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WATER POLICY IN SOUTH AFRICA

EFFECTS, IMPACTS, AND THE ASSOCIATED TRANSACTION COSTS IN THE OLIFANTS BASIN

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Abstract

South Africa as a water scarce country recognizes that it is no longer possible to augment existing water supplies. The country has therefore intensified efforts to implement its comprehensive National Water Act, which stipulates various Integrated Water Resource Management (IWRM) policies for better water management. However, water policy reforms continue to face challenges such as the lack of relevant supporting institutional frameworks and problems associated with water allocation continue to persist. The current study presumes that water management policies affect the efficiency, quantity, and quality of irrigation water use and have significant impacts on the welfare of irrigation water users. Additionally, the study posits that significant transaction costs characterize and could inhibit the water policy implementation and compliance processes.

Firstly, we followed a framework by McCann & Easter, (2004) and McCann et al., (2005) to measure transaction costs and used OLS regression methods to assess the determinants of transaction costs. Findings from the study indicate that transaction costs accruing to water managers' varied between 13 and 29 percent of total water budget costs. Water users' transaction costs were 2 percent of other input costs, 1 percent of farm benefits and 27 percent of water purchase costs. Various factors such as compliance to water policy (water pricing, membership in WUAs) and use of ICT for water management significantly influenced transaction costs incurred by water users.

Results from the Data Envelopment Analysis (DEA) show that on average, the water use efficiency for irrigation water users was as low as 31 percent. Among the policy factors of interest, compulsory licensing significantly influenced water use efficiency while water pricing and membership in WUAs influenced water use quantities. Water pricing, compulsory licensing and membership in WUAs on the other hand determined water use quality.

Evidence from the mathematical programming approaches show that, rising water tariffs have a negative though minimal impact on farmers' welfares. Smallscale farmers are more adversely affected by rising water tariffs and license fees increases compared to their largescale counterparts. The effect of price increases on irrigation water demanded for the two types of farmers investigated was somewhat inelastic; however, the large-scale farmers' water demand was moderately elastic as there were slight reductions in quantities of water consumed due to water price increases. Compulsory licensing fees increases on the other hand resulted in smaller changes in welfare compared to water tariff increases.

This study finds various relevant factors affecting transaction costs, water use-quantity, quality, and efficiency, which can act as policy indicators towards better water policy reform and management. The evidence of existing transaction costs is important feedback to guide water policy design and improvement in South Africa. The negative impact of water pricing on small-scale farmer welfare could suggest the need for different pricing strategies for different farmer groups, while an elastic water demand is a necessary condition for water pricing to effectively reduce water use and enhance conservation.

Zusammenfassung

Südafrika, welches ein wasserarmes Land ist, erkennt, dass es nicht weiter möglich ist bestehende Wasservorräte weiterhin auszuschöpfen. Deshalb hat das Land die Bemühungen erhöht den umfangreichen National Water Act umzusetzen, der verschiedene Politiken für ein ganzheitliches Wasserresourcen Management (Integrated Water Resource Management - IWRM) für ein besseres Wassermanagement festsetzt. Diese Arbeit misst Transaktionskosten des Wandels im Massermanagement und deren bestimmende Faktoren im Olifants Basin, Südafrika. Außerdem werden die Effekte des Wassermanagements auf die NUtzung des Bewässerungswassers und der Einfluss der Politik auf die Wohlfahrt der Wassernutzer ermittelt. Die Arbeit benutzt ein Rahmenwerk von McCann & Easter, (2004) und McCann et al., (2005) um die Transaktionskosten zu messen und verwendet eine OLS Regressionsmethode um die Einflussfaktoren der Transaktionskosten zu bestimmen.

Die Ergebnisse der Arbeit zeigen, dass die anfallenden Transaktionskosten der Wasserverwalter zwischen 13 und 29 Prozent der gesamten Wasserkosten ausmachen. Die Transaktionskosten der Wassernutzer betragen 2 Prozent der Inputkosten, 1 Prozent des landwirtschaftlichen Gewinns und 27 Prozent der Kaufkosten des Wassers. Unterschiedliche Faktoren wie die Einhaltung der Wasserpolitik (Wasserpreisfestsetzung, Mitgliedschaft in Wassernutzerverbänden) und die Nutzung von Informations- und Kommunikationstechnik (ICT) für Wassermanagement beeinflussten die Transaktionskosten der Nutzer signifikant.

Ergebnisse der Data Envelopment Analyse zeigen, dass die durchschnittliche Wassernutzungseffizienz bei nur 31 Prozent lag. Verpflichtende Zulassungen verbesserten die Wassernutzungseffizienz signifikant, während eine Preisfestsetzng des Wasserpreises und die Mitgliedschaft in Wassernutzerverbänden die nachgefragte Menge des Wassers erklären. Andererseits bedeuten alle diese drei Faktoren auch die Nutzung einer unakzeptabler Wasserqualität.

Mathematische Programmierungen zeigen auf, dass steigende Wasserpreise einen negativen, jedoch minimalen, Einfluss auf die Wohlfahrt der Landwirte hat. Kleinbäuerliche Landwirte sind stärker nachteilig von steigenden Wassertarifen und Zulassungsgebühren betroffen als Großlandwirte. Der untersuchte Effekt eines Preisanstiegs von Bewässerungswasser für die zwei verschiedenen Landwirtschaftssysteme ist eine gering unelastische Nachfrage; trotzdem war der Wasserverbrauch der Großlandwirte gemäßigt elastisch, da der Wasserverbrauch durch einen Anstieg des Wasserpreises gering sinkt. Andereseits ergaben steigende verpflichtende Zulassungsgebühren eine kleinere Veränderung der Wohlfahrt verglichen mit einem Anstieg des Wasserpreises.

Diese Studie findet verschiedene, relevante Faktoren, die die Transaktionskosten beeinflussen. Diese sind die Menge, die Qualität und die Effizienz des Wasserverbrauchs, die auch als politische Indikatoren für eine bessere Reform der Wasserpolitik und des Management dienen können. Der Nachweis der vorhandenen Transaktionskosten ist eine wichtige Rückmeldung für die Planung und Verbesserung der Wasserpolitik in Südafrika. Der negative Effekt von Wasserbepreisung auf die Wohlfahrt der kleinbäuerlichen Landwirte könnte eine unterschiedliche Preissetzung für unterschiedliche Landwirtschaftstypen empfehlen, wobei eine elastische Wassernachfrage eine notwendige Bedingung für eine Wasserpreisfestsetzung ist um den Wasserverbrauch effektiv zu reduzieren und Wassereinsparungen zu fördern.

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List of Abbreviations

Cl	Chloride
CMA	Catchment Management Area
CMS	Catchment Management Strategy
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DMU	Decision making Unit (farm)
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
EUT	Expected Utility Theory
FGD	Focus Group Discussions
GDP	Gross Domestic Product
GM	Gross Margin
Ha	Hectare
ICT	Information and Communications Technology
KM	Killo Meters
MNL	Multinomial Logit
NEMA	National Environment Management Authority
NH_3-N	Ammonia
NWA	National Water Act
NWRS	National Water Resource Strategy
OLS	Ordinary Least Squares
O&M	Operation and Maintenance
PO_4-P	Orthophosphate
PPS	Probability Proportionate to Size
RAC	Risk Aversion Coefficient
SO_4 2	Sulphate
TCs	Transaction Costs
TCE	Transaction Cost Economics
VRS	Variable Returns to Scale
WMA	Water Management Area
WUAs	Water User Association
WUE	Water Use Efficiency
ZAR	South African Rand

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Chapter One

1. General Introduction

1.1 Background and Research problem

Water is critically important to the livelihoods of many populations all over the world yet it remains a scarce resource or of poor quality (Faysse, 2004). In many developing countries, water as an input to production majorly constrains output and population incomes (Namara et al., 2009). Its management and development is of prime importance (Ashraf et al., 2007). There is consensus on the need for a functional institutional framework to ensure sustainability and social optimum water use (Nagaraj, 1999). Irrigated agriculture is the single largest user of fresh water on the planet and the largest economic activity of rural populations; forty percent of the world's food supply comes from irrigated agriculture (Jacomia, 2005). However, current water scarcity and deteriorating qualities, amid competitive allocation between different users and uses poses great challenges in continued water use and management (Nagaraj, 1999).

South Africa is a water stressed country; with many areas facing water shortages as demand exceeds supply (Mallory, 2011). It is indeed rated among the 30 most water stressed countries in the world by UNESCO (Tsegai et al., 2009; Mwendera et al., 2003). The Olifants river basin ranks as the country's third most water stressed basin (Kloos, 2010; Walter, 2010; Mallory, 2011). It is also one of the most polluted with its basin ecosystem in a generally poor condition (Van Veelen, 2011). This arises from intensified demand for water from competing economic activities including mining, industry, and agriculture. Additionally, population growth, climate change, and increasing economic development further aggravate the water scarcity and quality situations (ibid). Therefore, there is a likelihood of a serious water crisis affecting both humans and wildlife if no comprehensive management interventions are put in place (Earle et al., 2005; Van Veelen, 2011).

It is widely recognized that an integrated approach to freshwater management offers the best means of reconciling competing demands with supply in the phase of water scarcity (Alfarra, 2004). Integrated water resource management (IWRM) offers a framework for actualization of effective operational actions such as water demand management (Alfarra, 2004; Earle et al., 2005). IWRM has received support and constant emphasis from scholars, agencies, and international declarations. However, it has not been easy for many developing countries especially due to lack of the relevant supporting institutional frameworks (Wang, 2012a). In South Africa, the IWRM approach has been highly prioritized (Kloos, 2010). The country is accredited to having one of the most comprehensive Water Acts in the world (Kapfudzaruwa &

Sowman, 2009), in attempts to move away from the long history of water provision to only a few favored minority (Lange et al., 2003). The National Water Act (NWA) No. 38 of 1998 recognizes water as a scarce resource belonging to the people. The Act therefore aims to protect, use, develop, conserve, manage, and control water resources as a whole. It addresses equity, efficiency, and sustainability in management of the water resource unlike the previous riparian rights system (Kloos, 2010). Numerous stipulated policies in the water Act are envisaged to attain these water Act goals. The policies are currently under implementation and are expected to highly impact water management (Hassan & Thurlow, 2011). This study will specifically examine different aspects of water trade, compulsory licensing, effluent discharge permits, water tariffs and participatory water management through Water User Associations (WUAs) / groups in water management.

Firstly, this study considers the transaction costs (TCs) faced by water users/private agents and water managers/public agents in the water policy process. Transaction costs are important in influencing policy implementation and compliance as they can inhibit the process especially when they are a big percentage of the total policy costs (McCann et al, 2005b ; Blore et al., 2013; Coggan et al., 2010). Therefore, knowledge of all the associated transaction costs in a policy process is important. When transaction costs are explicit, it helps in making comparisons of the existing policy alternatives and foster effective design and implementation ex ante (McCann et al., 2005). It also allows evaluation of existing policies ex post for improvement purposes, and assessment of their budgetary impact to establish their sustainability and efficiency gains (McCann et al., 2005; McCann & Easter, 2004). Knowledge of transaction costs also guides and prioritizes the policy making process based on current needs and resources (Diao et al., 2005; McCann & Easter, 2004; McCann et al., 2005). On the flipside, this study further discusses the concept of transaction benefits in the same context of water management.

Recent innovations in Information and Communication Technology (ICT) provides a great potential in reducing transaction costs (Singh, 2008; Okello, 2011; Aker, 2010; Silva et al., n.d.;Jensen, 2007; Aker, 2008). Specifically it makes easier the communication of knowledge and information, delivery of information and training at low costs, improving access to markets and credit, empowerment of farmers to negotiate better prices and facilitating and strengthening networking (Okello, 2011). Nevertheless, the ICT potential to reduce transaction costs in water management remains untapped. Lack of communication and feedback pertaining to water policies between stakeholders is indeed identified as one of the biggest drawbacks to water management (Kay, 2011; Lévite et al., 2003). In the agricultural sector, several studies have attributed benefits such as better prices, reduction in price dispersions and improvement in margins to ICT due to reduced transaction costs (Aker, 2008, 2010;Silva et al., n.d.;Jensen, 2007). Unlike these studies that have mainly focused on small-scale farmer access to input and output market information, the current study attempts to fill a unique gap by assessing the potential role ICT (mobile phones use) could play in water management through a trial experiment between water users and water managers.

Secondly, this study examines the effect of WUAs, compulsory licensing, and water pricing on irrigation water use in the Olifants basin among other socio economic factors. Participatory water management is an important component to achieving the goals of water resource management (Harpe, n.d.). Its importance is well documented by international agreements such as the Duplin principles and the 1992 Rio conference (Orne-Gliemann, 2007; Manzungu, 2004). However, participatory water management through WUAs in South Africa has not been entirely successful (Kloos, 2011; Muller & Schreiner, 2009). Little progress through establishment of Catchment Management Agencies (CMA) and WUAs is reported and the envisioned goals such as devolved water allocation have not been attained (Enright, 2011). Water rights on the other hand, are a first step towards IWRM. They promote growing water productivity and foster rural livelihoods (Speelman et al., 2010). As such, water rights determine the real value of water and encourage investment due to security of ownership. It would be interesting to examine the context specific effects of water rights on water use for the Olifants basin amid implementation of the NWA. Additionally, there exist mixed outcomes and arguments of the effects of water pricing as an instrument to minimize over abstraction of water and maintain water quality. Little, if any, quantitative assessments exist on the effect of these three aspects (WUAs, compulsory licensing, and water pricing) on irrigation water use especially in the Olifants basin.

Thirdly, following Muller & Schreiner, (2009) we suggest that water management through different policies largely impacts on a country's welfare and economic activities. The effects of selected water policies remain of key importance as they translate into the competitiveness of a region which further influences peoples' welfares (Diao et al., 2005). Water trade for example increases water use efficiency by directing water consumption to sectors where its use provides a higher marginal value (Dinar & Xepapadeas, 1998; Schoengold & Zilberman, 2007). Water prices on the other hand create the necessary awareness of water scarcity to stakeholders and induce the thinking of water allocation to higher value activities such as crops with higher returns, thus leading to efficient water use (Wang, 2011 ; Speelman et al., 2009). However, this is not always the case as water prices might not be viable for all stakeholders' especially resource poor farmers. It might lead to a reduction in farm production and profits which may in turn dampen the food security situation (Speelman et al., 2009). Therefore, due to mixed results of policy interventions, and in order to attain sustainable management of water resources, knowledge and understanding of context specific consequences of water policy interventions on human welfare is needed (Jogo & Hassan, 2010; Hassan & Farolfi, 2005).

Against the above background and problem definition, this study aims at addressing the following research objectives:

1.2 Objectives

1. To estimate the transaction costs associated with implementation and compliance to different water policies
2. To assess the effect of different water policies; (compulsory licensing, water tariffs and WUAs) on irrigation water use (quantity, quality, and efficiency)
3. To assess the impact of water policies (compulsory licensing, and water tariffs) on the large scale and small scale holders’ welfares

1.3 Research hypothesis and expected value added of the research

The implementation of IWRM principles in South Africa, is expected to meet the water Act goals of efficiency, equity, social development, and sustainability. However, this has not been entirely successful as water allocation challenges such as poor water quality, poor services in water supply, water restrictions in dry periods, administrative delays, water distribution and storage difficulties still persist (Enright, 2011). Therefore, this study aims at contributing towards policy in the water sector by equipping decision makers with evidence-based research on the effects, impacts, and transaction costs of selected water policies in South Africa. We hypothesize that water management policies affect irrigation water use (efficiency, quantity, and quality) and have significant welfare effects on irrigation water users’ welfares. In addition, significant transaction costs characterize the water policy implementation and compliance processes in the Olifants basin. The study will inform and guide water policy reform in South Africa, specifically the Olifants. The research fits into ZEF's thematic area on water resources with specific focus on water management aspects. It adds onto previous research conducted in the first phase of the Olifants project by widening the scope of the study area to incorporate all the three sub-basins unlike in the first phase, which considered only the middle Olifants sub basin. The current research further brings in the institutional and governance aspect by exploring the organization of actors in the Olifants basin and the roles they play in water governance. The study further considers the indirect costs of institutions by assessing the transaction costs of water policy implementation and compliance. This work further builds on previous Olifants research by considering a larger number of irrigation farmers both small scale and large scale, growing a wider array of crops. The wider project scope develops a hydro-economic water allocation model that determines the real economic value of the water resource throughout the Olifants river basin.

1.4 Study area

1.4.1 Biophysical profile

The Olifants Water Management Area (WMA) is divided into three management zones/sub basins namely upper, middle and the lower Olifants (Vogel, 2011). The whole Olifants WMA measures $54570m^2$ in area and cuts across three provinces namely Mpumalanga, Limpopo, and a small part of Gauteng (Baker, 2011). The basin is under the jurisdiction of several municipalities namely; Mopani, Ehlanzeni, Sekhukhune, Capricorn, Waterberg, Nkangala, Gert Sibande and Metsweding. The Olifants river is served by several tributaries; most importantly to the left bank are Wilge, Elands, and Ga-selati while to the right is Steelpoort, Blyde, Klaserie, and Timbavati. The river is 770 km long and flows northerly originating from the East of Gauteng province to Mozambique where it joins the Limpopo river (Vogel, 2011; Lange et al., 2003). Figure 1.1 shows the Olifants basin within the bigger South Africa and Africa context.

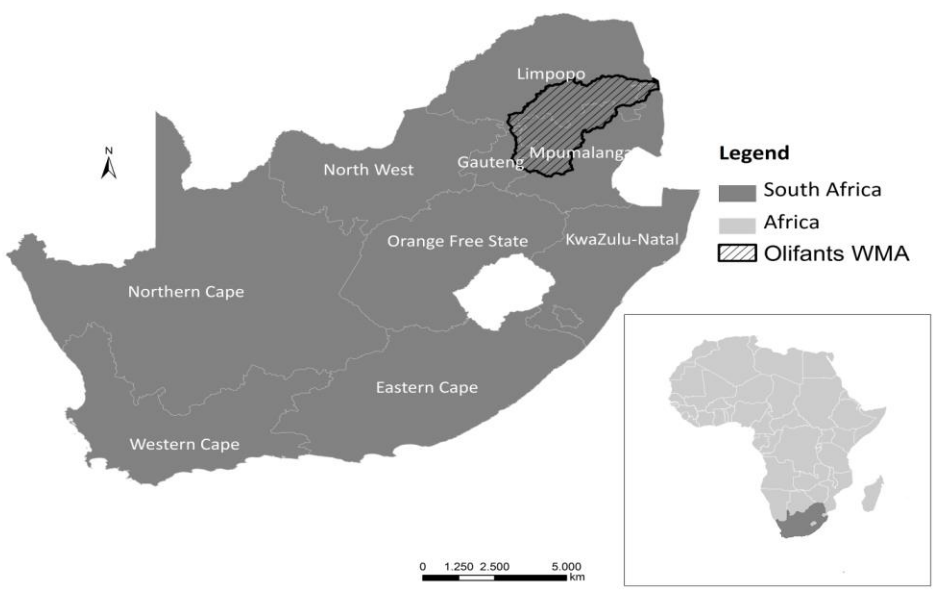


Figure 1.1: Map of the Olifants river catchment

Source (Mallory, 2011)

Hard rock mainly comprises the geology of this catchment. In the upper Olifants, there are extensive coal reserves while large deposits of dolomite occur along the Blyde River. Other minerals such as copper, chrome, and vanadium occur lower in the catchment (ibid). The area's topography is very varied comprising of undulating plains, hills and mountain terrain (Baker, 2011). The Olifants WMA falls under four climatic conditions namely:

(i) The Highveld characterized by moderate maximum temperatures with cold winter nights and regular severe frost

(ii) The Bushveld significant of high maximum temperatures and cool winter nights without frost

(iii) The Escarpment partially lying in the mist belt, maximum moderate temperatures and cool winter nights

(iv) The Eastern Lowveld characterized by a hot sub-tropical climate (Baker, 2011).

The whole Olifants experiences a summer rainfall regime and is highly varied e.g. dry areas with 325 mm/annum to 550 mm/annum occur in parts of Sekhukhune and the northern parts of the eastern Lowveld. In the Highveld region and the southern part of the eastern Lowveld, rainfall varies between 550 mm/annum to 750 mm/annum, the escarpment receives a higher rainfall of between 750 mm/annum to 1000 mm/annum and the Wolkberg area receives an annual rainfall exceeding 1 000mm/annum (ibid).

1.4.2 Socio economic profile

The Olifants is home to about 10 percent of south Africa's total population (Lange et al., 2003). This is an estimated 8 million people according to the 2007 population data. Of the population, around 7 percent are whites scattered in the basin while majority of the black population live in the rural areas, and densely populated in the former homeland areas (Lange et al., 2003; Kloos & Tsegai, 2009). The former homelands are about a quarter of the total area but support about 60 percent of the total population (Kloos & Tsegai, 2009). Education levels in many of the districts remain low. Illiteracy levels are as high as above 50 percent; with this being highly pronounced in the middle Olifants (Lange et al., 2003). Due to the inequities of the apartheid regime, most of the population in this region lack access to basic needs and services such a good healthcare, sanitation, and clean water (Lange et al., 2003; Kloos & Tsegai, 2009).

Majority of the population in the basin are youth under 24 years of age. Poverty levels are high in the region with majority of the population (88 percent of the economically active) earning approximately ZAR 1600 per month. 60 percent of these economically active people have zero income and lack alternative sources of revenue other than government support (Baker, 2011; Kloos & Tsegai, 2009). 45 percent of population are unemployed, 43 percent formally employed and 12 percent in the informal sector (Kloos, 2010). The public sector takes up 48 percent of those in formal employment with mining and agriculture accounting for 21 and 19 percent respectively (Kloos, 2010). The land remains under communal system hence a poor incentive to conservation and appropriate land use (ibid).

Approximately, 5 percent of South Africa's GDP comes from the Olifants region with economic activities ranging from mining, power generation, metallurgic industries, irrigation, eco-tourism, forestry, and subsistence agriculture (Vogel, 2011). The largest of these sectors are manufacturing, power generation, agriculture, and mining contributing 18.2, 15.6, 7, and 22.1 percent to Gross Geographical Product respectively (Kloos & Tsegai, 2009; Vogel, 2011). Coal is the dominant mineral in the catchment (ibid). The upper Olifants sub catchment is highly urbanized, though parts of the north western and its central regions remain undeveloped. Land in the upper Olifants is under extensive mining for its rich coal deposits, which are for both export, and local use in the coal fired power stations. The transition from the upper to the middle Olifants on the other hand is predominantly used for agriculture and extensive irrigation especially around the Loskop dam (Walter, 2010). Vanadium, platinum, and chrome mining also occur in this area. The lower Olifants is characteristically rural. Eco tourism is the main industry with several game parks and the Kruger national park being a major tourist attraction site. Copper and phosphorous mining also take place here (Vogel, 2011).

