 2000, 2005, 2010, 2015, 2020) were then calculated (using the formula $\mathbf{X_{t1998}}*(1+2,5\%)(^{n-1998)})$. It was also assumed that water use coefficients stayed constant, implying no improvement in water use efficiency, in other words, there were no technical changes in water utilisation. The resultant water use ($\mathbf{E_{wn}}$) for each of these periods was then calculated using the formula $\mathbf{E_{wn} = e_w.X_{tn}}$ and expressed as a percentage of the MAR (Mean Annual Runoff) of 1,263 million m^3 ($\mathbf{E_{wn}}$ / **MAR**).

Under economic growth conditions of 2.5% per annum, the water use-MAR ratio increases from 50% in 1998 to 85% in 2020 (Table 5.4.1). The interpretation of this ratio is important, as it is an indicator of imminent absolute water scarcity in a catchment. Not included in this ratio is the environmental (ecological) water use requirement, or the in-stream flow requirement and river losses. Based on national averages (Crafford et al. 2001), this component could be expected to be 30% of MAR. If this assumption also holds for the study area, absolute water scarcity is reached when the water use-MAR ratio is approximately 70%.

Therefore, if the assumed conditions prevail (2.5% growth, constant water use coefficients and a constant water supply) it can be assumed that a situation of absolute water scarcity will be reached between 2010 and 2015, and possibly by 2012. This implies that water users in the catchment can expect water allocation systems that are based on water scarcity values, to be implemented much sooner than the widely publicised "water scarcity" date of 2025. It is important to realise that individual economic sectors will experience variable growth rates, while the technologies and management practices that underlie the water use coefficient vector $\mathbf{e_w}$ may also change for each sector as WDM interventions are implemented. These calculations may therefore be refined on a sector-specific basis for economic growth and water technology improvement.

Table 5.4.1: Projecting absolute water scarcity in the Crocodile River Catchment ***(2.5% growth and no change in efficiency of water use)***

All values given in R'000		Xt					
Sectors		1998	2000	2005	2010	2015	2020
5	Sugar Cane	406 019	426 574	482 629	546 050	617 806	698 991
8	Sugar	51 616	54 229	61 355	69 418	78 540	88 861
12	Avoes	75 316	79 129	89 527	101 292	114 602	129 662
13	Mangoes	26 765	28 120	31 815	35 996	40 726	46 078
14	Citrus	186 788	196 244	222 032	251 209	284 220	321 569
15	Bananas	159 709	167 794	189 844	214 791	243 016	274 951
21	Roundwood	70 681	74 259	84 017	95 058	107 549	121 682
	Other (Urban & Industrial)	9 104 155	9 565 053	10 821 979	12 244 076	13 853 048	15 673 453
	Total	10 081 049	10 591 402	11 983 200	13 557 890	15 339 509	17 355 246
		E					
	Water Use	623 066	654 609	740 630	837 954	948 069	1 072 653
	Water Use / Mean Annual Runoff (%)	49%	52%	59%	66%	75%	85%

5.5 Scenario 5: The role of water metering in water trade

Well-defined and secure water use rights are at the core of well-functioning market systems. In the case of water markets, accurate water metering is an important prerequisite to ensure the volumetric measurement of water use. Agricultural water use in SA has historically been based on a pre-determined per hectare quota, which was calculated based on climatic and other geographical conditions of a specific area. Water charges have subsequently been based on flat rates on planted areas. One major implication of implementing WDM measures such as volumetric charges will require the use of water metering, an aspect which is a future source of conflict between irrigators and water regulators. Farmers claim that it is too expensive and inaccurate to install water meters, whereas DWAF's WDM strategies rely for the most part on accurate water metering. The question can then be asked what the economic impact will be of an intensive water meter installation programme.

In the study area, the registered irrigation areas and their quotas are 11 206 ha between the Kwena dam and the Crocodile River Gorge, with a quota of 8 000m^3/ha/annum, and 17 089 ha below the gorge with a quota of 13 000m^3/ha/annum (DWAF, 2002). The water tariffs in 1998 were R31.78 and R51.64 above and below the gorge, respectively. Inter-sector water trading will bring about a move away from the hectare-based tariff in favour of a volumetric system, which will enable users to trade volumes of water[11]. Monitoring water use volumetrically will therefore require accurate water metering.

Water metering is however, not a trivial exercise. Studies by the University of Pretoria have revealed two challenges to ensuring that agricultural water use is properly measured: the cost of water meters and their installation, and the accuracy of water meters (Van der Stoep, 2003). A policy simulation experiment was accordingly designed and implemented to analyse the implications of water metering, and imminent change in water management in SA.

This section evaluates the cost implications to the economy of installing water metering systems for the irrigation agriculture activities in the study area. The following assumptions were made (Van der Stoep, 2003):

- The total cost of a water meter and its installation is R20,000 (R10,000 equipment + R10,000 installation);
- This cost would be depreciated over 5 years by the farmers using a straight-line formula;
- One water meter is required for every 50 hectares irrigated.

This means that the cost of installation of water metering would amount to an increased cost of capital for irrigators of R80/ha/year that is equivalent to an increase in water price of nearly 300% for irrigators.

Water metering implies a move away from a quota based system to a volumetric measurement and pricing of water. This is important as it creates incentives for water users to use less water. However, it remains important for policy makers to assess the net benefits of a water meter installation programme. There are both private and social costs that need to be assessed. The private costs are the costs to the water user as calculated above. In return for these costs, the user gets the benefit of only having to pay for the water used, and not the total allocation whether its is used or not, as is currently the case, especially in a wet season where little irrigation is

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[11] Most of the water trading that currently takes place are intra-sectoral, i.e. within an irrigation area between irrigation farmers, and are hectare-based.

required. In addition, the user can now trade excess water, and can therefore get financial gains from excess water sold or from additional production from extra water bought. The main social benefit lies in the fact that water can now be allocated to the most efficient users.

Unfortunately the scope of this study did not allow the modelling of such a scenario to determine the economy-wide impact as this would require a complete restructuring of the SAM model. However, it can be expected that a water metering installation programme results in a transaction cost that impacts on the total economy. The benefits of water metering should outweigh this transaction cost in order to result in a positive total economic impact (ΔX). These benefits can only be realised through reducing water losses, and allocation of water to its most productive uses and users. Water metering however, is only one of the cost aspects of moving to a water trading system. These and other transaction costs need to be carefully considered and planned for as each additional transaction cost component will impact the economy.