1.4.3 Overview of operations and water use

Surface water in the Olifants WMA is highly developed comprising of several dams, independently run of each other. These have been built over time to meet increasing water demands from the various sectors in the phase of droughts and varying rainfall in the region (Baker, 2011). Groundwater is also in use especially for rural water supply in the entire catchment for both domestic and irrigation uses (Kloos, 2010). This maybe however threatened by over abstraction and traces of pollution from poor agricultural practices. Water users obtain water from the major dams, farm dams, surface river abstraction, and groundwater. In terms of water use, households, agriculture, mining, and industry are the main water use sectors. The catchment has experienced rising water requirements over the past few years and it is projected that population increase will raise the pressure further on existing water reserves. This is due to intensified water use activities of mining, power generation, urban development, improved service delivery to rural communities, and irrigation (Mallory, 2011). These affect the water quantity and quality situations and there are concerns of demand outstripping supply despite construction of newer dams (ibid). Table 1.1 below shows the water balance for the Olifants catchment in the year 2010 indicating a small surplus. However, this is not inclusive of the reserve requirement, which would bring it down to a deficit. Projection from this indicates that by the year 2035, the area will be experiencing a negative water balance (Mallory, 2011). The water requirements are summed up over all user sectors (urban, rural, industrial, mining, irrigation, and power generation) while the water resource is the yield from major dams and diffuse resources such as farm dams, run off river abstraction, and ground water.

Table 1.1: Water balance for the Olifants basin in the year 2010: Million m^3 /annum

Sub catchment	**Water requirement**	**Water resource**	**losses**	**Water balance**
Upper	609	630	0	21
Middle	187	185	(19)	(21)
Lower	220	248	(5)	23
Total	1016	1063	(24)	**23**

Source: (Mallory, 2011)

1.4.4 Agricultural water use

In South Africa, irrigation-farming accounts for approximately 57 percent of national water use making it the largest water-using sector. Agriculture remains the largest water user for the middle and lower Olifants sub basins while power generation takes up the big part of water use in the upper Olifants (Walter, 2010). Land under irrigation in the Olifants basin is approximately 100,000 ha (Masiyandima et al., 2000). Commercial irrigation is well developed and organized with sophisticated technology and produces a wide variety of crops such as maize, soya beans, citrus, cotton, vegetables, wheat, and tobacco (Kloos, 2010; Lange et al., 2003). Almost all irrigation farming occurs in the commercial sector with majority of land owners being whites who take up about 95 percent of total irrigated area (Tsegai et al., 2009). Irrigated agriculture makes a great contribution to the national economy and employment through several backward and forward linkages created across and within sectors. Water for irrigation is accessed through WUAs, government water schemes and un associated farmers who withdraw water directly from the rivers in execution of the riparian principle (Lange et al., 2003).

Small holder irrigation also referred to as the emerging farmers mainly fall under government managed irrigation infrastructure which are characterized by high inefficiency levels (Masiyandima et al., 2000; Lange et al., 2003). This could be due to the dependency syndrome arising from over reliance on the government and the fact that the emerging farmers are highly heterogeneous (Masiyandima et al., 2000). Only a small part of the Olifants irrigated area is occupied by small holders, but most households at least derive some part of their livelihoods from the government schemes, individual, and communal vegetable gardens. The emerging farmers' sector is the most disorganized and under represented among other water use sectors in the Olifants; this is expected to be addressed with the rise of the CMAs (Lange et al., 2003). There exists little knowledge on exact water use amounts by the farmers as well as their total irrigated areas. The emerging farmers also use much less water than the recommended for full irrigation (Masiyandima et al., 2000).

1.4.5 Mining water use

Mining is an important sector in the Olifants through its contribution to employment and exports. Most mining activities in the Olifants are concentrated in the upper Olifants sub basin. The need for water in significant large quantities in the mines stiffens the competition for the scarce resource (Walter, 2010). However, the mines are trying to control this through newer technologies that utilize less water in producing the same output. A downside to the mining activities is the negative impact on water quality. This is especially through abandoned mines found in several parts of the basin. This problem is further aggravated by the fact that water quality control through the effluent discharge permit system is still non-operational and in the trial stages (Walter, 2010 ; Calmeyer, 2014). Table 1.2 illustrates water use by sector for the year 2011.

Table 1.2: Sectoral water requirements in the Olifants basin in million m^3 /annum

Sub-catchment	**Power generation**	**Industrial**	**Urban**	**Rural**	**Mining**	**Irrigation**	**Total**
Upper	228	9	93	4	26	249	609
Middle	0	0	56	22	28	81	187
Lower	0	0	29	3	32	156	220
Total	**228**	**9**	**178**	**29**	**86**	**486**	**1016**

Source: (Mallory, 2011)

1.4.6 Overview of the water quality situation

Water quality is an important aspect to consider because if neglected, it jeopardizes the sustainability of agriculture among other sectors of the economy (Van Veelen, 2011). The general water quality of surface and ground water resources in South Africa is on the decline as competition for water use intensifies (Armour & Viljoen, 2000; Van Veelen, 2011b). In the upper Olifants for example, there is a lot of waste discharge especially from coal mining which leads to localized acidification and salinization of surface water leading to losses especially in the irrigation sector (Zyl & Maree, 2001). Some commercial farmers especially the exporters go to the extent of purifying irrigation water for themselves in order to curb any associated losses (van Stryp, 2014). The main water quality problems in irrigation are eutrophication, turbidity, and salinization. These lead to sedimentation, irrigation clogging, soil salinity, high water treatment costs and algae growth (Van Veelen, 2011). Mine water use is as low as four percent of total water used in the catchment yet contributes to about 78 percent of total sulphates load (Zyl & Maree, 2001). Further indications of water pollution are evident from fish and crocodile deaths in some parts of the catchment. Water quality has been of much concern but insufficient resources, lack of capacity on the ground, and difficulties in quantifying pollution due to its diffuse nature, limit its assessment and monitoring by the DWAF. DWAF hence relies on results of water quality assessment conducted independently by the mines, with occasional random audits of water samples just for verification purposes (Ashton et al., 2001; Lévite et al, 2003). The quality monitoring covers many determinants but is non-comprehensive as it fails to monitor heavy metals concentration. Water users get zero feedback from quality assessments and therefore remain aware of only the visible water contamination. This results in lack of enough social pressure to conduct intense monitoring (Lévite et al., 2003). Wastewater treatment plants targeting domestic water use on the other hand exhibit poor performance due to an array of factors in regulation, management, and technology design. More than fifty percent of wastewater treatment plants, especially smaller ones, do not meet effluent standards and some do not even measure effluent quality. Insufficient or poor allocations of funds at municipalities lead to poor technology choices of treatment plants that often do not meet municipal demands in terms of physical loading or suitable treatment processes. Advanced technologies are not an option because of inhibitions arising from high maintenance costs, lack of skill, and the necessary capacity. Water treatment problems are further aggravated by the lack of by-laws and implementation to control effluent discharge (Merwe-botha & Quilling, 2012). The government of South Africa has come up with an incentive-based certification termed as the ‘Green Drop’ to address the existing water quality gaps and enhance the performance of municipal wastewater service providers. The Green Drop process involves measuring and comparing the outcomes of the performance of Water Service Institutions, and consequently rewarding (or penalizing) the institution upon evidence of their excellence (or failures) according to the minimum standards or requirements that has been defined. Nevertheless, recent audits indicate that the wastewater treatment services are below par in comparison to the required national standards and international best practices (DWAF, 2009).

1.4.7 Organization of dissertation

This thesis is organized into five chapters. The first chapter gives the introduction and background of the problem, objectives of the research, hypothesis, and an overview of the study area. Chapter 2 identifies and quantifies transaction costs of the water policy process and further examines the determinants of these transaction costs accruing to irrigation water users. The chapter further outlines suggestions of possible transaction benefits. The timeliness and cost of ICT (mobile phone) use on water management is also explored in this chapter through a trial experiment on communication of water management information between water users and public agents. Chapter 3 gives an overview of the current institutional organization of the water sector in South Africa and describes some of the investigated IWRM policies in the 1998 water Act. Additionally, chapter 3 examines the effects of different water policies on irrigation water use-quantity, quality, and efficiency. In chapter 4, we assess the impact of compulsory licensing, and water pricing on the large scale and small-scale holders' welfares and irrigation water demand. Chapter 5 gives the major thesis conclusions and policy recommendations.

Chapter Two

2. Transaction Costs associated with water policies in the Olifants basin of South Africa

2.1 Introduction

Water is a complex economic good (Garrick et al., 2013). This is due to existing interdependence between its private and collective values, mixed property regime for its governance and high externalities hence high transaction costs in its management (ibid). Recent management fronts have advocated for market based water policy reforms to solve the water scarcity and allocation problems (Rosegrant, & Binswanger, 1994; Earle et al., 2005). However, high transaction costs inhibit success of the proposed reforms, which so far portray a mixture of successes and failures from different parts of the world (ibid). In South Africa, little progress with the water reforms is reported; water users continue to face challenges of deteriorating water quality, poor water service/administration, water shortages, and poor water distribution.

Transaction costs are important determinants of policy sustainability, economic efficiency, and equitable outcomes (McCann et al, 2005b ; Blore et al., 2013). Coggan et al., (2010) identifies transaction costs as the biggest hindrances to policy implementation and compliance when they constitute a large component of total policy costs. Several authors emphasize that transaction costs should be lower than the expected benefits, for market based water policy reforms to work (Easter et al., Rosegrant, & Dinar, 1999; Rosegrant & Binswanger, 1994; Honey-Rosés, 2009; Slaughter, 2009; Garrido, 2000; Carey, 2002; Coggan et al., 2010). To attain low transaction costs, proper institutional arrangements such as water rights and organizational settings have to be set up and running, in addition to good infrastructure and management (Easter et al., 1999). However, the institutional strains arising from the policy transition process, further aggravates transaction costs. Research in this regard is however not sufficient to explain the complete interplay of issues (Garrick et al., 2013).

Given their significance, transaction costs should remain an important part of any policy analysis and design (McCann et al., 2005b). However, this is not possible to do when the said transaction costs are unknown (ibid). Identifying and measuring transaction costs is thus a step towards incorporating the transaction costs in evaluation of policy alternatives (Ofei-Mensah & Bennett, 2013). There are intensified efforts geared towards transaction costs measurement but problems arise due to ambiguity in their definition, and especially for environmental resources since the 'good' is not so well defined. There are no measurement boundaries and explicit and implicit costs such as the cost of time are difficult to measure (Carey, 2002; McCann & Easter, 2004; McCann et al., 2005). This leads to lack of clear and location specific transaction costs quantification (Ofei-Mensah & Bennett, 2013). Transaction benefits on the other hand are rarely discussed in literature despite being the flipside to transaction costs (Blomqvist et al., 2002; Boudreau et al., 2007; Watson et al., 2005). Transaction benefits are benefits accruing to an individual or organization, in an economic exchange process over and above the anticipated direct benefits of a transaction (Boudreau et al., 2007; Watson et al., 2005). For example, in addition to expected financial returns, an employee might incur additional benefits of skill development, reputation, and improved self-esteem. A firm on the other hand might experience additional benefits such as cumulative learning, economies of scope and scale due to specialization and flexibility (ibid). In the case of a community at large, the transaction benefits are all that most community members gain in the event of an intervention or reform (Watson et al., 2005). To the best of our knowledge, no study has estimated the transaction costs and benefits of water policy in South Africa, specifically in the Olifants basin. This paper contributes to filling this literature gap by identifying and quantifying the transaction costs associated with implementation and compliance to water pricing, compulsory licensing, water trade, formation of WUAs and effluent discharge permits. Additionally, the study highlights the possible transaction benefits of water policy. A second step for the study was to explore the determinants of the identified transaction costs.

Transaction costs measurement is not an easy task (McCann et al., 2005b). Nevertheless, several studies have so far attempted to measure transaction costs for environmental policies. Ofei-Mensah & Bennett., (2013) found that transaction costs existed and were sizeable for three greenhouse policy alternatives in Australia; the transaction costs ranged from 19 percent of compliance costs, 4 percent of total costs, and 10 percent of program benefits for the 3 programs studied. Pannell et al., (2013) reported significant transaction costs (about 68 percent of total program costs) incurred by policy makers of a water salinity program in Australia. Falconer, (2000) on the other hand reported transaction costs ranging from 5-10 percent of farmer compensation costs in agri-environmental schemes in the European Union; these transaction costs were significant barriers to farmer participation in the schemes hence reduced supply of conservation goods. Similarly, Falconer & Saunders, (2002) found transaction costs amounting to 21 percent of farmers' compensation costs in a study to examine agri environmental goods provision schemes in the North of England. Colby, (1990) examined transaction costs of policy in western water markets in the U.S and reported transaction costs of about 6 percent of prices paid for application to transfer water. McCann & Easter, (1999) examined transaction costs associated with agricultural nonpoint pollution reduction and found that lower transaction costs were associated with tax policies in comparison to educational programs or conservation tillage. Other studies have reported high transaction costs incurred in natural resource management but fail to quantify the costs (Kuperan et al., 2008; Blore et al., 2013; Garrick & Aylward 2012; Mburu, Birner, & Zeller, 2003).

Few empirical studies have so far been undertaken to assess the determinants of transaction costs in environmental policy (McCann & Easter, 1999; Coggan et al., 2010; Falconer, 2000; Falconer & Saunders, 2002; Rørstad et al., 2007). Coggan et al., (2010) summarizes determinants of transaction costs under three broad important categories; i) nature of the transactor, ii) characteristics of the transaction and iii) current institutional environment. Transaction characteristic factors relate to asset specificity and timing or frequency of a transaction while transactor characteristics relate to opportunism, bounded rationality, common ideas, trustworthiness and social cohesion in addition to demographics. Coggan et al., (2010) further indicate that determinants of transaction costs are different between parties, and are affected by the nature of the policy and the interelationships between the parties to a policy. Coggan et al., (2013b), reported transaction costs drivers under the three broad categories for terrestial conservation development offset schemes in Australia; transaction characteristics factors included, asset specificity, biophysical uncertainty, and transaction frequency. Relevant transactor characteristics included, past experience, opportunism, trust in information and fellow actors, common preferences and community practices. Institutional environment factors included rules, institutional inconsistencies and means of exchange. McCann & Easter, (2004) reported physical determinants of transaction costs for water markets as infrastructure and technology, water scarcity and shortages, nature of water transfers, water rights, location and water characteristics such as quality and quantity. Institutional related determinants historical institution arrangements, legal system, social norms, and social capital. Additional studies that have investigated the determinants of transaction costs in environmental policy include, Mburu et al., (2003), and Garrick & Aylward (2012). Following literature reviewed, we posit that future policy choice and design stands to greatly benefit from more empirical examinations of factors affecting transaction costs.

Section 2.2 gives the theoretical and conceptual frameworks, 2.3 highlights the emprical procedures, 2.4 describes the data acquisition methods, 2.5 discusses the results while 2.6 gives the conclusion and recommendations. Box 2.1 at the end of the chapter gives the overview of a trial experiment implemented to assess the timeliness and cost of ICT (mobile phone) use for water management purposes.

2.2 Theoretical and conceptual framework

Transaction Cost Economics (TCE) originates from the work of Coase, (1937) in his seminal article on 'the nature of the firm' (Coase, 1960; Carey, 2002; Beare et al., 2003; Kuperan et al., 2008; McCann & Easter, 2004; McCann et al., 2005b; Rosegrant & Binswanger, 1994). TCE was initially applied for studying economics of industrial organisation but has since been applied in many other fields (Zhang et al., 2009). TCE theory posits that if individuals are confronted with choices, they will go for institutions and contracts that minimize transaction costs (Kuperan et al., 2008). It describes human agents on basis of two key attributes, namely; cognitive ability (bounded rationality) and self interestedness (opportunism). Bounded rationality occurs in the sense that all contracts are unavoidably incomplete with gaps, errors, and omissions; contracts are further complicated by opportunism in which agents make incomplete promises or withhold relevant information (Williamson, 1998). TCE is however criticized for its one sided economic view of human behavior as only rational (Watson et al., 2005). This view is invalid because human behavior is driven by both rational and social goals (Boudreau et al., 2007). The theory emphasizes only on transaction costs and overlooks transaction benefits, which brings in the social aspect of humans (ibid). Thus this study tries to extend the TCE theory by incorporating transaction benefits in our discussions albeit data limitations.

No standard definition of transaction costs exists in literature. However, several studies have termed them as costs of market exchange over and above the actual costs of goods and services (Singh, 2008; Silva, 2010; Coggan et al., 2010). They include search costs, costs of negociation, monitoring costs and enforcement costs (McCann et al., 2005; Diao et al., 2005; Singh, 2008; Silva, 2010; Coggan et al., 2010). They are the costs incurred to overcome any form of uncertaity surrounding any contract or interaction (Singh, 2008; Silva, 2010;Coggan et al., 2010). In the context of environmental policy, transaction costs have been defined as the costs incurred to define, establish, maintain and transfer property rights (Coggan et al., 2010; McCann et al., 2005). An even broader definition is given by Marshall, (2013) as the costs related with the creation or change of an institution or organisation and the use of that institution; transaction costs give the allowance for change of institutions.

In Figure 2.1, the dotted oval lines (touching on all the five boxes from water policy to welfare), indicate the transaction costs underlying the water policy process in the Olifants basin. We use dotted lines to reflect the fact that transaction costs are not entirely explicit but remain in the background along the entire policy process (McCann et al., 2005a). In this case, we see the interplay of transaction costs along the entire policy process from policy formation, through water managers to the implementation process and compliance. Transaction costs indirectly impact on the expected water management outcomes of quality, quantity, and efficiency through the implementation and compliance processes. Transaction costs also affect the overall welfare of key players because they incur the transaction costs albeit unknowingly or inexplicitly. A dotted arrow line connects the transaction costs back to the policy formation process. This implies that knowledge of the the existing transaction costs is indeed important, and would be valueable feed back into the policy process to allow for better policy evaluation, decisions, and choice ex ante and ex post (McCann et al., 2005; McCann & Easter, 2004). The bold line connecting water policy and welfare implies that water policy is expected to impact on welfare while the welfare status should inform policy choice. Socio economic, demographic and institutional factors are also expected to influence policy formation, implementation, compliance, and outcomes.

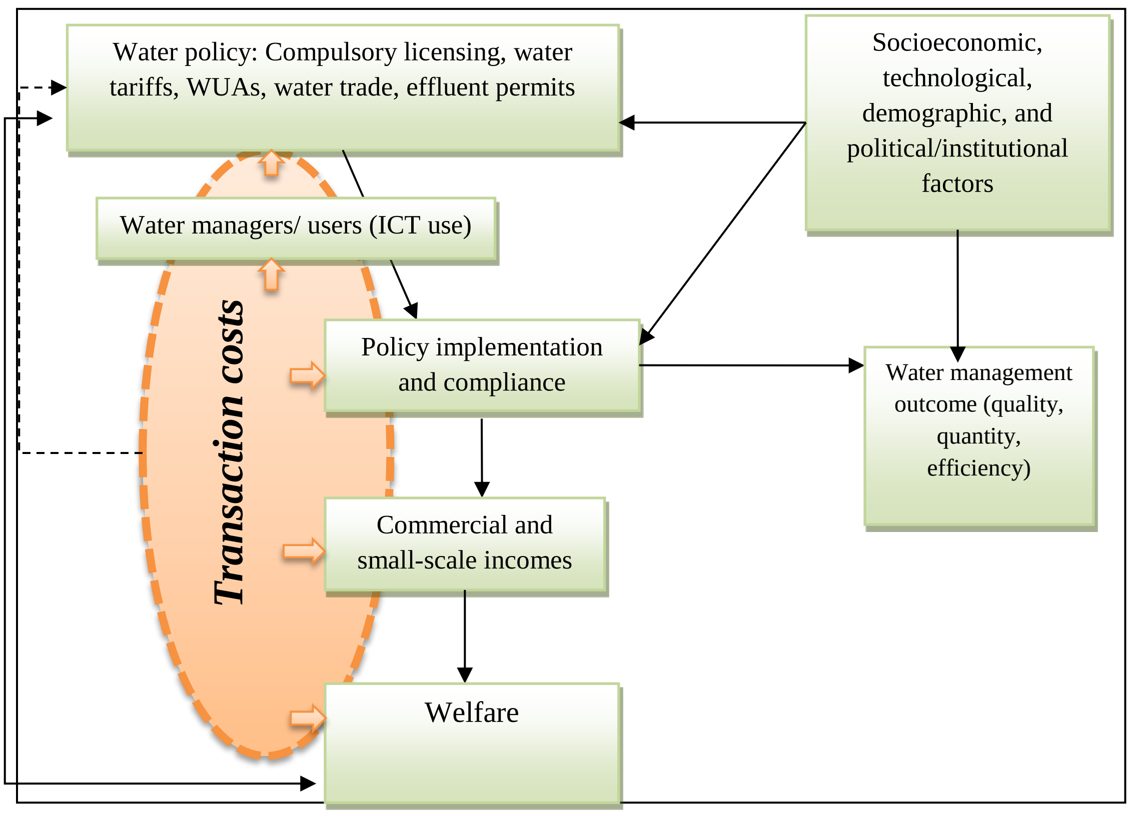


Figure 2.1: Conceptualization of transaction costs

Source: Own compilation

Coase, (1960) argued that market transactions take place efficiently when there are well defined property rights and zero transaction costs. This, however, is not the case for water resources management transactions because the definition of water rights and policies is associated with high transaction costs. High transaction costs are barriers to cost free transactions (Garrick & Aylward, 2012; McCann et al., 2005; Nieuwoudt & Armitage, 2004; Rosegrant & Binswanger, 1994a ; Williamson, 1979). Water management involves multiple actors with different and competing interests hence the need for coordination. Coordination of actors and operations however, leads to the occurance of transaction costs. The transaction costs arise from acts of information collection, policy design, policy enactment, policy establishment, policy implementation and contracting, administration, monitoring and enforcement (Coggan et al., 2010; McCann & Easter, 2004; McCann et al., 2005). The transaction costs impede the exchange process on both the public parties (water managers) and private parties (water users). For example, Brill et al., (1997) and Easter et al., (1999) identifed assymetry in information flow between water supply managers and users as one of the major obstacles to water allocation and water markets.

2.3 Empirical framework

2.3.1 Measuring Transaction Costs

Transaction costs measurement is not an easy task but "what gets measured gets managed" (McCann et al., 2005b; Marshall, 2013). There is no constant or uniform method for transaction costs measurement and this translates to lack of optimality in choice of policy instruments (Blore et al., 2013; McCann et al., 2005b; Marshall, 2013; Pannell et al., 2013; Ofei-Mensah & Bennett, 2013). Consistency lacks in the measurement methods, i.e. definitions, precision, and treatment of time for transaction costs. Previously, transaction costs have failed to be included in any form of economic analysis due to these challenges in measurement (McCann et al., 2005b). Transaction costs occur ex ante (before) or ex post (after) of policy implementation. In the current study, we identify and quantify ex post transaction costs related to water policies in the Olifants basin, as incurred by water managers and users.

We follow a transaction costs categorization framework by McCann & Easter, (2004) and McCann et al., (2005) as indicated in Table 2.1. The framework is comprehensive in outlining the different cost types, their time of occurrence, their best measurement approach, and the different parties to whom the transaction costs accrue. The transaction costs types considered for this study included, support and administration, contracting, monitoring/detection, and prosecution/enforcement costs – as outlined in the green section in Table 2.1. We further consider the relevant specific costs under each transaction costs category i.e. travel cost, labor (opportunity cost of time), telephone costs, decision costs, negotiation, and conflict resolution costs as depicted in Table 2.2. Activities such as discussions, meetings, and follow-ups captured the opportunity cost of time. The transaction costs were identified chronologically through early implementation, full implementation, and establishment for each policy in order to capture transaction costs variation through time.

Table 2.1: Typology of Transaction costs encountered in the public policy process

Transaction type	**Incurred by**			**Time of occurrence and measurement**					**Recommended measurement methods**			
	Legislature/courts	agencies	stakeholders	baseline	development	Early implementation	Full implementation	Established program	Ex ante		Ex post	
									implicit	explicit	implicit	explicit
Research and information	*	**	*						1,2	5	1	1,3,4,5
Enactment or litigation	**	*	**						1,2	5	1	1,3,4,5
Design and implementation		**	*						1,2	5	1	1,3,4,5
Support and administration		**	*						1,2	5	1	1,3,4,5
Contracting		*	**						1,2	5	1	1,3,4,5
Monitoring/detection		**	*						1,2	5	1	1,3,4,5
Prosecution/enforcement	*	**	*						1,2	5	1	1,3,4,5

Source: McCann & Easter, (2004) and McCann et al., (2005)

*=low **=high .1= surveys/interviews of government personell and stakeholders. 2 = expost results from other studies. 3 = government reports. 4 = financial accounts. 5 = proposed budgets

Specific costs and activities under each TCs category in Table 2.1

- Research and information: any analysis related to problem definition
- Enactment or litigation: includes costs of lobbying, public participation, law modification
- Design and implementation:costs of regulatory delay
- Support and administration: mainly in creating awareness of policies through notices and hearings and oveseeing other processes of contracting, monitoring and prosecution.
- Contracting: additional information costs, bargaining costs, decision cost, identifying profitable opportunities, negociating.
- Monitoring/detection: of outcome/compliance, monitoring transfers, costs of monitoring and mitigating third party effects, infastructure costs of conveyance.
- Prosecution/enforcement: costs of conflict resolution

Activities under the different time periods given in Table 2.1

- Baseline: starting point when there is realization and upcoming awareness of the need for policy. Information on costs collected here helps to evaluate alternative policies and guide the design process
- Development: this is a time when there is lobbying, debate and negociations for and against proposed policies whereby they undergo modifications after which they are finally adopted
- Early implementation: here rules of administration are crafted and adopted, public agents hired for administration, public notices and hearings
- Full implementation: policies come into full effect
- Established program: policy instruments are fully established and are part of the routine

Table 2.2: Specific transaction cost activities considered for each transaction cost type and policy

Policy	**Transaction cost type (ex-post)**	**Specific transaction costs**	**Early implementation**	**Full implementation**	**Established program**	**Main paying entity**
e.g. compulsory licensing	Support and administration	• Notices and hearings • Discussions • Meetings • Follow ups • Travel costs • Telephone costs				Water managers
	Contracting	• Additional information • Decision cost • Arranging for finance • Negotiating • Travel costs • Telephone costs				Water users
	Monitoring/detection	• Travel costs • Telephone costs • Time used(labor) • Transfer costs				Water managers
	Prosecution/enforcement	• Discussions • Meetings • Follow ups • Travel costs • Telephone costs • Fines				Water managers

Source: Own compilation

Following McCann et al., (2005b) and Ofei-Mensah & Bennett, (2013), the size or extent of transaction costs (*T*) for a policy program was quantified using the following reduced form equation;

$$T_{ijt} = \Sigma\,(A_{ijt} + B_{ijt} + C_{ijt} + D_{ijt}) \qquad (2.1)$$

Where;

T=Transaction cost

i= policy

j= the paying entity: water users (private agents) and water managers (public agents)

t=time period (early implementation, full implementation and establishment)

A,B,C,D, are the transaction cost variables including; support and administration, contracting, monitoring/detection, and prosecution/enforcement.

2.3.2 Factors influencing transaction costs

Following recommendations by several previous studies, (Coggan et al., 2010; Falconer, 2000; Falconer & Saunders, 2002; Rørstad et al., 2007; Mburu et al., 2003), this study further identified the factors influencing the transaction costs incurred by irrigation farmers in the Olifants basin. We used an Ordinary Least Squares (OLS) regression as guided by the continuous nature of the dependent variable (Verbeek, 2012).

An operational model takes the form:

$$T_j = \mu_j + \varepsilon_j \qquad (2.2)$$

Where;

T_j is the total transaction costs of an irrigation farming household *j* for all policies adhered to across the three time durations calculated using equation *2.1*

μ_j is a vector of observable factors likely to influence the transaction costs magnitudes

ε_j is the unobservable error term.

The implicit functional form of the estimated model is given as;

$$TotalTCs = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon \qquad (2.3)$$

Where;

TotalTCs= Total transaction costs in (ZAR), is the continous dependent variable

x_1= vector of transactor characteristics (geographic location, gender, main occupation, farming years, farm size, income, and schooling years)

x_2 = vector of transaction characteristics (policy compliance, use of ICT tools for water management purposes, technical assistance source, water quality)

$x3$= vector of institutional environment related factors (market distance, leadership position in formal and informal water use groups, tenure security)

ε = error term

Table 2.3 gives the list of variables included in the regression analysis, their hypothesized signs and summary statistics. Since little empirical research exists on drivers of transaction costs for environmental policies and specifically water policy, some of the variables included are exploratory in nature but categorized under the three broad categories of determinants of transaction costs guided by economic theory. Firstly, we hypothesize that farmers compliant to any of the water policies are likely to incur transaction costs of water policy compliance. Farmer location would influence transaction costs negatively or positively depending on policy spread and nature of farming systems. Farmers holding leadership positions in water user groups are hypothesized to incur less transaction costs due to their exposure to the current policy operations and they do not have to incur many additional information transaction costs. Gender could be positive or negative depending on levels of farm activity and compliance to water policy between male and female farmers. Farmers with more years of schooling are hypothesized to incur less transaction costs because they are better able to comprehend and avoid additional transaction costs such as costs of decision making and additional information. Coggan et al., (2010) suggest that education and past experience reduce bounded rationality and associated information related transaction costs. Small scale farmers and respondents involved in other main activities are expected to incur less transaction costs due to their minimal compliance to water policy. Farmers with bigger farm sizes on the other hand are expected to incur more transaction costs stemming from their increased number of farm activities including compliance to more water policies. Tenure secure farmers are hypothesized to have more incentive to invest in farm activities and comply to stipulated water policies thus incur more transaction costs. Farmers receiving their technical assistance from DWAF were expected to incur more transaction costs while those that used ICT to obtain policy information were expected to face lower transaction costs. Farmers receiving ideal water qualities are hypothesized to have the incentive to comply to more water policies hence incur higher transaction costs of water policy unlike the low water quality counteparts. Lastly, the influence of market distance could be positive or negative;

farmers in far away distances can marginally comply to water policy therefore zero or reduced transaction costs. They could also face high transactions costs of compliance due to large distances covered in their quest for policy information.

Table 2.3: List of the variables included in the OLS regression and their summary statistics

Variable	Description	Expected sign	Mean	Std.Dev	Min	Max
Total TCs	Total transaction costs (ZAR) per farming household for all policies complied to	Dependent	2738.13	4428.29	0	19960
ICT tool	ICT tools used for water management purposes (1=radio,TV,phone,email 0=none)	-	0.62	0.48	0	1
Technical assistance	Source of technical policy information (1=DWAF,0= other sources)	+	0.47	0.89	0	5
Region	Farmer geographic location (upper,middle and lower Olifants)	+/-	2.48	0.80	1	3
WUA	Farmer involvement in WUAs/groups	+	0.43	0.49	0	1
Compulsory licensing	Compliance to water licensing	+	0.08	0.27	0	1
Water cost	Natural log of total cost of irrigation water based on current tariffs paid	+	0.40	0.23	0	0.44
Market distance	Distance to nearest input/output market in Kms	+/-	50.10	54.98	0	300
Leadership in WUA	Leadership position held in WUAs/ groups	-	0.06	0.24	0	1
Gender	Male or female farmer	+/-	0.56	0.49	0	1
Schooling years	Total number of years of school attendance	-	8.66	5.52	0	24
Occupation	Main activity of respondent (1=largescale 2=smallscale 5=other)	+/-	1.84	0.73	1	3
Farming years	Total number of years of farming	-	19.42	13.26	1	55
Farm size	Natural log of farm size	+	71.32	170.80	0.05	900
Land claims	Proxy for tenure security	+	0.072	0.25	0	1
Income	Natural log of income	+/-	11.46	2.81	0	20.7
Water quality	Water quality type (1=Ideal 2=acceptable 3=tolerable 4=unacceptable)	+/-	2.03	0.88	1	4

Source: Own compilation

2.4 Data

A data base of water use/users and authorization in the Olifants Water Management Area was obtained from the Department of Water Affairs and Forestry (DWAF) regional office, which was the relevant authority for the Olifants. The data base was used to compute the numbers of all the water users of interest such as farmers, miners, and industry in the three sub basins. Stratified random sampling and Probability Proportionate to Size sampling (PPS) were used to obtain the suitable number of survey respondents by sector and region. Firstly, each sector of water users i.e. farmers, miners, and industry in the entire basin were chosen as the relevant strata and their actual representations identified. Probabilities proportionate to size calculations were then made to obtain the total number of survey respondents from each strata; 313, 6, and, 13 farmers, miners and industrial water users were identified respectively. Secondly, the sub basins were used as strata and Probabilities proportionate to size calculations were made to obtain totals of survey respondents by region. The research randomizer found at www.randomizer.org., helped to obtain the specific respondents for the survey. Farms with less than 10 ha of cropland were regarded as small scale while those above 10 ha were taken as commercial farmers. Miners and industry were not included for the regression analysis due to lack of, and the personalized nature of demographic information required in the regressions.

Data was then collected through a survey from a total of 183 irrigation farmers and 16 water managers in the Olifants basin. We used a semi-structured questionnaire to elicit data that was relevant for all the chapters in this study. The information collected from farmers included household socio economic characteristics, farm activities, water policy compliance, and individual estimates of relevant transaction costs. With regard to transaction costs, the first step was to find out how many of the five policies investigated a farmer was compliant. Under each policy, we outlined the transaction cost types i.e. support and administration costs, contracting costs, monitoring costs and enforcement costs. Under these transaction cost types, we outlined the relevant activities through which a respondent would incur transaction costs; these were costs incurred in meetings, travel, communication, negotiation, giving notices and hearings, and financing as outlined in Table 2.2. Given that transaction costs are usually not recorded, the costs obtained were based on recall for past and present water policy phases. This was a difficult task and a limitation for our data collection process. In addition, irrigation water users were reluctant to attend to interviews while ministry staff hesitated to avail information. Nevertheless, focus group discussions conducted with leaders of water use groups, extension personnel, and farmers, substantiated the farmer interview responses.

Information collected from water managers included positions held in the water ministry, water issues of concern raised to them by users, level of involvement with water policy responsibilities, and personal estimations of transaction costs incurred following Table 2.2. Additionally, departmental budgets and reports for the past ten years were obtained from the DWAF to complement the data collected from the water managers. The budgets and reports indicated amounts of money budgeted for different water activities in the ministry such as administration, water sector regulation, regional implementation, international water cooperation, water services, forestry, and water infrastructure management. Each of these categories consisted of more specific water policy activities under which budgeted money was incurred. The reports further indicated staff numbers and their salaries at different levels of operation. Additional information was obtained through emails, phone calls and informal personal communication.

2.5 Results and Discussion

2.5.1 Water users transaction costs across policies

Firstly, we quantified and compared the total transaction costs incurred by water users for the different water policies (Table 2.4).

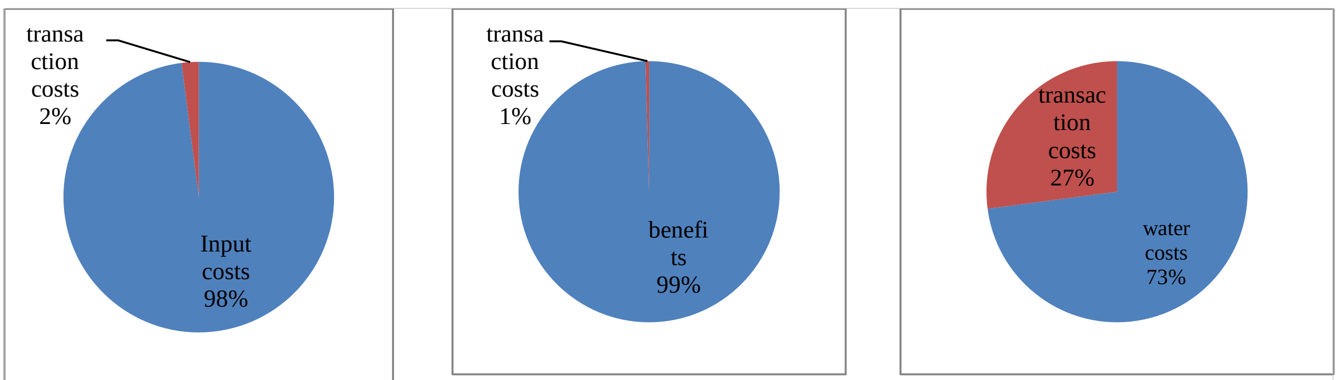
Table 2.4: Total transaction costs of water policy incurred by water users (ZAR)

Water policy	Number of water users compliant	Administration Costs	Contracting Costs	Monitoring Costs	Enforcement Costs	Total for each policy
Water tariffs	81	_	638495	_	_	638495
Water trade	16	_	_	_	_	_
WUAs	80	112770	112432	220613	_	445815
Compulsory licensing	39	_	261099	_	_	261099
Effluent discharge	15	_	341400	15187100	_	15528500
Total	231	112770	1353426	15407713	_	16873909

Source: Own compilation

Results (Table 2.4) show that most of the reported transaction costs related to contracting costs for the policies complied to by irrigation water users. This was expected because administration, monitoring and enforcement costs were likely to be incurred by water managers (McCann et al., 2005) . Water tariffs was the most popular policy among water users in the study region (81 users), followed by WUAs (80 users) and compulsory licensing (39 compliant users). Water trade was non operational and interviewed farmers were not able to document any transaction costs relating to this policy; however, the reported water exchanges were between relatives and friends. The effluent discharge transaction costs were highest among the policies and only reported by industries. The high costs of effluent-discharge policy (amounting to about ZAR 15.5 milion) were attributable to the different scales of operation between the farming water use and industrial water use. Because the official effluent discharge permit system was not yet operational in the Olifants, the reported effluent transaction costs were incurred in monitoring effluent at an individual industry capacity; i.e. industries procured external expert services for pollution monitoring purposes as required of them by the National Environment Management Authority (NEMA) of South Africa. This information is sometimes also used by DWAF in their random pollution audits. Trials on the effluent discharge system by DWAF are, however, underway for its implementation. Monitoring costs were the highest across all water policies; totalling about ZAR 15.4 million. This may be attributed to the high monitoring costs reported by industrial water use. Contracting costs followed in magnitude then administration costs. Contracting transaction costs by water users were reported for majority of the policies while monitoring costs were reported for effluent permits and WUAs only. Administrative transaction costs were the lowest because the cost of policy implementation is a responsibility of the water managers. WUAs however recorded some administration costs because they involved self administration by participating water users. Enforcement costs were not reported for any of the policies, probably because this is a responsibility of the water managers as well.

Transaction costs were further compared to water users' input costs, farm benefits, and water purchase costs on average (Figure 2.2). The results show that water users' average transaction costs were 2 percent of other input costs, 1 percent of farm benefits and 27 percent of water purchase costs. Comparison of transactions costs incurred by water users to input costs and farm benefits seem negligible. Following McCann et al., (2005), we posit that this is because water users only incur a small portion of total policy costs; these are usually the contracting costs of policy compliance. The bigger portion of transaction costs goes to the water managers/public agents as demonstrated in Figure 2.9. However, the reported transaction costs are substantial in comparison to the average total water costs (27%).



Transaction costs versus input costs

Transaction costs versus farm benefits

Transaction costs versus water costs

Figure 2.2: Transaction costs versus input costs, farm benefits, and total water costs

Source: Own compilation

Contracting transaction costs were reported for most of the policies studied. Figure 2.3 demonstrates these contracting costs as percentages between the four policies. Water tariffs recorded the highest of all the contracting transaction costs at 47 percent probably because it was one of the widely adopted policies across the study region. Contracting transaction costs incurred for the effluent discharge were second highest at 25 percent while compulsory licensing followed at 19 percent. We attributed this to limited compliance and the fact that compulsory licensing was a once off payment per annum. Compulsory licensing was also not extensively known to many though partially beginning to spread out in the basin. Formation of water-user groups here in referred to as WUAs tagged last at 9 percent of reported contracting transaction costs. We attributed this to the already established WUAs which had been in operation for many years dating as far back as 1930's; this was especially so for the commercial farmers' WUAs. This implied that their WUA systems were already in place and not much of operational contracting transaction costs would be incurred. Similar suggestions were reported by Falconer et al., (2001). Small scale water users on the other hand, were organized into informal water-user groups and reported minor contracting transaction costs.

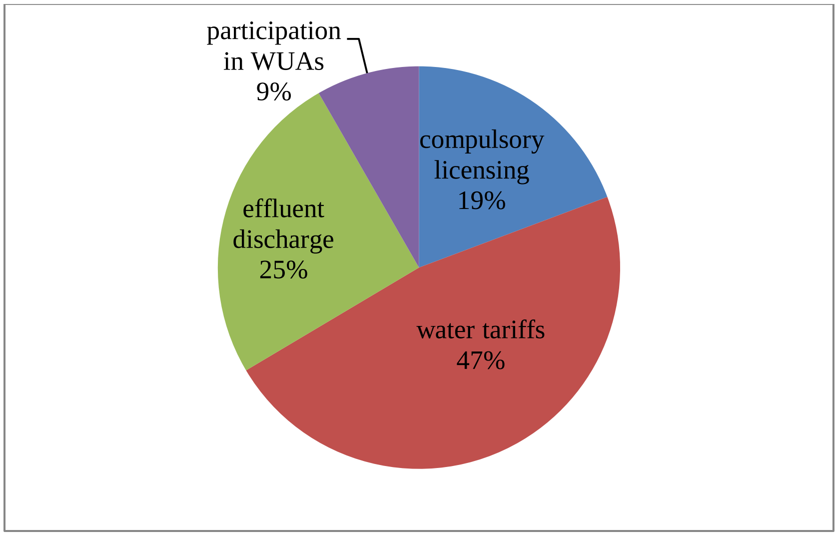


Figure 2.3: Contracting costs across four policies

Source: Own compilation

Water tariffs policy recorded the highest contracting transaction costs, we therefore highlight the specific transaction costs elements (travel, telephone, additional information costs, finance and decision costs), and their magnitudes in Figure 2.4. All the transaction costs elements were high during the early implementation phase of the water tariffs and declined through time. However, transaction costs incurred to arrange for finances remained constant over the three time durations probably because water payment remained consistent throughout the three phases (early implementation, full implementation and establishment).

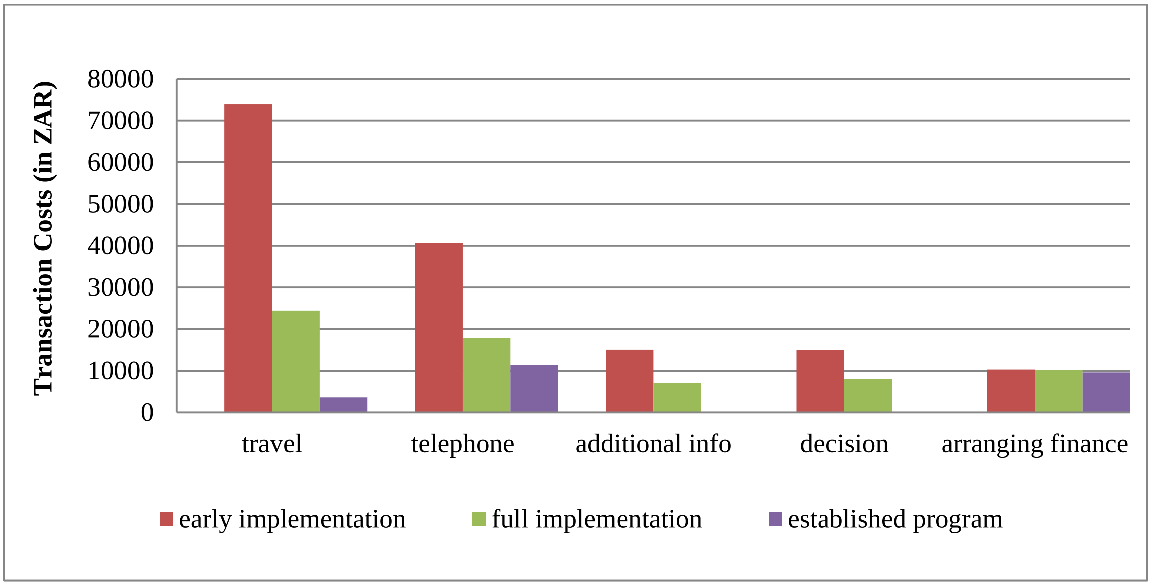


Figure 2.4: Water tariff contracting transaction cost components over time

Source: Own compilation

We further compared water users' transaction costs across policies over the three time durations considered in this study. Our findings as indicated in Figure 2.5 showed that transaction costs for all the policies were higher during early implementation and slightly decreased through to establishment. We attributed this to smoothing out of transaction costs, because experience is gained with continued policy implementation as observed by Coggan et al., (2010); Falconer et al., (2001); Rørstad et al., (2007). Effluent-discharge transaction costs incurred by industries are left out in Figure 2.5 due to the differences in scales of operation between the industries and irrigation farmers. The effluent costs were however high and followed a similar trend.

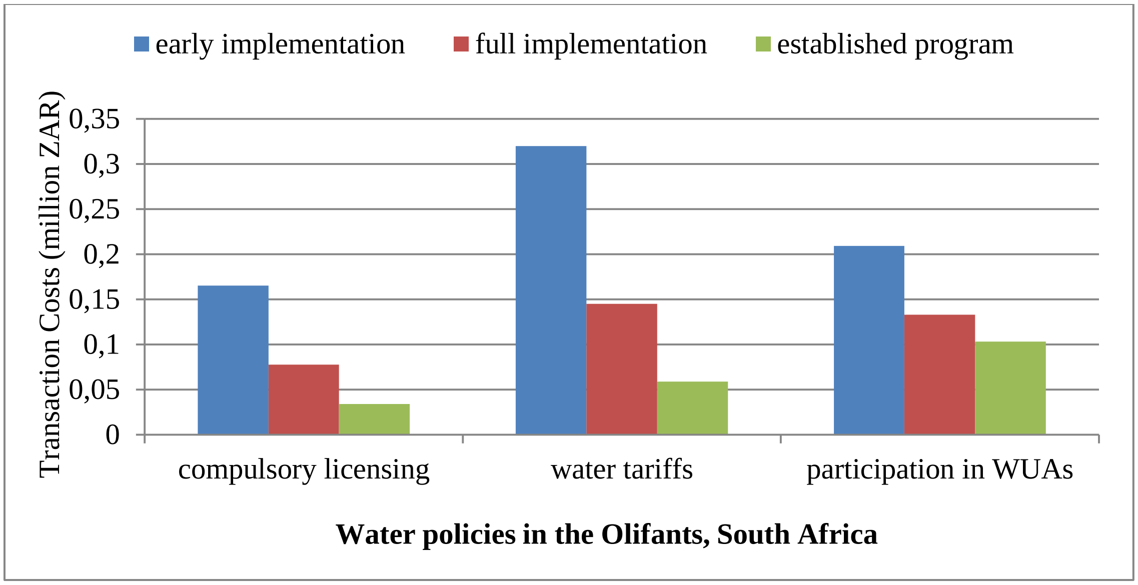


Figure2.5: Transaction costs incurred by water users across the three time durations

Source: Own compilation

2.5.2 Water managers' transaction costs

We assessed transaction costs faced by water managers to understand the cost of policy implementation. The data was both primary and secondary – obtained from interviews with government personell, government budgets, financial accounts and reports. Findings from the primary data assessment showed that across the policies implemented, transaction costs incurred by water managers varied between 17 - 24 percent as indicated in Figure 2.6. This pointed out to an almost similar transaction cost budget allocation for all the policies within the water ministry. Compulsory licensing policy recorded the highest transaction costs incurred (24 percent) probably signifying its level of prioritization amongst the water policies. Even though water trade and effluent-discharge policies are largely not in operation, high transaction costs were associated with them – about 21 percent of all transaction costs experienced by the water managers. This signified efforts made towards operationalizing water trade and the effluent permit systems. Transaction costs incurred for water tariffs and WUAs were the least (each at 17 percent) probably indicating less activities and effort from the water managers to implement the two policies. WUAs required involvement of water managers only at the inception stages while water tariffs were somewhat operational but lacking consistent follow ups.

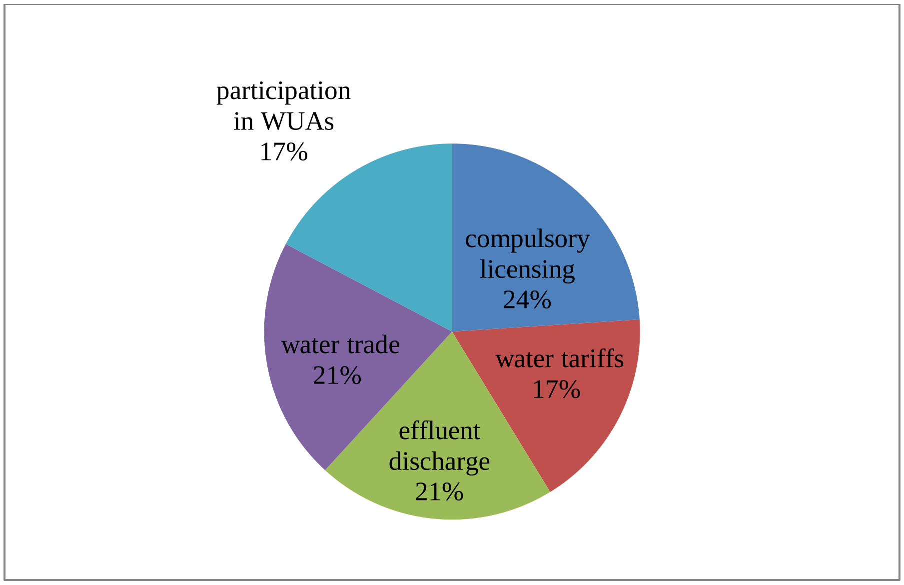


Figure 2.6: Water managers' transaction costs across policies

Source: Own compilation

The pie charts in Figure 2.7 depict an assesment into the specific policies from the water managers perspectives. They reveal that support and administration costs were the highest for all the targeted policies for implementation. The administration costs were 78, 58, 78, 80 and 64 percent for compulsory licensing, water tariffs, effluent permits, water trade and WUAs respectively. This was expected because similar indications are made in previous studies by McCann & Easter, (2004), McCann et al., (2005) and Falconer, (2000). Administration costs further tended to be fixed over time. Monitoring costs in water management closely followed in magnitude for all the policies. Contracting transaction costs by water managers were only reported for the WUAs. This was because of an initial level of involvement between the irrigation farmers and the government in formation of WUAs unlike for other policies (Jean de la Harpe, n.d.; Gazette, 1998). Enforcement costs on the other hand were minimally reported or lacking for the examined policies which could suggest failure in policy enforcement. However, examined budgets and financial accounts revealed provisions for enforcement costs. Additionally, reviewed documents from the water court of South Africa (water tribunal) showed the existence of water disputes and their execution.

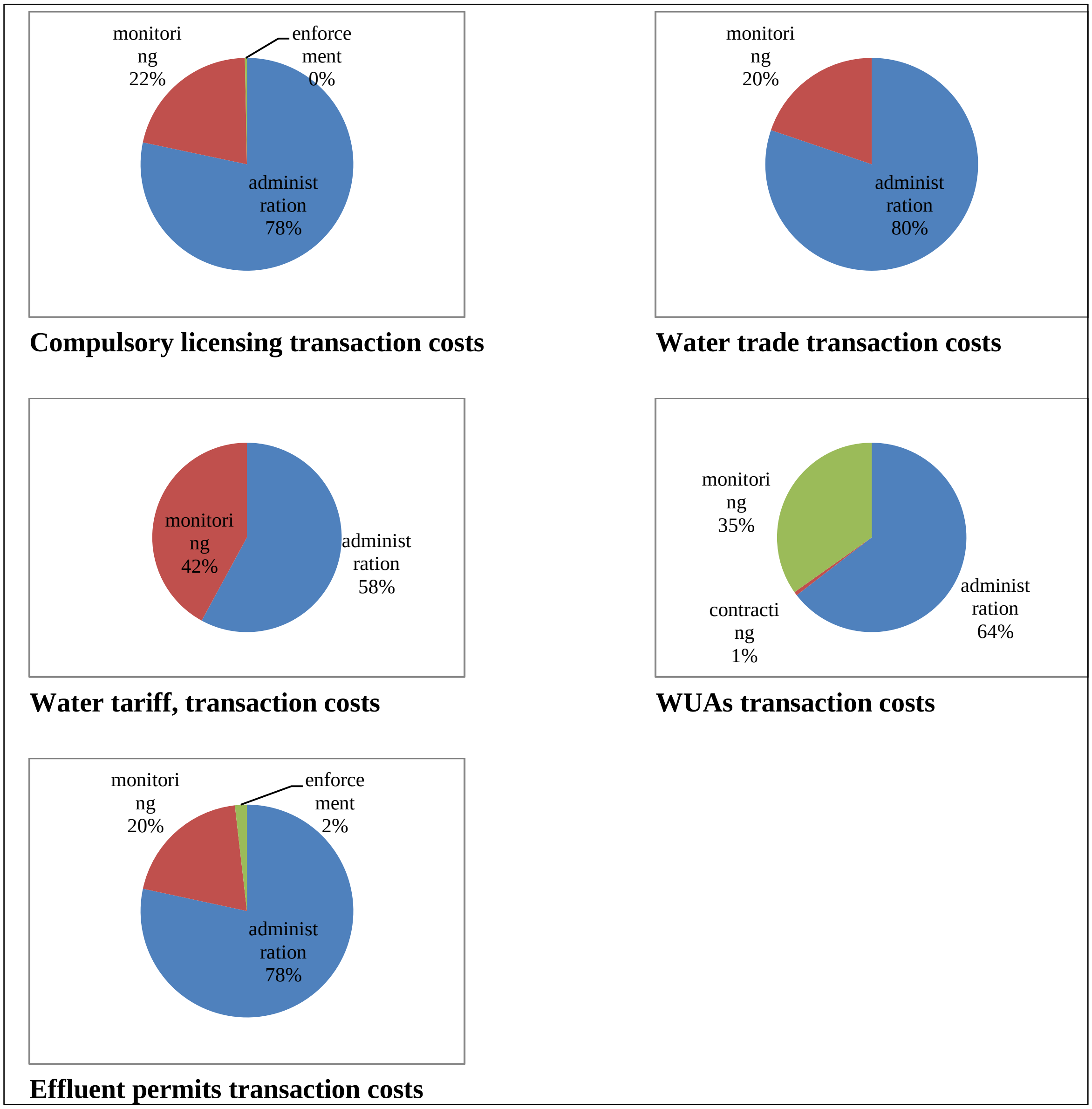


Figure 2.7: Water management transaction costs by cost components
Source: Own compilation

Figure 2.8 indicates water management transaction costs magnitudes over the three time periods studied. The figure shows that effluent discharge and water trade transaction costs are very high in the inception period and minimal in later durations of implementation. The early high implementation transaction costs could be good indicators of why these two policies are not yet steadily operational several years after the 1998 water Act. The initial high transaction costs for water trade could point to the aborted implementation of the policy in the Olifants region while the minimal transaction costs in the later periods indicate the current policy stagnation. Similarly, the initial high transaction costs for the effluent discharge system could explain the delayed kick off for this policy. Compulsory licensing and water tariffs management transaction costs show an almost uniform trend with minimal variation over the three time periods. The transaction costs do not smoothen out over time and we link this to current flawed implementation.

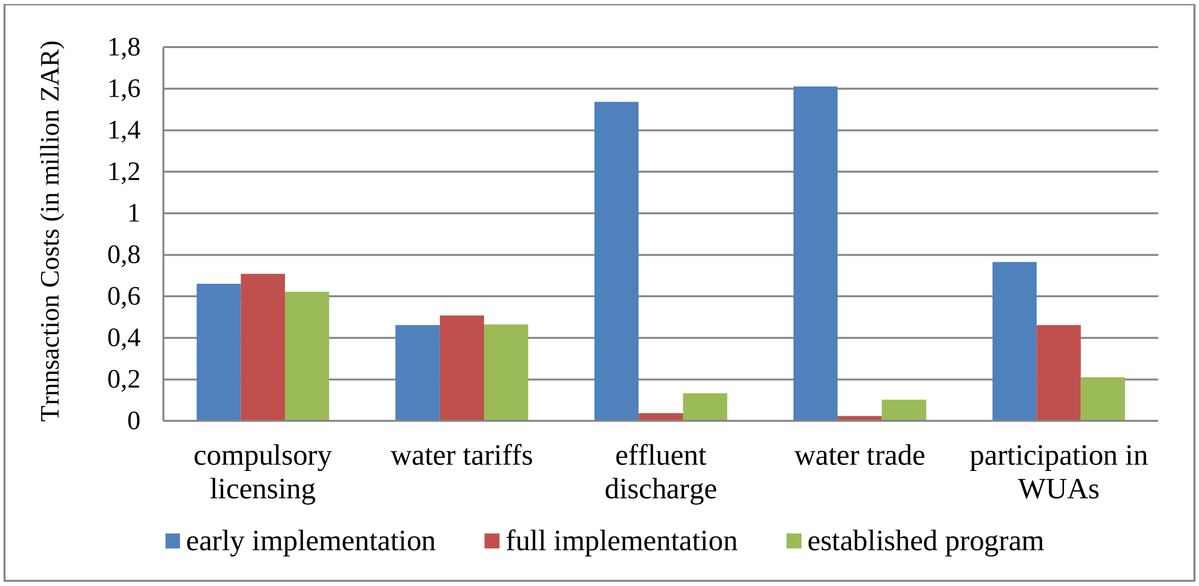


Figure 2.8: Water management transaction costs across policy and time

Source: Own compilation

The DWAF water budgets and financial accounts on the other hand were used to assess water policy transaction costs in relation to total water budget costs. The budgets did not indicate transaction costs for each individual policy but total costs for outlined activities of water management in the South African water sector. Therefore, the total policy transaction costs obtained from the budgets comprised of administration costs and water sector regulation costs. Water sector regulation costs consisted of compliance monitoring, enforcement costs and general resource regulation and support. The total transaction costs were compared to the total water budget costs as depicted in Figure 2.9.

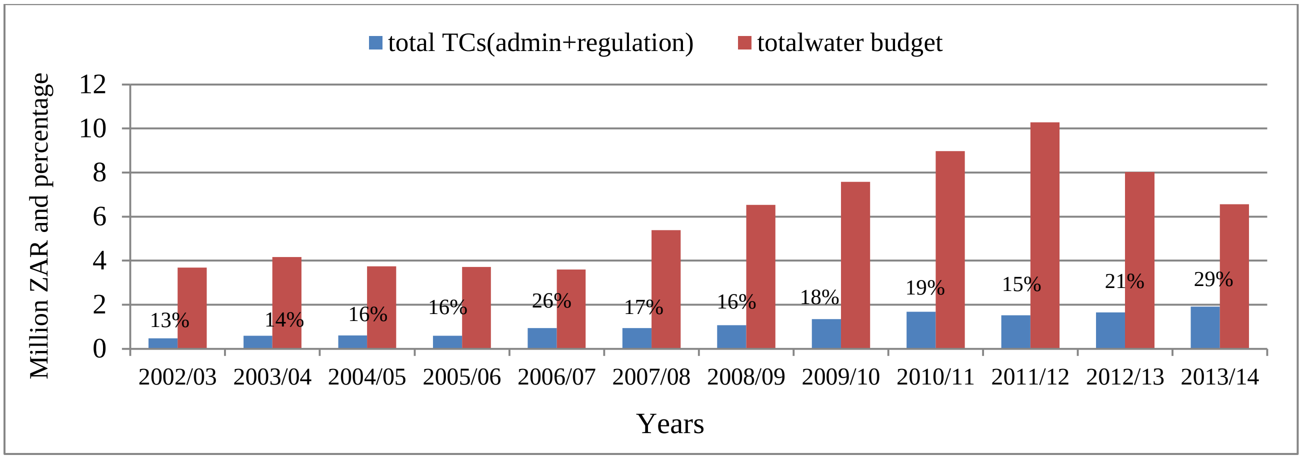


Figure 2.9: Water policy transaction costs proportionate to the water budget over a 10-year period

Source: Own compilation

Figure 2.9 shows that the total transaction costs were considerable and varied between 13 and 29 percent of total water budget costs over the ten year period examined. Similar findings were reported by Ofei-Mensah & Bennett., (2013), Pannell et al., (2013), Falconer., (2000), Falconer & Saunders., (2002), Colby, (1990) who all suggest that transaction costs formed a significant part of total environmental policy costs.

2.5.3 Transaction Benefits of water Policy

In an attempt to balance the TCE view on transactions, this study highlights the possible transaction benefits associated with water policy reform in South Africa (Table 2.5). Unfortunately, we envisaged the transaction benefits component post the time of fieldwork hence not empirically measured. Nevertheless, this list of possible benefits could be a good starting point for broader future research on transaction benefits in water management.

Table 2.5: Possible transaction benefits of water policy reform in the Olifants

Private Benefits		**Social Benefits**	
Water users	**Water managers**	**Community**	**Government body**
Skills development (negociation, bargaining)	Skills development/knowledge	Infrastructure development	Cumulative learning
Networking	Reputation	General policy awareness	Efficient internal communication network
Built capacity	Intellectual challenge	Information sharing	Enhanced competence
	Enhanced self esteem		

Adopted from (Blomqvist et al., 2002)

Synonymous to transaction costs, Table 2.5 shows that transactions also have benefits (Boudreau et al., 2007). The anticipated direct benefits of water policy in South Africa resonate with water use efficiency, equity, and sustainability. In addition, there are private and social transaction benefits stemming from the water policy implementation and compliance processes. In order for water policy reforms to work, there is prior establishment of certain investments in the form of human and physical capital to facilitate policy implementation and compliance. This results in additional hidden benefits to the relevant stakeholders and community at large. Water users become better negotiators to contracts; they network more in the transaction processes and build their capacity. Water managers develop their skills in their working environment, intellectual challenges and probably enhance their self-esteems. The community benefits from infrastructure development and rehabilitation such as roads and canals. The community also gains from public notices, hearings, information sharing and can be said to be more empowered. The government bodies responsible for water policy implementation on the other hand benefit from cumulative learning in the organizations, better internal communication, and improved competence in water service delivery.

2.5.4 Determinats of Transaction Costs among irrigation water users: OLS results

This section discusses results of the OLS regression presented in Table 2.6. The results showed that various factors significantly influenced the magnitude of transaction costs incurred by irrigation farmers. The model fitted the data well – with p-value = 0.0000 for the F statistic. We tested for multicollinearity using the *vif test* and from the correlation matrix, explanatory variables with correlation coefficients of greater than 0.5 were dropped. All variables included in the final model did not show evidence of multicolinearity. In addition, the regression model was approximated using heteroskedastic-consistent-standard error estimators.

Table 2.6: Determinants of transaction costs in the Olifants basin: OLS results

Variable	Coefficient	Standard error	P-value
WUA-membership(1=yes,0=no)	3064.79***	402.84	0.000
Compulsory Licensing (1=yes,0=no)	363.33	1045.28	0.729
Region- Middle Olifants	3031.50	1063.60	0.339
Region- Lower Olifants	-879.38***	917.67	0.005
Leadership in WUA(1=yes, 0=no)	-1130.65	1046.46	0.282
Gender(1=male, 0=female)	118.78	288.15	0.681
Years of schooling	-40.42	30.30	0.184
Main occupation-small scale	-2063.51***	708.87	0.004
Main occupation-other	-2197.20**	872.09	0.013
Farming years	-9.242	12.75	0.470
Farm size- natural log of farm size	2.29	1.94	0.246
Land claims (1=yes,0=no)	84.04	754.77	0.911
Income- ln income	-56.32	68.46	0.412
Technical assistance (1=DWAF,0=others)	602.42	469.92	0.202
ICT tool	-900.57**	344.38	0.010
Water cost- ln water cost	226.10***	73.26	0.002
Water quality-acceptable	-824.49**	398.22	0.040
Water quality-tolerable	-633.87	436.62	0.149
Water quality-unacceptable	-39.75	603.02	0.949
Market distance	-5.34	4.16	0.201
Constant	2560.05*	1313.85	0.053
N=179	R^2 =0.815		P=0.000

Source: Own compilation

Results from the OLS regression (Table 2.6) indicate that several factors significantly determine transaction costs incurred by irrigation water users. Firstly, the results show that irrigation water users involved in WUAs were likely to incur higher transaction costs than non members. Farmers who complied to water pricing were also likely to incur higher transaction costs than those who did not. This suggested that compliance to water policy is indeed underlied by transcation costs. The results further showed that farmers from the lower Olifants region were likely to incur significantly lower transaction costs compared to farmers from the upper Olifants region. We posit that farmers in the lower Olifants region did not actively participate in the water policy process due to the subsistence nature of their farming. They, therefore, incurred lower transaction costs compared to their upper Olifants counterparts who were mainly largescale farmers. The results further suggest that small scale farmers and people with other occupations outside farming faced lower transaction costs compared to the large scale farmers. This result implied that this category of farmers was less likely to participate in irrigation water use activities therefore less transaction costs of policy compliance.

Results further show that irrigation water users who obtained their policy information via ICT related means such as radio, televisions, phones and emails incurred less transaction costs compared to non users. This was in line with recent developments which portray the potential of ICT in decreasing transaction costs (Singh, 2008; Okello, 2011; Aker, 2010; Silva et al., n.d.;Jensen, 2007; Aker, 2008). ICT eases the communication of knowledge and information resulting in decreased bounded rationality and transaction costs. The water quality categories used in the regression were as perceived by farmers following the definitions by DWAF (i.e. '*ideal(good)', 'acceptable (moderate)', 'tolerable (bad)'* and *'unacceptable (very bad)'*. The results indicate that irrigation farmers who used water of acceptable quality were likely to incur lower transaction costs compared to farmers who used water of ideal quality (base group). We argue that recipients (users) of acceptable water quality lacked the incentive to comply to water policies and therefore incurred lower transaction costs unlike the users of ideal water quality. A secure water supply with guaranteed quality would encourage irrigation investment and compliance to proposed water policies. We liken water rights to land rights and as Shah, (2002) suggests, insecure property rights are associated with less farm investments because they limit farmer incentives for development. More secure water rights such as guaranteed irrigation water of good quality (ideal) is therefore likely to spur more farm investment including proposed government water policies; this would act as a powerful instrument for fostering compliance to water policy.

2.6 Conclusions and policy recommendations

Following McCann & Easter, (2004); and McCann et al., (2005), this study identified and quantified the ex post transaction costs related to the water policy process in the Olifants basin of South Africa. The study focussed on irrigation water users' and public agents transaction costs. The results indicated that sizeable amounts of transaction costs were incurred by the two groups of stakeholders. Transaction costs formed between 13 to 29 percent of the total water policy budget. The public agents' transaction costs remained higher than that of water users. This could be explained by the high support and administration costs which minimally varied over the three time phases of policy implementation. Transaction costs were high for the widely implemented policies but they fairly decreased in the course of policy implementation. The transaction costs incurred by irrigation water users mainly comprised of travel, telephone, additional information costs, finance and decision costs .Very high start-up transaction costs were associated with the implementation of water trade; a policy that is currently not in operation in the Olifants. High start up transaction costs were also associated with the effluent discharge system; a policy which is also yet to kick off. We conclude that different levels of transaction costs for the different water policies existed and could be contributing factors to inefficient policy implementation and compliance. In addition, knowledge of the relevant and existing transaction costs prior to policy implementation ensures optimality in the choices made . Moreover, it helps to make comparisons between policy alternatives and nurture effective design and implementation ex ante. It further permits evaluation of existing policies ex post for improvement purposes, and assessment of their budgetary impact to establish their sustainability and efficiency. The study further highlights possible transaction benefits of the water policy reform and recommends a more empirical approach in order to gain a deeper understanding of transaction benefits.

The study results further show that different factors significantly explained transaction costs. These can act as policy indicators towards better transaction costs management. Specifically, the significant negative effect of ICT tools used to acquire policy information for water management shows how ICT can save on information gathering costs. Additional empirical research would also deepen the understanding of determinants of transaction costs and help to establish a more general theory on the matter. It would further aid future predictions of the interactions between factors; especially on the direction, they influence transaction costs.

Box 2.1: Assessing the timeliness and cost of mobile phone use in water management

Presence of transaction costs inhibits any policy process. Easter et al., (1999) suggest that transaction costs can be reduced through proper institutional and organizational arrangements in addition to flexible infrastructure and management. However, this process of institutional and organizational arrangements is associated with high transaction costs. This study postulates that Information and Communication Technology (ICT) can reduce transaction costs experienced in water management. This is in line with recent innovations which indicate that ICT provides great potential in reducing transaction costs in many different fields (Singh, 2008; Okello, 2011; Aker, 2010; Silva et al., n.d.;Jensen, 2007; Aker, 2008). Specifically ICT makes easier the communication of knowledge and information, delivery of information and training at low costs, improving access to markets and credit, empowerment of farmers to negotiate better prices and facilitating or strengthening networking (Okello, 2011). In the agricultural sector, several studies have attributed benefits such as better prices, reduction in price dispersions and improvement in margins due to reduction in transaction costs arising from ICT use (Aker, 2008, 2010; Silva et al., n.d.; Jensen, 2007). Nevertheless, the ICT potential to reduce transaction costs in water management remains untapped. Lack of communication and feedback pertaining to water management between stakeholders is indeed identified as one of the biggest drawbacks to water management (Kay, 2011; Lévite et al., 2003). Unlike the previous studies which mainly focus on small-scale farmer access to input and output market information, the current work attempts to fill a unique gap by assessing the potential role ICT could play in water management and policy.

ICT has been defined as a" wide range of computerized technologies that enable communication and electronic capturing, processing and transmission of information such as computers, mobile telephony, radio, television, teletext, internet and fax (Cohen-Blankshtain et al., 2004). ICTs have become more available, much cheaper, and more affordable even in rural areas. They have developed and become ubiquitous and relevant in agricultural innovation systems. Expanded telecommunications networks, have led to speedy, reliable, and accurate information exchange through both text and voice (Porcari, 2009). Specifically, mobile phone penetration in the rural areas of developing countries creates opportunities for farmers to connect with extension workers, agribusiness, researchers, and each other (Ballantyne et al., 2010). ICTs can be tapped to effectively empower rural communities such as farmers "gain a voice" so that they can express their needs and demands, negotiate better deals with other actors in value chains, and generally get practical benefits from the services intended for them (Fara, 2009). Some of the ICTs integrated into rural advisory and information services are radio, television, video, internet, and mobile phone services (SMS and voice).

The information relayed through ICTs is increasingly becoming diverse from climate change mitigation and adaptation, disaster management, early warning of drought, floods and diseases, price information, political empowerment, natural resource management, production efficiency, and market access (ibid). ICTs also create an opportunity for farmers to relay their experiences with experts (IICD 2006).

Narrowing down to mobile phone technology, recent indications show that phones have created opportunities for crowd sourcing among farmers. Instead of performing data collection through paper surveys, researchers can collect data through SMS or voice calls (Hoffmann, 2008). For example, data on pest outbreaks is obtainable by asking farmers to text information to a premium number. Crowd sourcing has eased monitoring of farming activities and local problems, and enhanced prediction of challenges with greater certainty at the local, national, regional, and global levels in cost effective way (Balaji, 2009). Asking farmers to send information or relevant questions via mobile phone is an effective way of data collection and feedback communication at reduced costs and labor. It also allows increased participation from diverse stakeholders in areas where mobile phones are widespread.

The previous chapter identified and quantified transaction costs related to water management incurred by both water managers and irrigation water users. We find a significant negative relationship between ICT tools (radio, TV, mobile phone and email) used for water management purposes and the incurred transaction costs. In this sub chapter, we conduct a trial experiment, and use mobile phones for crowd sourcing water management information. Specific focus was on transaction costs of communication. We set up a 'local community-oriented experimental project' that involved the use of mobile phones to communicate various aspects of water management between water managers and irrigation water users. Some of these aspects included problems of access to water, restricted water quantity, poor water quality, irregular water distribution, and administrative delays. Previously, many irrigation water users in the study area have had to wait for days, weeks, months, or years for assistance from extension workers, water managers, or other technical personnel. For example, water quality monitoring information rarely reaches the water users. Therefore, the 'project experiment' aimed at determining the timeliness and cost effectiveness of mobile phones use in communicating water management information.

The 'project experiment' involved 38 randomly selected irrigation water users from the Olifants basin who were already using mobile phones but for other purposes. A shortcoming of this 'project experiment' was the short time period of implementation of two months attributable to shortage of resources. This limited observation of the full cycle of communication between irrigation water users and water managers. The experiment also lacked participants from the middle Olifants sub basin stemming from lack of cooperation. The next section outlines the steps followed for the experiment.

Steps:

1. The local community and the water managers helped to develop a list of actual water management concerns.
   a. Water users enumerated the actual water management concerns that they experienced in the course of their water use activities. These included water access, quality, distribution, administrative delays, pollution, blockage of irrigation canals, *et cetera*.
   b. Water managers and other technical personnel itemized some of the common concerns they addressed regularly in the basin.
2. The channel and cost of communication was then established:
   a. The water users enumerated ways in which they communicated their issues of concern to the managers and technical personnel. These included how they passed information, time taken to pass the information, the cost involved in communicating the water management concerns, as well as time taken to have the issue addressed/resolved
   b. Water managers and the relevant technical personnel indicated ways in which they responded to the information in 2 (a) above.
3. A platform that enabled farmers to interact directly with distant water managers, technicians, and experts through mobile phones was established through the following steps:
   a. A direct line "hotline" to the water managers was available to the farmers; through which, they could reach the managers promptly in case of need (there were three different hotlines for the three sub basins).
   b. Additionally, farmers received airtime facilitation that enabled them to send/call the hotline in time of need.
   c. Water managers helped recruit an assistant who managed the "hotline" for the entire project trial period of two months. His responsibilities were to receive, record, and channel the information/questions/concerns raised by the water users to the respective water managers.
   d. The assistant would then monitor the duration of response/feedback to the water users, or time taken to address the concern, together with the respective costs.

Results

Table 2.7 shows the issues of concern in irrigation water management as enumerated by water managers and irrigation farmers through Focus Group Discussions (FGDs) in three parts (upper, middle, and lower) of the Olifants basin. We observed that high water costs were a concern only in the lower Olifants while inadequate water supply was a concern in the upper and lower Olifants. Other issues of concern that were raised included poor water quality, water restrictions in dry periods, poor water distribution, expensive irrigation equipment and maintenance costs and limited canal capacities. The modes of communication of the identified issues to the responsible personnel included visits to DWAF offices, visits to the municipal offices, visits to WUA staff and limited mobile communication. The maximum number of days taken to get the water managers attention on an issue as indicated in Table 2.7 was 12 days while the average number of days required to communicate an issue to the managers was 3 days. Communication costs in this regard ranged from ZAR 0 to ZAR 1000 and on average ZAR 297.

On the other hand, using the mobile phone for communication between irrigation water users and managers as depicted in Table 2.8 shows that the minimum time required to pass information was 0.2 minutes while the maximum was 5 minutes. Averagely, the time required passing information between water users and managers using the mobile phone was 1.75 minutes. With regard to costs of mobile phone communication, we find that the costs ranged from ZAR 0.8 to ZAR 11 while the average cost of communication was approximately ZAR 4.

Table 2.7: Water concerns outlined by water use stakeholders in the Olifants basin

Region	Concerns	Reported to	Communication channel	Time taken	How many	Cost in ZAR	Time to address issue
Upper (Loskop)	High water costs	Not reported	-	-	0	0	0
	Inadequate water supply	WUA	Mobile phone voice, email	Minutes	2	10	3 months
	Poor water quality	Water manager	Visit DWAF offices, email, meetings	Days	2	1000	Many years
	Water restrictions	WUA	Mobile phone text/SMS	Minutes	5	10	7 days
	Limited canal capacity, lack of treatment from municipalities	Water manager	Visit DWAF offices	Days	1	1000	Not yet addressed
Lower (Tzaneen)	High water costs	Water manager	Visit DWAF offices	Days	1	200	Many days
	Operation/maintenance costs	Water manager	Visit DWAF offices	Days	12	600	Not yet addressed
	Inadequate water supply	Water manager	Visit DWAF offices	Days	12	700	Many days
Lower (Giyani)	High water costs	Municipality	Visit municipal	Days	2	112	Not yet addressed
	Expensive equipment	Municipality	Visit municipal	Days	2	112	Not yet addressed
	Operation/maintenance costs	Municipality	Visit municipal	Days	2	112	Not yet addressed
	Inadequate water supply	Municipality	Visit municipal	Days	2	112	Not yet addressed
	Poor water quality	Municipality	Visit municipal	Days	2	112	Not yet addressed
	Water restrictions	Municipality	Visit municipal	Days	2	112	Not yet addressed
Lower (Nelspruit)	High water costs	WUA group committee	Visit t WUA staff	Days	7	1000	Many days
	Inadequate water supply	WUA group committee	Mobile phone voice, visit WUA staff	Days	2	100	30 days
	Poor water distribution	WUA group committee	Mobile phone voice, visit WUA staff	Days	3	150	Not yet addressed
	Poor water quality	WUA group committee	Mobile phone voice, visit WUA staff	Days	1	80	1 year
	Water restrictions	WUA group committee	Mobile phone voice, visit WUA staff	Days	2	120	3 months

Source: Own compilation

Table 2.8: Duration and cost of different modes of communication of water management information

	Minimum	Maximum	Mean	Std. Deviation
Other means of communication				
Duration of communication (Days)	0	12	3.26	3.43
Cost of communication (ZAR)	0	1000	296.95	360.82
Communication with mobile experiment				
Duration of communication (Minutes)	0.2	5.0	1.75	1.45
Cost of communication (ZAR)	0.8	11.0	3.99	3.03

Source: Own compilation

Conclusions

This study examined communication costs as part of transaction costs incurred in communicating water management concerns between irrigation water users and water managers. We elicited the water related issues of concern faced by water users through FGDs, the mode of communication to water managers, and the respective costs of communication incurred. Secondly, we conducted a trial experiment involving the use of mobile phones to create a platform for communication and interaction between water users and managers; this examined the timeliness and cost effectiveness of using mobile phones as ICT tools for water management. We found that, mobile phones were faster and cheaper, averaging at 1.75 minutes for time and ZAR 4 in terms of costs to communicate to water managers. This was in comparison to the usual communication channels farmers used which averaged to 3 days and ZAR 297 required for communication with water managers. We conclude that, ICTs and in particular, mobile phones stand a chance to play an important role in water management. We recommend upscaling of such an experiment in terms of duration and number of participants in order to draw basin wide recommendations.

Chapter Three

3. The effects of water policy on irrigation water use in the Olifants

3.1 Introduction

Water is a critical resource for economic advancement, yet commitment to enforce the essential policy and institutional reforms for its management is lacking (Duda & El-Ashry, 2000). This translates into non-optimality and unsustainable use. Water management presently faces completely different challenges in comparison to five decades ago. These include acute water scarcities, changes in climate, environmental restoration, energy policy, rising populations, agricultural transformations, urbanization, migration, changes in dietary preferences, lack of institutions and improper water management (Duda & El-Ashry, 2000; Dungumaro & Madulu, 2003; Jaspers, 2003; de Fraiture et al., 2010). These challenges have led to agricultural water expansion which endangers the resource base upon which many other sectors are dependent (Duda & El-Ashry, 2000). Consequently, there is urgent need to take action in terms of better approaches to land, water, and ecosystem management in an integrated approach.

In the presence of irrigation water management at the global level, land and water resources are sufficient to meet the world's food demands for the next fifty years (Duda & El-Ashry, 2000). However, water scarcity at the regional levels will constrain increases in agricultural production in the food prime producing areas (ibid). At present, around 900 million people are living in water scarce basins, 700 million in places where scarcity is almost evident while one billion others face economic challenges for water investments (Molden et al., 2007a; de Fraiture et al., 2010). Water scarcity is synonymous to Africa and a big barrier to development (Duda & El-Ashry, 2000). Some projections indicate that by the year 2025, a third of Africa's populations will be undergoing a water crisis. Therefore, effective water management policies are recommended (Bazzani, 2005). Research points to better institutions and policy reforms that consider the interconnectedness of land, water and ecosystem management over and above technological and infrastructural investments (Duda & El-Ashry, 2000; Dungumaro & Madulu, 2003; Jaspers, 2003).

Internationally, the current approach to effective water management is Integrated Water Resources Management (IWRM). The main objective of IWRM is sustainability in water resource management through multidisciplinary and interdisciplinary approaches to balance water demand between various users and uses (Bazzani, 2005; Dungumaro & Madulu, 2003). IWRM involves planning at a basin scale level, incorporating subsurface and surface water quantities and qualities, considering environmental integrity and the interactions between land use and water resources and not forgetting the natural constraints, social, economic, legal, political and administrative processes and demands (Jaspers, 2003). IWRM requires institutions to facilitate its multiple facets; for example, an administrative set up and a planning system for the river basin and their rules (Jaspers, 2003). In many countries, IWRM principles are usually implemented through some form of organization such as water shed authorities or cooperative coordination stemming from governments (Blomquist & Schlager, 2005). However, the IWRM concept is hard to attain and does not always result in successful management. In many instances, it results in social, economic and ecosystem compromises and tradeoffs between sectors, even for the developed nations (Duda & El-Ashry, 2000; Jønch-Clausen & Fugl, 2001). This is attributable to lack of coordination between sectors, disjointed approaches, political interference, and institutional obstacles in implementation (ibid). Jønch-Clausen & Fugl, (2001) suggests that, IWRM should be context specific following a country's stage of social and economic development rather than a universal blueprint for water management. Its enactment should mirror differences in local conditions for different countries accordingly taking on different forms. In the Southern Africa region for example, IWRM institutions seem to operate parallel to the already existing institutions (van der Zaag, 2005); this brings in competition and wastes institutional resources.

South Africa's National Water Act (NWA) lays great emphasis on IWRM through its current water laws which are underway in implementation (Kloos, 2010). The NWA is regarded as highly comprehensive and ambitious following countries like Australia and USA (Kapfudzaruwa & Sowman, 2009). However, just like in many other countries, South Africa faces a knowledge gap between the theory and implementation of IWRM principles (Jewitt, 2002). This is evidenced by the persistent challenges in the water sector contrary to the envisioned water reform objectives of equity, efficiency and sustainability (Enright, 2011). Evidence from other African countries further suggests that IWRM principles have not been successful and water laws remain largely non-enforced, stagnant, or failed (ibid). This could be due to failure of reforms to address current water priorities, limited spread in water basins, not being based on existing practices, having stakes among the elite, and a top down donor style approach (Shah & Koppen, 2006). In countries with high levels of income inequalities like South Africa, IWRM only seems to work for the rich modernized sections of the economy while the poor continue to be worse off (ibid). However, little empirical evidence exists in this regard and the current study seeks to contribute to literature by examining the effects of the current water laws on irrigation water use – quantities, quality, and efficiency. Firstly, this study gives an overview of the current institutional organization of the water sector in South Africa in section 3.2, and describes some of the stipulated IWRM policies in the 1998 Water Act in section 3.3. Section 3.4 describes the conceptual and empirical frameworks while 3.5 gives the results and discussions. Section 3.6 presents the conclusions.

3.2 Current institutional organization in the South African water sector: an overview

Prior to the year 1994, many policies in South Africa skewed towards provision and protection of only a few minorities, disregarding the needs of the majority black population. Accordingly, water use rights were based on the riparian system which linked use of water to ownership of adjacent riparian land (Kloos, 2010; Thompson et al., 2001; Backeberg, 2005). This was not equitable since 87 percent of South African land belonged to the white population who had unrestricted access to water (ibid). Discrimination reigned in water services provision as the administrators of water at irrigation boards remained biased towards the whites' population needs (Perret, 2002). This became ground for protest against the apartheid regime during the 1980's (Kloos, 2010). With the political changes of 1994, democracy came into being with emphasis on social justice and fundamental human rights such as rights to water (Thompson et al., 2001). The reform process in the water sector resulted in various changes such as; the water supply and sanitation policy (DWAF 1994), enactment of water services act (RSA,1997), white paper on national water policy (DWAF 1997b), the National Water Act (RSA 1998) and the pricing strategy for raw water use charges (DWAF 1999; Kloos, 2010 ; Backeberg, 2005).

The 1998 National Water Act (NWA) recognizes water as a scarce resource belonging to the people and aims to protect, use, develop, conserve, manage, and control water resources as a whole. The four main objectives of the Act are social equity, ecological sustainability, financial sustainability and economic efficiency (Kloos, 2010). The Act puts emphasis on an integrated approach to water management by promoting participation in decision making from the relevant stakeholders (ibid). The Act further categorizes water management under different institutions at the national, regional and local levels (Perret, 2002). In terms of water allocation, the Act gives priority to the ecological reserve and the human basic water needs (Jean de la Harpe, n.d.;Gazette, 1998). Furthermore, the Act acknowledges the importance of IWRM strategies such as water licensing, water pricing, and water trade.

The national, regional and local framework for water management outlines the responsible institutions and their respective roles targeted at fulfilling the goals of the water Act (Perret, 2002;Jean de la Harpe, n.d.;Gazette, 1998). At the national level as depicted in Figure 3.1, the minister in-charge of water affairs and forestry is recognized as the overall custodian of water resources on behalf of the country (Pienaar, 2007). The minister has the responsibility of ensuring protection, use, development, conservation, and sustainable control of water resources. This is for the benefit of all while also ensuring equitable and beneficial allocation of water for the public interest and promoting environmental values. The Act further allows the minister to delegate his or her duties to departmental staffs, water management institutions, advisory committees, and water boards. The minister's powers – as outlined in the Act – are delegation, expropriation, he acts as a CMA where there is none and assigns powers to CMAs (Harpe & Ramsden, 1999). Presently, the DWAF is responsible for overseeing all aspects of the water Act on the minister's behalf (ibid). However, in the long run, the DWAF will delegate most roles to water management institutions such as CMAs as they continue to be formed while it retains the role of policy formation and general regulation over the smaller institutions (Harpe & Ramsden, 1999).

The government implements its functions through water management strategies. The National Water Resource Strategy (NWRS) of 2002 is the channel through which implementation of water reform currently takes place (Kloos, 2010). The NWRS provides a framework for water use and control for the entire country, and at the regional and local levels within the 19 Water Management Areas (WMA) in the country. It enables proper water management by classifying water related development opportunities, constraints and giving information on all aspects of water resource management (Harpe & Ramsden, 1999). It is the responsibility of the minister of water affairs and forestry to ensure the existence of a functional NWRS. The NWRS is reviewed every 5 years and stems from public consultation; it contains objectives for institutions undertaking water resource management and the inter relationships between these institutions. The strategy is binding for all water users and institutions.

At the regional level (Figure 3.1), the water governing bodies are the Catchment Management Agencies (CMAs) established in each of the 19 Water Management Areas (WMA) in the country. A CMA is a statutory body instituted by a government notice and has a governing board appointed by the minister. The board comprises of all the stakeholders; both current and potential and their stakes in the respective WMA (Harpe & Ramsden, 1999). CMA's are organs through which the minister acting through DWAF is supposed to delegate water management activities at the catchment level (ibid). CMAs have the responsibility of developing and implementing the Catchment Management Strategies (CMS) consistent with the NWRS. The CMAs are envisioned to set principles for water allocation to users, provide a framework for water management in a WMA and ensure sustainable use of water resources in line with the Act, CMS and NWRS (Perret, 2002). CMA's envisage the involvement of the local communities and emphasize on cooperation with enough representation among stakeholders especially the marginalized populations. The water Act stipulates that CMAs formation originate from the community or by the water minister depending on a region's needs. In regions where a CMA is nonexistent, the regional DWAF office acts as the CMA. The water Act tasks CMA's with the responsibility of water licensing if already in existence and if not; this remains a responsibility of DWAF. The minister has the power to assign additional functions to a CMA whereby, if fulfilled, the additional functions become the CMA's permanent responsibility. These additional functions may include but not limited to being the responsible authority over water use and allocation and general management of water resources in the WMA, (Harpe & Ramsden, 1999).

At present, several years after the promulgation of the 1998 water Act, only two CMAs are so far in existence out of a possible 19 that were planned for the entire country (Bourblanc & Blanchon, 2013). The slow implementation is attributable to power struggles between DWAF and the CMAs, as well as construction of inter-basin transfers, which have been in existence since the apartheid regime. Inter basin transfers (IBT) inhibit cooperation of stakeholders due to different interests driven by differences in economic activities. Other possible challenges arise from poor administration, poor management, and lack of capacity for personnel, which leads to frustration, inadequacy, and poor cooperation between institutions. Currently, the CMAs have been reduced in number from the possible 19 to 9 for easier management especially in monitoring performance (Bourblanc & Blanchon, 2013).

At the third and local level are Water User Associations (WUAs) (Figure 3.1). A WUA is defined as a statutory body established by the minister and comprises of individual water users coming together to carry out water related activities for mutual benefit (Harpe & Ramsden, 1999) . A WUA allows people to pool their resources together such as finances and expertise in performing their water related activities. Management Committees (MC), govern WUAs, which may represent a single sector or different sectors. A single sector WUA comprises of similar water users such as emerging farmers, and acts in their interests. A multi sector WUA comprises of different types of water users such as industry, miners, and farmers to act in their interests. The water Act envisages that all existing irrigation boards, boards for stock watering and control boards be converted to WUAs and probably extend areas of their authority (Harpe & Ramsden, 1999).

WUAs provide a means through which implementation of CMS takes effect and have a role to play in poverty alleviation and food security issues. The functions of any WUA depend on the purpose for which it was established. This may range from maintenance of water works, prevention of water wastage and unlawful use, regulation of flow of the water course, investigation on water quality, general supervision of the water resources and management of water use in various activities such as irrigation, afforestation and recreation activities (Jean de la Harpe, n.d.;Gazette, 1998). The respective CMA or the minister supervises and regulates the activities of the WUAs, which is preferred than dealing with individual farmers. Presently, the water law is under review and WUAs face disbandment to form one regional body for water management (Marius Classen; Backerberg, 2014). We explain more on WUAs in the upcoming sections.

The water Act further makes several other provisions on various issues such as international water management, offences and remedies, government waterworks and advisories. The Act empowers the minister to set up advisory committees as he finds fit for different purposes and functions. For example, an advisory committee to determine the governing board of a CMA. The advisory committees remain answerable to the minister. The Act further allows establishment of bodies responsible for entering into international agreements for management of water resources shared with neighboring countries. The water minister is responsible for the powers of these bodies, their duties, and their governance in consultation with the cabinet.

Additionally, besides water management, the Act provides for the government to construct, own, or purchase water works for public interest. Just as the government apportions water from the resource, it does the same from its dams at a certain cost in accordance with the national water pricing strategy for the purposes of cost recovery. Eventually, the aim of the DWAF is to focus on policymaking, supervisions, and handover any infrastructural works to water management institutions such as the WUAs. The Act further provides for safety measures of dams as a way to protect the environment and the people. The Act classifies dams that pose a safety risk and through the DWAF, monitors, controls and maintains dam establishment. The Act further requires that a monitoring and information base be set up with regard to all aspects of water resources such as quantity, quality, water use, rehabilitation of resources and aquatic health. The Act deems this information base necessary for the purposes of planning, disaster management, public safety, and ensuring people's constitutional rights of access to state information. Importantly, the water Act provides for the creation of an independent water tribunal whereby water users can appeal against certain decisions of water management institutions such as CMAs. These decisions may regard water costs, water allocation schedules, license applications, verification of existing lawful use and compensation. The tribunal's jurisdiction is countrywide and it receives its funding from the national treasury. However, the tribunal's procedural rules require approval from the minister before publication in the government gazette. In case, a water user is not content with the tribunals ruling, they make an appeal at a high court. The water Act further lists all the water resource related offences and their penalties that a water user faces in case of contravention. The offences might be either activities or omissions, e.g. unlawfully interfering with a water work or failure to register lawful water use respectively. The Act further gives the courts and management institutions the powers to solve arising offences or omissions in addition to provision of compensation for damages to aggrieved parties (Harpe & Ramsden, 1999).

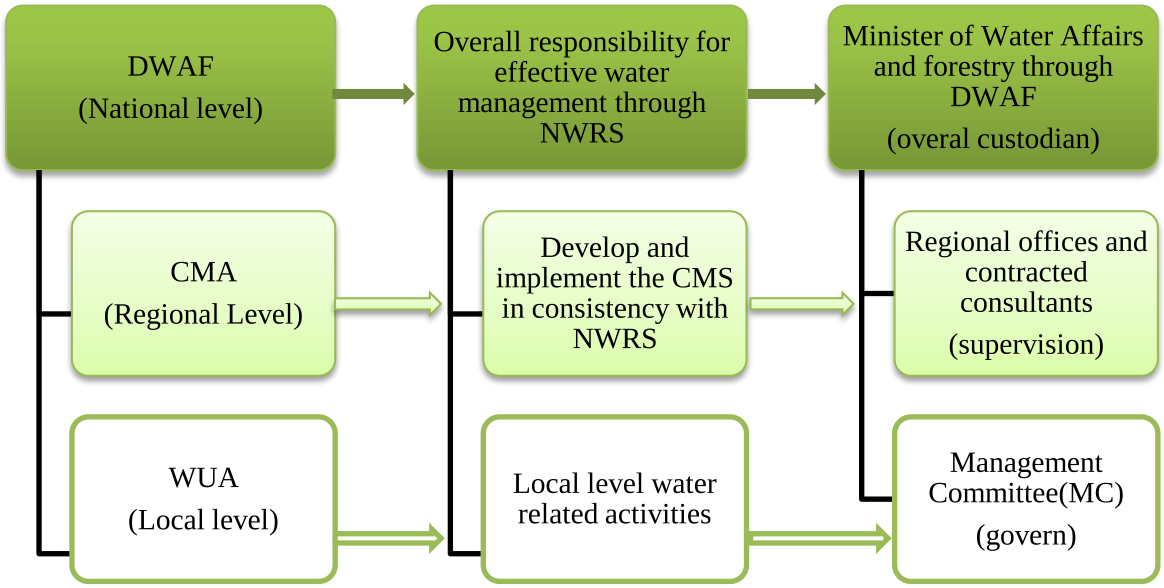


Figure 3.1: Current institutional organization of the South Africa water sector

Source: (Harpe & Ramsden, 1999)

3.3 Overview of some IWRM policies in the South African National Water Act

3.3.1 Water Pricing

As one of the strategies for IWRM, many governments are now treating water as an economic good; opting for water pricing in an attempt to streamline water management (Jaspers, 2003). Water pricing as an economic instrument promotes sustainable water use and fosters water cost recovery in water management (Bazzani, 2005). This is by creating opportunity costs to water use and covering the costs of water provision by governments (ibid). There exist many proponents and opponents of water pricing as a water management policy. This is because water remains a complex good with many social attributes. For example, in some cultures such as Islam, payment for water is not well accepted (Jaspers, 2003). However, many stakeholders agree that water pricing is necessary to manage water demand and pollution control. It's no doubt that water pricing introduces the aspect of water scarcity to users hence more efficient use (Shah & Koppen, 2006). Proponents of water pricing argue that it is no longer effective to depend on government budget allocations for river basin management due to political interference. Additionally, government allocations are less likely to encourage any development and efficient accountability at the basin scale level (ibid). Water pricing, is therefore seen as an operative instrument to minimize over abstraction of water and maintain water quality.

Though necessary for economic sustainability, water pricing is not popular or as successful for many countries due to the complexities of river basin management (Bazzani, 2005). For example, as much as water pricing is regarded a good instrument to foster water use efficiency, Speelman et al., (2009) suggest that it's not promising and suitable for the poor small scale farmers who cannot afford. Water charges reduce farm profits hence incomes and might affect overall rural development (Tardieu & Préfol, 2002; Speelman et al., 2009). Other problems that could arise include declined overall agricultural production for a country, higher prices for urban consumers and increased imports (ibid). Berbel & Gómez-Limón, (2000a) on the other hand note that water pricing, as a sole instrument is not appropriate to reduce irrigation water use. This is because irrigation water use in some instances only reduces at the water price level where farm income and agricultural employment are adversely affected.

Presently in South Africa, water tariffs are founded on full water use rights held by a water user per the planned irrigable land rather than the actual water used (Pott et al., 2009). This method of pricing does not foster water use efficiency unlike charges based on actual water use (ibid). However, it is usually preferred because it does not require metering for each individual water user and guarantees water managers of a constant income unlike actual water use. Actual water use implies varied returns from water use. A combined charge is however suggested as an option by Pott et al., (2009). Since the abolishment of the riparian rights system for water allocation and use, the water Act requires registration of all water users, followed by compulsory licensing then payment for use. However, the 1998 water Act still makes provisions for continuation of lawful water use in such a manner until a time when the water is eventually licensed.

The NWA stipulates that, the minister of water affairs through the minister of finance comes up with a water pricing strategy to calculate water use charges (Harpe & Ramsden, 1999). He further makes changes to the pricing strategy from time to time. The objectives of the pricing strategy are social equity, ecological sustainability, financial sustainability, and economic efficiency. It stipulates the how, when, who, and how much to pay for water. For example, it categorizes different water areas, water use types and water users to ensure equity through variation in pricing, it provides for refunds and waivers on charges for given users in an equitable manner, it encourages beneficial use of water, minimizes water wastage and pollution, and support municipalities in developing tariffs for water service provision (Harpe & Ramsden, 1999). The pricing strategy differentiates between types of water use by means of the technique of water abstraction, method of supply, how it is discharged, impact on the resource, water quality, and type of resource being utilized. Water users on the other hand, vary depending on the amount of water they use and that which they return to the resource plus their economic circumstances (ibid). The current water pricing strategy aims at cost recovery from water users and is planned at progressive increases over time (Backeberg, 2005). The recovery of costs targets the following:

a) Expenditure for water resource management; i.e. monitoring, water allocation and control, protection and conservation.

b) Expenditure for water resource development; these are the costs incurred in planning and design, constructions, and maintenance of water works.

c) Costs for efficient and equitable water distribution (Harpe & Ramsden, 1999).

The NWA envisions water pricing applied on actual volume of water used with the option of a combined fixed-variable charging system in consideration. The commercial farmers and government water schemes are foreseen to pay the full depreciation, operation and maintenance charges while emerging and subsistence farmers get subsidized for operation and maintenance (O&M) on a reducing scale over 5 years, after which depreciation costs will be phased in (Backeberg, 2006). Table 3.1 gives a summary of the different water costs applicable to different sectors as given in the 2007 water pricing strategy.

Table 3.1: Water costs and charges as proposed in the South African NWA

Sector	Resource management charges	Resource development charges	Phasing In on charges
Domestic/Industrial	Full cost recovery on abstraction and waste discharge related use	On-budget GWS: Depreciation; ROA: O&M • Off-budget GWS: CUC, Refurbishment, WRD and O&M • WMI's: Full cost recovery	WRM charges introduced fully after registration of water use in WMA • Waste discharge related WRM charges implemented after registration of waste users. • Annual increase on development charge will be limited to PPI + 10% until target development charge achieves on state funded GWS.
Stream flow reduction activities (commercial growers)	Full recovery of allocated costs Note: Cost of Dam Safety Control and waste discharge related costs not allocated to the forestry sector.	Not applicable, except where negotiated for new development.	WRM charges introduced fully after registration but capped to R10 per ha plus PPI with 2002/03 as base year
Stream flow reduction activities(resource poor growers)	Full recovery of allocated costs, achievement in 5 years Note: Cost of Dam Safety Control and waste discharge related costs not allocated to the forestry sector.	Not applicable, except where negotiated for new development	As above, but subsidized for 5 years from date of registration Subsidy starts at 100% and reduces by 20% annually. No charge for forest plantation that is <= 10 hectares.
Irrigation(commercial farmers)	Full recovery of allocated costs • Waste discharge related costs not applicable	GWS: • Full recovery of Depreciation plus O&M on existing schemes • Full financial cost recovery for new schemes WMI: • Full financial cost recovery	• Depreciation charge capped to 1.5 c/m^3 plus PPI from 2007/08. • WRM charge introduced fully after registration of water use in WMA, but capped to 1.5 c/m^3 plus PPI from 2007/08. • O&M cost increases limited to 50% p.a.
Irrigation(resource poor farmers)-schedule 1	As above, but subsidized for a 5-year period • Waste discharge related costs not applicable	GWS: • O&M subsidized for a 5-year period on existing and new schemes. • Depreciation charges waived for a 5-year period. WMIs: • Subsidies available under certain conditions	GWS: • O&M charges phased in over 5 years after registration at 20% per annum, 0% in the first year. • Depreciation charge applied from year 6 onwards and capped to 1.5 c/m^3 plus PPI from 2007/08. • WRM charges phased in over 5 years @ 20% per Annum, 0% in year one

Source: (Government Notices, DWAF, 2007).

GWS: Government Water Schemes, ROA: Return on Asset O&M: Operations and Maintenance, CUC: Capital Unit Charge, WRD: Water Resource Development, WMI: Water Management Institutions, WRM: Water Resource Management, WMA: Water Management Area, WMI: Water Management Institutions, PPI: Producer Price Index

Current water pricing scenario in the Olifants

Results from our focus group discussions indicated that there were discrepancies between what farmers were currently paying for water and the rates indicated by DWAF. The rates from DWAF seemed higher compared to what the farmers were currently paying. Large-scale farmers indicated that water prices were rising but they were not yet paying the increased DWAF tariffs. For example, in the year 2012/2013 the stipulated irrigation tariffs for the Olifants river (Loskop dam) region in Mpumalanga, Mooi river in Gauteng and Groot Letaba river (Tzaneen dam) in Limpopo were ZAR 3.0/m^3, ZAR 3.26/m^3 and ZAR 6.16/m^3 respectively (DWAF 2013/2012). Yet at the time of this study, farmers were still paying as low as ZAR 0.2 cents per m^3 of water used in irrigation in the respective areas. This suggested that the pricing policy lacked strictness and follow up in implementation. This could be due to weak structures/institutions and lack of capacity and resources as suggested by Coleman (2014). Water prices remained approved but not implemented; hence poor cost recovery. Additionally, there was evidence of a poor billing system, as some areas remained entirely unbilled.

The water quotas for the large-scale farmers on the other hand indicated some uniformity with DWAF stipulated water quotas. The irrigation boards reporting unique water quotas for their member farmers in accordance with DWAF regulations evidenced this. Examples of these water quotas and their respective irrigation boards included, Loskop irrigation board – 7700m^3 per ha per annum per farmer, Rust de winter irrigation board – 7000m^3, Hereford irrigation board – 6200m^3, Spekboom irrigation board – 10392m^3, and Blyde river irrigation board – 9900m^3. Currently, farmers in these boards paid for the entire allocated water quota whether one used the water quota or not; a cost that they indicated was not significantly high to influence their farm profits and production costs. The large-scale farmers paid their irrigation water costs on a six monthly basis. Table 3.2 indicates that all 46 commercial farmers interviewed were actively paying for their received water quotas. Twenty small-scale farmers were paying for their water use directly to DWAF while the remaining 117 of small-scale farmers incurred indirect costs of water abstraction. The small-scale water payments were inform of monthly payments for water pumping costs through generators, comprising of fuel costs and electricity costs used to draw water from the rivers and boreholes. The non-compliant category of water users in Table 3.2 represents interviewed irrigation and industrial water users that were not actively involved by way of (payment, participation) or using the stipulated water policies by DWAF.

Table 3.2: Farmer compliance to water policies in the Olifants

Water policy	Number of compliant water users	Large scale farmers	Small scale farmers	Industry/ mines	Non compliant
Water tariffs	81	46	20	15	117
Water Trade (non official)	16	12	4	0	-
WUAs	80	40	39	1	118
Compulsory Licensing	39	26	6	7	159
Effluent discharge	15	0	0	15	-

Source: Own compilation

3.3.2 Water trade

Water transfer and trade base on the premise that water transfers occur between users with low returns per unit of water used to users with much higher returns per unit of water used. In essence, water has an attached opportunity cost thus attracting conservation for both buyers and sellers (Gillitt et al., 2005). It is one way to re allocating scarce water resources (Nieuwoudt & Armitage, 2004). The pros of water transfer and trade include:

- enhances efficiency by promoting use of water for the highest returns per unit of use
- the transfer of water rights empowers water users by making them part of the decision with regard to any water re allocation and crop choices
- it enables water users to consider their opportunity costs of water use given the output prices they receive, hence encourage water conservation
- the properly defined and working water rights required for the proper functioning of a water market promotes investment due to security of water tenure (Nieuwoudt & Armitage, 2004; Pott et al., 2009).

The existence of a water market on the other hand requires a certain number of conditions fulfilled in order to operate effectively. These are:

- A very well defined and non-ambiguous rights system in terms of measurement, consistency, certainty and importance
- the rights have to be fully enforceable to secure benefits of the holders
- the rights should be separate from land and transferable
- the rights have to be constitutionally viable with surety in title of ownership and legally sanctionable water transfers
- a working government or administration to maintain the flow of titles over water rights (Nieuwoudt & Armitage, 2004).

The South African water Act through the NWRS foresees water distribution via markets with the aim of attaining equity in water use and water use efficiency. Water transfers could be both temporary or permanent allowing access to those who did not previously have, and the use of water for the most high value crops (Backeberg, 2005). Temporary transfer is stipulated for a period of one year with possibility of extension while permanent transfer involves selling of all or part of water rights between users (Gillitt et al., 2005). As outlined in literature, water trade requires rules in place such as prior water registration, licensing, or confirmation that existing water use is lawful to facilitate effective water exchanges. Existing lawful use implies that water has been in use for 2 years prior to initiation of the NWA. Water transfers in South Africa started taking place after the year 1994. Prior to this period, water transfers had failed due to high transaction costs arising from common property problems of the riparian system, lack of private decision makers due to institutional failures and bureaucratic procedures. Past this period, water trade took place in various catchments due to increased institutional reforms, drought conditions, better returns to high value crops in the markets and decentralization which helped to reduce the macro level transaction costs (Backeberg, 2005). However, the water transfers were limited to large-scale farming only in few selected basins. This called for a review of water trade between subsistence and commercial farmers, and inter sector and inter basin transfers. Water trade seemed promising since no additional demands were made on the water resource but rather the transfer of already existing rights (Backeberg, 2005).

The biggest problem with water trade is setting the rules and adhering to them to ensure a fully-fledged water market. Water trade in South Africa has remained limited to a few catchments due to inhibiting factors such as incomplete licensing. The compulsory licensing process is slowed by uncertainties of its outcomes, how to balance actual water use and reserve requirements, and the tension surrounding water and land reforms (Pott et al., 2009). South Africa stands a chance in using water trade to promote water use efficiency, when and if the bureaucratic nature of the process reduces while other water market requirements are in place (ibid). For example, Nieuwoudt & Armitage, (2004), studied two regions of South Africa and found that in the orange river basin, water trade was operational between farmers with low returns and those with highest returns per unit of water applied. On the other hand, water trade did not emerge for Nkwaleni valley of Kwa Zulu Natal despite it having similar water scarcity conditions. This was attributable to farmers (potential buyers and sellers) facing the same crop profitability in output markets hence, transaction costs of water trade outweighed the benefits for them.

At the time of this study, there were not many cases of water trade reported in the study region as indicated in Table 3.2. In the upper Olifants region for example, many of the farmers preferred to keep water in the dams as security rather than take part in water trade. Large-scale farmers interviewed regarded the trading process as bureaucratic, ambiguous, slow, and time consuming with many controls from the DWAF. Some termed the process as no longer existent and cited lack of cooperation from the DWAF. The few cases of water exchanges encountered were between family and friends.

3.3.3 Compulsory Licensing

There is increasing international recognition of the importance of water rights and the role they play in the effective management of scarce water resources (Speelman et al., 2010). This is because rights to property determine the value people attach to natural resources. For water resources, improperly designed water rights raises the transaction costs of water management decisions therefore inhibiting efficient water allocation and use. Clearly defined property rights result in people paying lower prices for their water use due to reduced transaction costs (Speelman et al., 2010). Water rights further foster government water cost recovery (ibid). Improving water rights is one way to address increasing water scarcity by fostering its productivity, increasing investments, and benefits from more investments in water supplies thus improving rural livelihoods (Speelman et al., 2010).

Speelman et al., (2010) suggest that the current water problems in South Africa lean more towards limited institutional capacities such as inadequate water rights rather than water scarcity. This has prompted efforts towards the right decisions, investments, and innovations in good time to curb existing water scarcities, as is already seen taking shape through implementation of policies outlined in the Water Act. The NWA lays emphasis on water re-allocation and the first step is through compulsory licensing. This is in order to achieve envisaged equity to all populations by addressing past inequities in water resource allocation and use (McCartney & Arranz, 2007). Compulsory licensing is a way of giving entitlement to water use and users in an attempt to move away from the previous riparian water use system. Compulsory licensing aims at achieving fairness in water allocation, improving efficiency in water use in the public interest, efficiency in water management, and protecting water quality. Therefore, a license gives new or existing water users formal authorization to use water for productive purposes (Harpe & Ramsden, 1999).

A license is definite to a given user, property and usage, valid for a number of years not exceeding 40 and has to be reviewed as often as every five years (Backeberg, 2005). The water Act stipulates that the licensing process should focus especially on the historically disadvantaged groups in order to meet the set objectives of equity in water allocation (Backeberg, 2005). Currently, source directed controls are in place as a way to control water use and reduce negative impacts associated with human water use (McCartney

& Arranz, 2007). Together with compulsory licensing, the water Act stipulates several other types of water use authorizations, namely:

- Schedule 1

  This is water use that has a small or minimal impact on the water resource and does not require licensing or registration e.g. domestic use, small gardening and rain water storage (Perret, 2002)

- General authorizations

  This is slightly larger withdrawal of water in comparison to schedule 1 type of water use; e.g., storing a limited amount of water in a dam. It has a minor or inconsequential impact on the water resource and allowable in less stressed water situations. It does not require licensing unless in water stressed circumstances; registration of the water is however necessary. General authorizations are allowable under certain bounds and conditions, and are valid for three to five years. Review of general authorizations takes place at intervals of not less than two years and is applicable to new water use post promulgation of the water Act.

- Water use licenses

  Water use licenses are required for much larger water use that does not fall under schedule 1 and general authorizations. Any license application usually undergoes evaluation for several factors such as existing lawful water use, past discrimination, time- frame for authorization, investments of the water user, foreseen impact on the water resource, and effect on other users. After successful evaluation, water users receive their water licenses outlining several conditions such as time for which the license is valid, which is usually up to 40 years. The authorities reserve the right to change license conditions in case of any changes in the water resource but in an equitable way: the time duration for the license however is not changed but can be reviewed and extended up to 5 additional years (Harpe & Ramsden, 1999). If one violates the license conditions, they receive a notice to make amendments of which failure to do so results in withdrawal of the license or the user faces prosecution. Compulsory licensing stems from the water minister issuing a gazette notice requiring all existing and potential water users (general authorizations and existing lawful users) to apply for water licenses. This is especially in stressed catchments experiencing water shortages and pollution.

- Continued lawful water use

  The water Act further provides for continued lawful water use without requiring one to obtain a license, as long as their water use is registered. Compulsory licensing in this case is only applicable in water stressed situations. This kind of water use corresponds to water use that was in existence exactly two years before promulgation of the 1998 water Act.

- Reserve requirement

  This is the only right to water in the water Act. It consists of the ecological reserve and the basic human needs reserve which comprises of drinking water, water for food preparation and personal hygiene. The reserve stipulates quantity and quality of water that must be retained in a given water resource given hydrological, ecological and demographic features. All other water use rights are subject to the reserve requirements.

The compulsory licensing process in South Africa has previously been criticized on a number of issues such as; firstly, the five year review period is regarded as too short to allow proper farmer investments due to insecurities associated with changes that might come up at every review period (Backeberg, 2005). Secondly, the licenses are insecure due to lack of surety that quantities and qualities indicated for abstraction on licenses will be available for supply (Speelman et al., 2010). Thirdly, the current water rights are limited in terms of transferability from one user to the other as the transfer process is laden with a lot of administrative procedures for each individual transfer; this in return raises transaction costs of transfer and renders the process less efficient with minimal or no efficiency gains (Speelman et al., 2010). Currently, compulsory licensing is a once-off annual payment of ZAR 114 per water user at the time of application, regardless of type or quantity of water used. Table 3.2 shows that, compulsory licensing was not widespread in the study region and was reported by only a few water users i.e. 26, 6, and 7 large-scale farmers, small-scale farmers and industrial water users respectively. Additionally, in some regions such as Kaspersnek in the middle Olifants, we found out that some farmers still regarded themselves as entitled to water use, as long as it was adjacent to their land. This confirmed the limited compliance to compulsory licensing observed in the study area; it implied a lack of awareness in the current water reforms from the water users' perspective. This also points to flawed implementation of the NWA. In this case, we also argue that the 'continued allowable lawful water use' stipulated in the NWA is apparently misunderstood; this could be due to the many provisions of the NWA that result to confusion among water users.

3.3.4 WUAs/ Water use groups

There has been considerable increased support for community involvement in management of natural resources over centralized management in many parts of the world (Vollan & Ostrom, 2010; Adhikari, 2005; Meinzen-Dick et al, 2002). This is because local users are seen to be in a better position to discern the local ecological, technical, economic, and social conditions out of their indigenous knowledge thus able to come up with well adapted rules, procedures, and sanction mechanisms easily supported by all resource users (Adhikari, 2005; Meinzen-Dick et al, 2002; Dungumaro & Madulu, 2003; Jaspers, 2003).

More so, their consent in public decision making on issues that affect their welfare is important (Dungumaro & Madulu, 2003; Jaspers, 2003). For IWRM to work, van Ast & Boot, (2003) emphasize on the importance of stakeholder participation in any water policy process; this way, visualizations, concepts, patterns of actions, and possible answers to apparent problems of actors are identified and incorporated into the decision making process. This improves the quality of decisions made and allows exchange of information between stakeholders hence better understanding of issues. Better information flow encourages transparency between parties and fosters effective management with better conflict resolution (Jaspers, 2003). Full stakeholder representation in the working base is encouraged in order to foster environmental, social, institutional, technical, and financial sustainability (ibid).

However, even with the many theoretical advantages attributed to participatory resource management world over, results from previous community involvement in management of natural resources indicate that these attempts are not always effective. Some have yielded desirable results with reports of better infrastructure upkeep and maintenance, efficiency in resource use, financial viability and overall sustainability (Kumar & Karande, 2000). In other instances, the targeted outcomes of resource productivity, equity, poverty alleviation, and environmental sustainability remain mixed or unrealized. (Meinzen-Dick & Knox, 2001; Srinivasan, 2006; Cardenas et al., 2009; Vandersypen & Bastiaens, 2008; Theesfeld, 2004; Place et al., 2004; Mukhopadhyay, 2004; Söderqvist, 2003; Gebremedhin et al., 2004; Marshall, 2004; Meinzen-Dick et al., 2002; Gorton et al., 2009; Bodin & Crona, 2008; White & Ford Runge, 1995; Khalkheili & Zamani, 2009; McCarthy et al., 2004; Bandiera et al., 2005).

The South African NWA stipulates participatory water use management through formation of WUAs (Harpe & Ramsden, 1999). The water Act defines a WUA as a statutory body established by the minister to bring together water users willing to work together in water use activities at the local level towards attainment of a common goal (Backeberg, 2005; Harpe, n.d.). The WUAs might be multi sector or single sector WUAs. The main purpose of WUAs is to enable water users to combine forces financially, human resource wise and expertise for effective water management activities (Harpe & Ramsden, 1999). Functions of WUAs may vary depending on the constitutional purposes for their formation. Some of the functions may include; preventing water wastage and unlawful use, supervision and regulation of water use and flow, monitoring water quality and maintenance of water works (Harpe & Ramsden, 1999). WUAs remain under the powers of the minister or CMA. The South African NWA targeted conversion of the existing irrigation boards to WUAs and formation of new WUAs for the small-scale farmers, a goal that is yet to be realized for majority of the basins.

Participatory water management has previously not been successful in South Africa due to lack of cooperation between stakeholders such as local governments, tribal authorities, farmers, and representatives of their associations (Backeberg, 2006). Failed cooperation stems from differences in cultures and backgrounds such as race, ethnicity, gender, language, and age. This heterogeneity has previously resulted in mistrust, bitterness, nervousness, fury, and accusations about the past (Backeberg, 2006). At present, only a few WUAs are operational in South Africa and two CMAs are in existence. Additionally, Orne-Gliemann, (2007) points out that the existing WUAs in South Africa fail to resolve any community water issues or attend to water infrastructure. The WUAs operate in isolation of other farm activities and lack full integration in farming activities, which is a drawback to success. In the Olifants, WUAs implementation has been slow. Faysse, (2004) outlines factors that have led to the slow conversion of irrigation boards to WUAs as the following:

- Resistance and conditional inclusion of small-scale water users by white commercial farmers in their irrigation boards thus WUAs
- Lack of clear specification of WUAs roles especially due to ambiguity in definition of equity
- The small scale farmers entitlement attitude to free water due to consequences of the past apartheid regime and drought
- DWAF's less strictness on water use for the emerging farmers; this gives rise to opposition by the commercial farmers who insist on proportionality in water allocation based on the level of investment in water works
- Failure by white farmers to involve the emerging farmers in decision making when they include them in the WUAs
- Confusion over who is best suited to represent the emerging farmers in the WUAs due to lack of capacity and gender balancing
- Lack of access to information especially on compulsory water licensing

Difficulties of new WUAs formation in small-scale irrigation schemes on the other hand, arise due to lack of management capacity, lack of land tenure security, small pieces of land, and lack of appropriate technologies, markets, and finances (Harpe & Ramsden, 1999).

Focus group discussions with the heads of the irrigation boards in the Olifants indicated that the WUAs only existed by name; the organizations remained as irrigation boards with minimal attempts of conversion into WUAs (van Stryp, 2014). The membership of the boards largely comprised of white farmers with minimal or no black farmers' representation. The reasons given for the slow and inexistent inclusion of emerging farmers into the irrigation boards included; emerging farmers inefficiency in farming, and tension between the two farmer categories due to land re allocation. As a result, emerging farmers have informally organized themselves into smaller water use groups to pool their resources together for irrigation farming purposes. This was especially in the lower Olifants region of Limpopo. Table 3.2 indicates that 40 small-scale and 39 large-scale farmers were involved in participatory water management activities. At the time of the study, the NWA was undergoing reform in an attempt to eliminate the WUAs to form one overall umbrella body for governing water use (van Stryp, Claasen, 2014). No multi-sector WUA existed in the Olifants at the time of the study.

3.3.5 Payment for effluent discharge

The current water quality situations in the world are far from adequate and sustainable water quality management remains a big challenge (Huang & Xia, 2001). This could be due to current forces of economic development and population increase (ibid). Policies for water quality management remain complex because there are many socio economic, environmental, and political factors to consider. Barriers to water quality management have been identified as lack of or poorly developed policies, poor legislation standards, poor monitoring, lack of finances, lack of capacity for stakeholders, and unclear institutional accountabilities (Huang & Xia, 2001; Serageldin, 1995). Further complicating water quality management, is the diffuse nature of some of the pollution especially from farming activities; therefore the need to distinguish between point source and non-point source pollution for any water quality management policy (Mattheiss, Mat, & Strosser, 2009).

There are two main schools of thought when it comes to the debate on water pollution control in developing and transition countries (Blackman, 2009). These are namely command and control requiring polluters to use certain technology in order to minimize discharges and economic incentives (market-based policies) that encourage polluters to minimize their pollution without stipulating on how they should do it. Examples of these economic incentives include effluent discharge permits which are tradable between polluters, and discharge fee programs which charge firms per unit of load emitted (Blackman, 2009; Glazyrina et al., 2006). Proponents of the economic incentives argue that they are best suited for developing and transition countries because they cut on social costs as these countries lack the private and public resources required for pollution control (Blackman, 2009). However, arguments exist that economic incentive policies are less likely to work in developing countries due to lack of proper institutional frameworks and capacity to implement (ibid). Evidence in literature however indicates mixed results on performance of the economic incentives in different countries (Fischhendler, 2007). One case in point is Colombia’s wastewater discharge program, which has been widely reported as a success story.

Other advantages such as flexibility, efficiency, and income generation have been outlined in favor of the effluent discharge permits (Blackman, 2009). On the other hand, some of the cons outlined against the discharge permit system in literature include, weak implementation stemming from weak institutions and regulations, the fees are set too low below the abatement costs and don't act as an incentive to cut pollution any more but rather a means to collect revenue. In cases where the discharge fees are two tiered to complement command and control policies, this beats efficiency as some polluters pay higher than others and the abatement costs are not equal at the margin (Blackman, 2009).

Currently in the Olifants, mines and industries do not pay any effluent discharge fees; they only operate under environmental licenses from the National Environment Management Authority (NEMA), which identify and evaluate their actual and potential impact on the environment in addition to options for mitigation activities, in order to minimize negative impacts and maximize benefits. The DWAF is in the process of implementing the effluent permit system in order to execute the polluter pays principle for wastewater discharge related uses. Trials are to take place in the year 2015/16 in selected catchments (Coleman, 2014). This system will levy a charge on the load of a specific constituent. The envisaged structure of the charges includes mitigation charge for water treatment, basic charge paid by all water users, and the incentive charge levied on the load. For the Olifants, focus will be on salinity and phosphates. Phosphates (eutrophication) remain high but within the acceptable range in the study region. This indicates contamination from the catchment activities such as improper fertilizer use and sewage discharge into the water; these have however no direct effect on water use (Van Veelen, 2011). Salinity levels as indicated by the Electrical Conductivity (EC) are also high but within acceptable and tolerable ranges. Trends analyses however show that EC levels are increasing for the entire Olifants and this could be detrimental for domestic and irrigation water use. Currently, users only pay the catchment management charge levied on all registered users and this applies to the water use described as taking water and not as waste discharge (van Veelen, ILISO 2014,). At present in South Africa, registration and licensing are ongoing for authorized and existing lawful waste discharge. Only registered waste discharge related to water use will be liable to water pollution charges, and this excludes non-point sources. The implementation of the waste charge will take effect once registration of licenses, general authorizations, and confirmation of existing lawful waste discharge is completed.

3.4 Effects of water policies on irrigation water use in the Olifants basin

3.4.1 Conceptual framework

Despite great emphasis on IWRM as the way forward to address water management issues of scarcity, the proposed IWRM principles continue to exhibit mixed outcomes while some of its effects on water use remain unknown (Dungumaro & Madulu, 2003). In South Africa, IWRM principles are embedded in the NWA, whereby better water saving and improved water quality are set to be attained through its implementation (Kloos, 2010). As a second step in this chapter, this study set out to examine how some of the water policies stipulated in the NWA have influenced the anticipated water management goals. Specifically, we examine the effects of WUAs, water pricing and compulsory licensing on irrigation water quality, quantity, and efficiency (Figure 3.2). The policy effects on water use could be positive thereby enhancing attainment of the desired water Act goals, have no effect (status quo), or the water users and water resource could be worse off (negative effects).

In the succeeding sections, we outline the empirical approaches used to attain the given study objective for this chapter. The subsequent sections further present the chapter results and discussions.

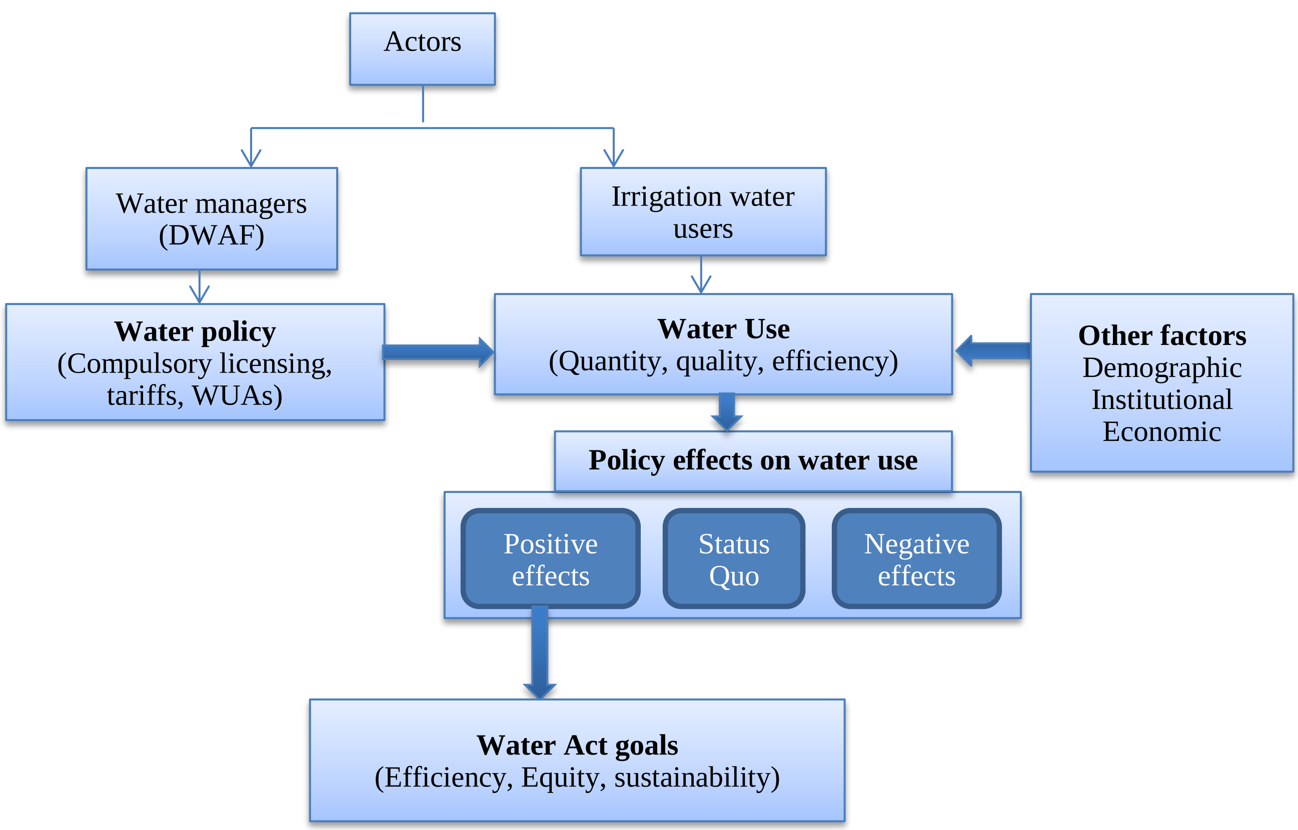


Figure 3.2: Conceptual framework on effects of water policies on irrigation water use
Source: Own compilation

3.4.2 Empirical Framework

We used various approaches to assess the effects of water policies on irrigation water use. Data Envelopment Analysis (DEA), Ordinary Least Squares (OLS), Tobit and multinomial logit (MNL) methods; the choice of the models was informed by the nature of the assessment and the availability of data.

3.4.3 Effects of water policy on quantities of water used for irrigation

An empirical review of literature identifies institutional, socio-economic and demographic factors to affect quality, quantity, and efficiency of irrigation water use. Firstly, we run an OLS regression as guided by the nature of our first dependent variable being continuous (Irrigation water quantity used per annum in m^3) (Verbeek, 2012). An operational model takes the form:

$$m_{yj} = \mu_j + \varepsilon_j \qquad (3.1)$$

Where;

m_{yj} is the total water used in m^3 per year *y*, by an irrigation farming household *j*

μ_j is a vector of observable factors likely to influence water use quantities

ε_j is the unobservable error term.

Following Sadeghi et al., (2012) the implicit form of the structural model linking water quantity used and the set of hypothesized independent varibles is as follows:

$$WatQused_y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \in \qquad (3.2)$$

Where;

$WatQused_y$ = quantity of water used in (m^3) per annum (*y*) per irrigation farming household

x_1 = vector of the water policy interventions (compulsory licensing, water pricing (water costs) and WUAs)

x_2 = vector of economic heterogeneity factors such as income, farm size, irrigation methods used, main occupation, crop choice

x_3 = vector of household demographic characteristics such as geographic location, gender, farming experience, and schooling years

x_4 = vector of other institutional related factors such as, leadership positions in informal and formal water use groups, tenure security, use of ICT tools for water management purposes, technical assistance and water quality types

ε = error term

However, we suspected endogeneity[1] in the model due to reverse causality[2] between the dependent variable (water quantity) and the water quality variable. This would mean that the endogeneous explanatory variable is correlated with the error term and OLS in such a case would produce biased and inconsistent estimates. This is corrected using an intrumentalvariables[3] (IV) regression approach, which is an extension of OLS. A common way to estimate the IV regression is the two-stage-least-squares (2SLS) method. It is a two-step application of the instrumental variables (IV) technique to correct for the correlation of the suspected endogenous explanatory variable with the error term in the equation of interest. In the first step, the suspected endogenous variable is regressed on all the exogenous (predetermined) variables in the model. The values of the suspected explanatory variable predicted from the first step are then used as instruments for the suspected endogenous explanatory variable in the equation of interest (Wooldridge, 2008). Therefore, we instrumented for water quality with willingness to pay for water quality in our IV regression. However, the post estimation tests for endogeneity showed that the water quality variable was indeed exogenous and there was no need for IV estimation. Wooldridge (2008) suggests that if the suspected endogenous regressors are found to be exogenous, then the OLS estimator is more efficient and should be used instead. We retained the OLS estimation for this part of the study.

3.4.4 Effects of water policy on irrigation water use efficiency

Additionally, we examine how water policies amongst other socio economic factors, influence water use efficiency (WUE) of irrigation farmers in the Olifants basin. We posit that WUE can better indicate the effects of water policy because it is one of the goals targetted by the South African water policy reform. Furthermore, efficiency measures usually indicate the relationship between all outputs and inputs in a production process (Díaz et al., 2004). Technical efficiency measures originate from the seminal work on technical efficiency by Farrell (1957). He defined it as the ability of a farm to produce the maximum

[1] A parameter is said to be endogenous when there is a correlation between the parameter and the error term due to measurement errors, omitted variables and simultaneity/reverse causation

[2] Reverse causality arises when the dependent variable causes at least one of the covariates

[3] An instrument is a variable not belonging in the explanatory equation and is correlated with the endogenous explanatory variable, conditional on the other covariates. It should not be correlated with the error term in the explanatory equation

feasible output from a given bundle of inputs (output-oriented measure) or to use minimum feasible amounts of inputs to produce a given level of output (input-oriented measure) (Coelli et al., 2002; Dıaz et al., 2004a, b). Sub vector efficiency measures on the other hand generate technical efficiency measures for an individual input, in this case is water. The concept of sub vector efficiency examines the possibility of reducing a subset of inputs while holding other inputs and outputs constant.

There are two main approaches in literature used for measuring technical efficiency. These are the parametric approach also known as the stochastic frontier analysis and the non-parametric approach also referred to as DEA (Speelman, et al.,2008;Frija, et al.,2009;Wang, 2010). The parametric approach estimates a parametric production function (or its dual cost or profit function) representing the best available technology. It also provides a convenient framework for hypothesis testing and the construction of confidence intervals. The non-parametric DEA on the other hand uses linear programming methods to construct a linear envelopment frontier over the data points. The DEA is considered to have several advantages over the parametric approach because firstly, it does not need to assume a functional form for the frontier technology (Speelman et al., 2008). Secondly, the constructed surface over the data allows comparing one production method with the others through a performance index. Therefore, DEA provides a straightforward approach to calculate the efficiency gap that separates each producer's behavior from best productive practices, assessment of which can be from actual observations of the inputs and outputs of efficient firms (ibid). The most important advantage of DEA to this study is its flexibility, which permits the calculation of technical efficiency for an individual input in a production process (sub vector efficiency) (Oude-Lansink et al., 2002). This would otherwise be computationally problematic using the stochastic frontier approach as the production technology assumed can limit the efficiency results (Speelman et al., 2008; Frija et al., 2009). DEA considers a farm using less inputs as more efficient than another which uses more inputs to produce the same amount of output (Speelman et al., 2008). Therefore, it simultaneously constructs a production frontier and attains the efficiency measures. The frontier surface is a result of piece wise accumulation through solving sequences of linear programming problems, one for each farm and in relation to the frontier (ibid). The frontier forms an envelop over the observed input and output data points of each farm.

Following Speelman et al., (2008), we give an example of a model where data is available on K inputs and M outputs for each of the N farms. Input and output data for the i^{th} farm, are given by the column vectors x_i and y_i, respectively. The K by N input matrix, X, and the M by N output matrix, Y, represent the data for all N farms in the sample. Equation 3.3 demonstrates the DEA model to calculate general technical efficiency

$$\begin{aligned}
&\text{Min}_{\theta\lambda}\theta, \\
&\text{Subject to} \quad -y_i+Y\lambda \geq 0, \\
&\qquad \theta x_i - X\lambda \geq 0, \\
&\qquad N1'\lambda = 1, \\
&\qquad \lambda \geq 0
\end{aligned} \tag{3.3}$$

Where θ is a scalar, $N1$ is a vector of ones, and λ is a vector of constants. Using the variables λ and θ, the model solves once for each farm, aiming for the largest radial contraction of the input vector x_i within the given technology. The value of θ corresponding with this contraction is the technical efficiency score for the ith farm. This score always lies between zero and one, one showing that the farm lies on the frontier and is efficient. The first constraint ensures that output produced by the i^{th} farm is smaller than that on the frontier. The second constraint limits the proportional decrease in input use; when θ is minimized to the input use achieved with the best-observed technology. The third constraint is a convexity[4] constraint that creates a variable returns to scale (VRS) specification of the model; it ensures a farm is benchmarked against farms of similar size. Without the convexity constraint, Equation 3.3 makes up the constant returns to scale (CRS) specification. CRS assumes that all farms are operating at an optimal scale, which is not possible in reality due to limitations such as finances and imperfect competition (Coelli et al., 1998). Therefore, the VRS specification is more suitable especially in agriculture where increases in inputs do not proportionately result to increased outputs (ibid).

Equation 3.4 shows the programming problem used to obtain the sub vector efficiency for the variable input k (water) for each farm i

$$\begin{aligned}
&\text{Min}_{\theta\lambda}\theta^k \\
&\text{Subject to} \quad -y_i + Y\lambda \geq 0, \\
&\qquad \theta^k x_i^k - X^k\lambda \geq 0, \\
&\qquad x_i^{n-k} - X^{n-k}\lambda \geq 0, \\
&\qquad N1'\lambda = 1, \\
&\qquad \lambda \geq 0
\end{aligned} \tag{3.4}$$

Where, θ^k is the input k sub-vector technical efficiency score for farm i. The terms x_i^{n-k} and X^{n-k} in the third constraint refer to x_i and X with the k^{th} input (column) excluded, while, in the second constraint, the terms x_i^k and X^k include only the k^{th} input. Other variables definitions remain as in Equation 3.3. Constraints 1, 4, and 5 are the same as in model 1, while constraint 2 and 3 ascertain that a value of θ^k exists which represents a maximum reduction of the variable input k remaining within the technology set and holding outputs and all other inputs constant.

Figure 3.3 demonstrates the measurement of technical efficiency and sub vector efficiency using DEA. The problem takes the i^{th} farm R and radially contracts the input vector, x_i, as much as possible, while maintaining the feasible input set. The inner boundary of this set is a piecewise linear isoquant (Y^F) determined by the frontier data points. The radial contraction of the input vector x_i produces a projected point on the frontier surface (R_0). This projected point is a linear combination of the observed data points, with the constraints in Equation 3.3, which ensure that the projected point cannot lie outside the feasible set. The overall technical efficiency measure of farm R relative to the frontier is given by the ratio θ = $0R_o/0R$. The sub-vector efficiency for input X_1 (water) is obtained by reducing X_1 while holding X_2 and output constant. This is a non radial concept of input efficiency measurement and it allows for a differential reduction of the inputs used (Reinhard,1999). Figure 3.3 shows that R is projected to R_1 and sub-vector efficiency is given by the ratio θ^1 = QR1/QR

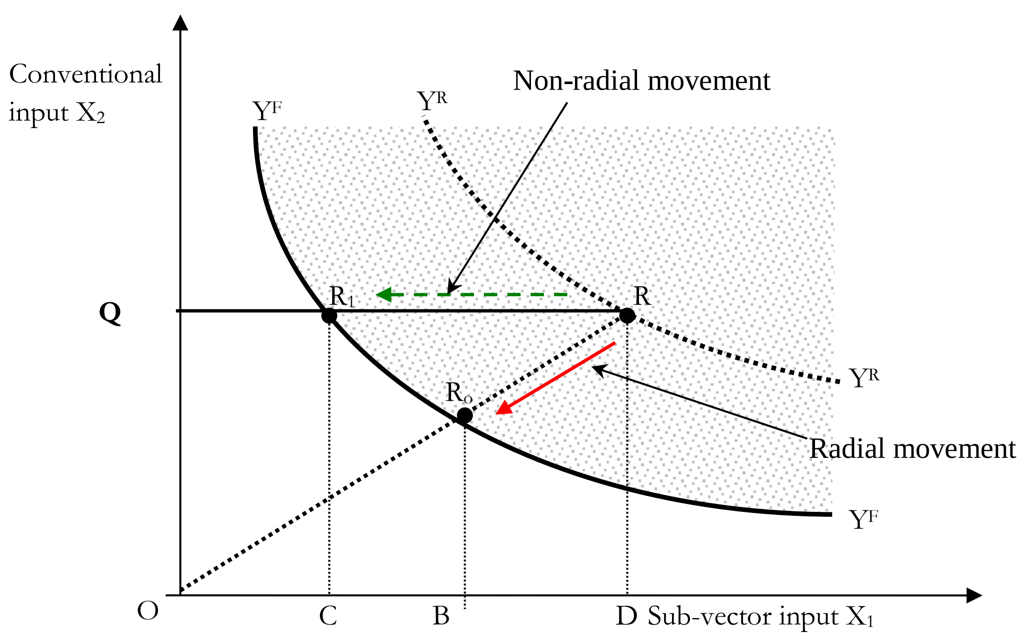


Figure 3.3: Measurement of technical and sub vector efficiency using DEA

Source: Mulwa 2006

After obtaining, the sub vector efficiency estimates as outlined above, the estimates were regressed on hypothesized correlates of water use efficiency through a second stage relationship using the Tobit model (Barnes, 2006; Chavas et al., 2005; Binam et al., 2003). Tobit regression, is an alternative to OLS for situations in which the dependent variable is bounded from below or above (or both) either by being censored, or by corner solutions (Frija et al., 2009). The Tobit model was suitable because the efficiency parameters vary between zero and one thus termed as censored. The dependent variable lacks a normal distribution, since its value lies between zero and one. OLS in this case, would produce biased and inconsistent estimates even at asymptotic levels Gujarati (2004). OLS further underestimates the true effect of the parameters, and decreases the slope. Tobit analysis therefore uses the maximum likelihood estimation methods. The theoretical Tobit model takes the form:

$$y_i^* = x_i'\beta + \varepsilon_i, \quad i = 1,2, \ldots\ldots, N, \qquad (3.5)$$
$$y_i = y_i^* \quad if\ y_i^* > 0$$
$$y_i = 0 \quad if\ y_i^* \leq 0,$$

Where, y_i^* is the latent variable for the i^{th} farm, x is the vector of independent variables hypothesized to affect efficiency. ($\beta = \beta_0, \beta_1 \ldots \beta_n$) are the unknown parameter vectors related with the independent variables for the i^{th} farm. ε_i is the error term, assumed to be normally distributed, and independent of x_i (0,σ^2) with zero mean and constant variance (Verbeek, 2012). This is a censored regression model whereby all the negative values map to zeros. The model assumes that there is an underlying stochastic term equal to, $+\varepsilon$. The model describes the probability that y_i= zero given x_i and the distribution of y_i given that it is positive; this is a truncated normal distribution. In this case, the efficiency values lie between zero and one hence the point of truncation is one and the dependent variable is not normally distributed. Accordingly, for the purposes of this study, the empirical model takes the form:

$$y_i^* = \beta_0 + \sum_{n=1}^{n} \beta_n x_i + \varepsilon_i \qquad (3.6)$$

Where,
$0 < y_i^* < 1$,
0 if y_i^* <0, and, 1 if $y_i^* > 1$

y_i^* is the DEA sub-vector efficiency index for water used as a dependent variable. x_i is a vector of independent variables related to attributes of the farmers listed in Table 3.4.

3.4.5 Effects of water policy on irrigation water quality

Technically, water quality is defined as the chemical, physical, biological, radiological, and aesthetic characteristics of water (UNESCO/WHO/UNEP, 1996). However, measurement and determination of water quality is relative to its intended purpose; hence, it is the ability of water to support all appropriate beneficial uses at a given point in time. In general, the parameters of measurement to describe water quality are:

1. Biological: bacteria, algae
2. Physical: temperature, turbidity and clarity, color, salinity, suspended solids, dissolved solids
3. Chemical: pH, dissolved oxygen, biological oxygen demand, nutrients (including nitrogen and phosphorus), organic and inorganic compounds (including toxicants)
4. Aesthetic: odors, taints, color, floating matter
5. Radioactive: alpha, beta, and gamma radiation emitters

Accordingly, the DWAF has categorized the fitness-for-use of water for various uses using six parameters, which give the discrete values that describe a specific effect due to a given set of conditions. These are namely:

i. Electrical Conductivity (EC): This indicates salinization of water resources and serves as a proxy for total dissolved solids (dissolved inorganic salts). Salinization affects domestic and irrigation water use. Aquatic life is only affected in extreme high levels
ii. Orthophosphate (PO_4-P): Phosphate indicates the nutrient levels in water resources (eutrophication). Phosphate has no direct effect on water use but indicates contamination from activities in a catchment such as fertilizer use and wastewater discharge.
iii. Sulphate ($SO_4$2): Sulphate is a naturally occurring substance found in mineral salts in the soil, decaying plant and animal matter. It is generally not toxic but affects human consumption at very high levels.
iv. Chloride (Cl): It shows the nature of salinity i.e. salty taste and corrosiveness. Mainly affects aquatic life and irrigation
v. Ammonia (NH_3-N): indicates presence of ammonia, which is highly toxic to aquatic life even in low concentrations. It has no effect on human life and irrigation in the state it occurs in rivers and dams
vi. pH (pH units): It is a measure of the acid-base equilibrium of various dissolved compounds and indicates the acidity/alkalinity of water. Water pH only affects water use at the extreme levels.

Based on the above values, the DWAF has come up with water quality guidelines or criteria used in conjunction with the statistical values to determine the fitness for use. The guidelines provide a description of the effect on a user if exposed to increasing concentration or changing values of quality components. The description consists of cut off values for each category of fitness for use in relation to the specific water use. Therefore, the guidelines show fitness for use of water in consideration of its biological, chemical, and physical characteristics. The guidelines have been set into four categories as:

1. Ideal: the user of the water is not affected in any way
2. Acceptable: slight to moderate problems are encountered
3. Tolerable: moderate to severe problems are encountered
4. Unacceptable: the water cannot be used under normal circumstances

Table 3.3 shows the cut off values for fitness for use range in irrigation activities.

Table 3.3: Cut off pollution values categorizing agricultural water use

variable	**units**	**Ideal**	**Acceptable**	**Tolerable**	**Unacceptable**
EC	mS/m	< 40	40-270	270-540	> 540
pH: upper range lower range	pH units	> 6.50 < 8.40			< 6.50 > 8.40
Nitrate	Mg/l N	-	-	-	-
Ammonia	Mg/l	-	-	-	-
Chloride	Mg/l	< 100	100-175	175-700	> 700
Phosphate	Mg/l P	-	-	-	-
Sulphate	Mg/l	-	-	-	-

Source (Van Veelen, 2011)

Irrigation farmers might not be aware of the exact values attached to each of the guideline categories. However, the assumption made in this study is that they are aware of the adverse effects of the water they use on their farming activities; following these effects, farmers were therefore able to categorize the water they used into the four categories, as they perceived.

Following the outlined categorization of water quality, we used the Multinomial Logit Model (MNL) for this section because it allows estimating choice probabilities for many categories (Maddala, 1983; Wooldridge, 2002). The dependent variable (water quality) is a multivariate variable with four possible categories as outlined by DWAF (Ideal, acceptable, tolerable, and unacceptable). The four categories enabled collection of water quality information from farmers, based on their perceptions. The multinomial logit model assumes all errors of the alternatives to be independent (independence of irrelevant alternatives-IIA) and this ensures the parameter estimates of the MNL model remain unbiased and consistent .i.e. P_j/P_k is independent of the remaining probabilities. However, this is not always the case especially if alternatives are very similar (Verbeek, 2012). A test is usually relevant to compare estimates from the model with all alternatives to estimates using a subset of alternatives.

The MNL model takes the form:

$$P\left(y = {}^{j}/_{x}\right) = \exp(x\beta_j) \;/\; [1 + \sum_{h=1}^{j} \exp(x\beta_h), \qquad j = 1,2,\dots,J] \tag{3.7}$$

Where *y* denotes a random variable taking on the values {1, 2, …, J} for a positive integer *J*; and *x* denote a set of conditioning variables. *x* is a 1xK vector with first element unity and β_j is a K×1 vector with j = 1,2, …, *J*. In this study, *y* denotes water quality (category) status while *x* signifies hypothesized factors influencing farm water quality described in table 3.4. Equation 3.7 above shows the effect of changes in an element of *x* (holding other factors constant), on the response probabilities $P(y = j/x)$, j = 1, 2, …, *J*. This indicates the direction of the effect of the explanatory variables on the dependent variable. Following (Sadeghi et al., 2012) the implicit form of the structural model linking water quality and the set of hypothesized independent varibles is as follows:

$$WatQlty_j = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \in \tag{3.8}$$

Where;

$WatQlty_j =$ quality of water, *j* (*j*=1,2,3,4) used and ranked by an irrigation farmer in the Olifants basin

$x_1 =$ vector of the water policy interventions (compulsory licensing, water pricing (water costs) and WUAs

$x_2 =$ vector of economic heterogeneity factors such as income, farm size, crop choice, main occupation

$x_3 =$ vector of household demographic characteristics such as, geographic location, gender, farming experience, and schooling years

$x_4 =$ vector of other institutional related factors namely, leadership positions in informal and formal water use groups, tenure security, use of ICT tools for water management purposes, and technical assistance

ε = error term

3.4.6 Choice of variables included in the regression models

Several studies have investigated the relationship between efficient quantities of water use and various farm or farmer characteristics (Speelman et al., 2008; Binam et al., 2004; Lilienfeld & Asmild, 2007; Frija et al., 2009; Wang, 2010). The farm and farmer characteristics previously examined include age, household size, gender, farming experience, education, involvement in WUAs, farm size, land tenure, farmer type, water costs, crop choice, income, farm location, and extension services. A few studies have assessed the effect of water pricing on water use efficiency (Wang, 2010), while others (Speelman et al., 2008; Frija et al., 2009) have recommended such assessments between water price/costs and water use. Little or no evidence exists of the relationship between water rights and irrigation water use, a gap that the current study seeks to fill.

To start with, Speelman et al., (2008), Wannasai & Shrestha, (2008) and Frija et al., (2009) reported that tenure secure farmers were more efficient in their water and land use decisions. This finding lays emphasis on land reforms in order to foster farm level investments and efficiency. Wang, (2010) found out that in China, secure water rights positively influenced water use efficiency; tenure security was important in fostering investment in irrigation farming and better water management. Water pricing on the other hand financially limits farmers' water use thus discouraging inefficient use of the resource (Wang, 2010). Speelman et al., (2008) suggest that introduction of water charges could be a trigger for more efficient water use. Farm size, has been found to both negatively and positively influence water use efficiency in several studies; implying the need for more research in this aspect. Speelman et al., (2008), Frija et al., (2009) and Wang, (2010) reported a negative and significant correlation between farm size and water use efficiencies in South Africa, Tunisia and China respectively. Contrary to this, Lilienfeld & Asmild, (2007) found that farmers with bigger farm sizes in their study had less excesses of water used thus were more efficient.

Farmer activity or occupation has previously influenced farm water use both positively and negatively depending on the occupation type. In Speelman et al., (2008), food gardeners were found to use less water compared to other smallholder farm activities. Additionally, farmers who had highly subdivided their land used irrigation water less efficiently, due to difficulties experienced in managing such fragmented farms. Farmer Crop choice is as well an important determinant of farm water use and emphasis is laid on growing crops that have a higher profit per m^3 of water used (Njiraini & Guthiga, 2013; Speelman et al., 2008). Irrigation technologies have significantly affected quantities of farm water use in the past. Speelman et al., (2008) found that bucket and hose irrigation methods negatively influenced the quantity of water used in farming compared to sprinkler technology. Njiraini & Guthiga, (2013) , Frija et al., (2009) found that drip irrigation technique positively influenced water use efficiency. On the contrary, Lilienfeld & Asmild, (2007) found that irrigation technologies (center pivot and flood) in their study were not strong significant influencers of water use; suggesting that farm management and other field techniques mattered more in influencing efficient water use.

Age in some studies has been non-significant while it retains a mixed effect in others. For example, Lilienfeld and Asmild, (2007), Wadud and White, (2000), Bozoğlu & Ceyhan, (2007) and Binam et al., (2003) found that younger farmers in their studies were more water use efficient with less excesses of water used while Wang, (2010), and Dhungana et al., (2004) reported older farmers as more water use efficient. Locational differences in farming also play a role in influencing water use quantities either positively or negatively; this is attributable to different management styles in in a river basin (Lilienfeld & Asmild, 2007; Wang, 2010). Further emphasis is put on the importance of technical assistance for farmers, which positively influences water use efficiency; this could be through better extension to create awareness on irrigation technology, better water management and timing of water applications (Frija et al., 2009). Additional factors positively influencing efficiency of water use are income and education (Wang, 2010;Bozoğlu & Ceyhan, 2007).

Given this background of mixed effects of factors influencing water use efficiencies in literature, this study seeks to find out the context specific factors influencing water use and efficiency in the Olifants basin. In addition to the hypothesized demographic, institutional, and socio economic factors, we include selected water policy interventions factors currently undergoing implementation in the study region; this is in attempt to assess the effects of water policy on irrigation water use. Table 3.4 gives the list of hypothesized factors included in the regression models and their hypothesized effects on water use quantities, efficiencies and quality.

Table 3.4: List of the variables included in the OLS, Tobit, and MNL analysis

Variable	Description	Model and Expected signs		
		OLS	Tobit	MNL
Water quantity	Natural log of Irrigation water quantity used per annum in m^3	Dependent		
WUE	The DEA sub vector water use efficiency measure.		Dependent	
Water quality	Water quality type (1=Ideal, 2=acceptable, 3=tolerable, 4=unacceptable)	+/-		Dependent
WUA	Farmer involvement in Water User Associations/groups	-	+	+
Compulsory licensing	Compliance to water licensing	-	+	+
Water cost/m^3	Natural log of total cost of irrigation water used based on current paid tariffs	-	+	+
Region	Farmer geographic location (upper,middle and lower Olifants)	+/-	+/-	+/-
Leadership in WUA	Leadership position held in water use groups/WUA	-	+	+
Gender	Male or female farmer	+/-	+/-	+/-
Years of schooling	Total number of years of school attendance	-	+	+
Main occupation	Main activity of a respondent (1=largescale, 2=smallscale, 5=other)	+/-	+/-	+/-
Farming years	Total number of years of farming	-	+	+/-
Farm size	Natural log of farm size	+/-	+/-	+/-
Land claims	Proxy for tenure security	+/-	+	+
Income	Natural log of income	+/-	+/-	+/-
Technical assistance	Source of technical policy information (1=DWAF,0=other sources)	-	+	+
ICT tool	ICT tools used for water management purposes (1= radio,TV,phone,email 0=none)	-	+	+
Irrigation methods	Irrigation technology used (1= center pivot, 2= drip, 3=flood, 4=other,5= sprinkler)	+/-	+/-	+/-
Perennial crops	Perennial crops grown (citrus, mangoes, grapes, cotton)	+/-	+/-	+/-
Cereal crops	Cereal crops grown (maize and wheat)	+/-	+/-	+/-
Vegetables and other	Vegetables and other crops (leafy vegetables, peas, potatoes, onions, beans)	+/-	+/-	+/-

Source: Own compilation

3.5 Results and Discussion

3.5.1 Effects of water policy on quantities of water used in irrigation: OLS results

This section discusses the results of the OLS regression given in Table 3.5. The results indicate that various factors significantly influence water quantities used by farmers in irrigation farming in the Olifants basin. The model fitted the data well and the F statistic (p-value < 0.0000) showed that the model was highly significant.

Results indicate that among the three policy variables of interest, water costs and involvement in WUAs were significant in explaining irrigation water use. Farmers involved in WUAs were likely to use less water quantities for their irrigation activities compared to non-members of WUAs. This finding was in line with several other studies which suggested that collective management of natural resources yields better management outcomes (White & Runge, 1995; Balooni et al., 2008; Gebremedhin et al., 2004; Gorton et al., 2009; Mushtaq et al., 2007 ; van Ast & Boot, 2003**;** Bekkari, 2008). This is an important finding for the South Africa water reform process because the law on formation of WUAs is already under review even before its full implementation and effects are realized (Claasen, 2014).

The results further show that farmers who used more water, readily paid the higher costs associated with larger quantities of water used. This is contrary to the expectation that a water price induces farmers to reduce their irrigation water consumption as suggested by Speelman et al., (2008). Following Frija et al., (2011) and Speelman et al., (2009), we attribute this to very low water tariffs that do not comprise a significant percentage of farmer production costs. This further validated the focus group discussions held with large-scale farmers who claimed that the current water tariffs were negligible and failed to count as part of farm production costs. Reports from the DWAF on the other hand indicated that water tariffs were higher but our findings showed that farmers were not currently paying the stipulated higher water tariffs.

The small-scale farmers in this study used less water for their farming activities compared to their large-scale counterparts. This was due to the subsistence nature of their farming practices. Income on the other hand was positive and significantly influencing quantity of water used. We posit that, farmers with higher incomes have an economic upper hand in access to farm inputs hence wider scopes in their farming activities and enterprises, which translates to probable higher quantities of water used. Farm size was also highly significant in explaining water use quantities; farmers with bigger farm sizes were likely to use more water for their farming activities. Results further showed that perennial crop growers (citrus, mangoes, and cotton) were likely to use more water for their farming activities. This could be due to the perennial nature of the crops requiring more irrigation per annum unlike the seasonal crops. However, careful interpretation of results from this section is necessary because quantities of water used for irrigation do not necessarily indicate efficiency or inefficiency. The next section explores water use efficiency.

Table 3.5: Effects of water policy on quantities of water used in irrigation: OLS results

Variable	Coefficient	Standard error	P value
WUA-membership(1=yes,0=no)	-0.506**	0.255	0.049
Compulsory Licensing compliance(1=yes,0=no)	-0.503	0.396	0.206
Region- Middle Olifants	0.067	0.418	0.873
Region- Lower Olifants	-0.188	0.484	0.699
Leadership in WUA(1=yes, 0=no)	-0.458	0.464	0.325
Gender(1=male, 0=female)	0.216	0.236	0.361
Years of schooling	0.023	0.021	0.268
Main occupation-small scale	-1.417***	0.437	0.001
Main occupation-other	0.059	0.646	0.928
Farming years	0.012	0.008	0.159
Farm size- natural log of farm size	0.003***	0.001	0.000
Landclaims (1=yes,0=no)	-0.266	0.502	0.597
Income- ln income	0.077*	0.044	0.082
Water quality-acceptable	0.121	0.269	0.652
Water quality-tolerable	-0.453	0.309	0.144
Water quality-unacceptable	-0.289	0.392	0.463
Water cost- ln water cost	0.137***	0.047	0.004
Technical assistance (1=DWAF,0=others)	0.376	0.294	0.203
ICT tool	-0.045	0.236	0.850
Perenial crop growers (1=yes,0=no)	1.082***	0.280	0.000
Cereal crop growers (1=yes,0=no)	0.345	0.295	0.245
Vegetable crop growers (1=yes,0=no)	-0.037	0.232	0.875
Irrigation method- drip	-0.745	0.452	0.102
Irrigation method-flood	-0.445	0.426	0.298
Irrigation method-other	-0.067	0.661	0.919
Irrigation method-sprinkler	-0.341	0.331	0.305
_cons	7.128***	0.854	0.000
N=179	R^2 =0.797	P=0.000	

3.5.2 Effects of water policy on irrigation water use efficiency: DEA and Tobit results

3.5.2.1 Water use efficiency results

Table 3.6 gives a summary of the inputs and output used for the efficiency analysis. It shows a wide variation between inputs used and output produced from irrigation farming. This can be explained by the subsistence and commercial nature of small scale and large scale farmers studied.

Table 3.6: Summary statistics of inputs and outputs used in the efficiency analysis

	Mean	Standard Deviation	Minimum	Maximum
Land(Ha)	39,40	106,43	0,04	690
Water(m^3)	70978,14	215345,63	11,25	1408200
Seeds(ZAR)	6089,78	14462,21	0	91000
fertilizer(ZAR)	49182,68	331305,18	0	3000000
pesticides(ZAR)	4912,74	21813,64	0	201500
Labour(mandays)	93	291,40	4	2412
Crop output(ZAR)	6806472,13	32936266,52	0	299970000

Source: own compilation

Figure 3.4 indicates the frequency distribution categorized in classes of water use efficiencies obtained from the DEA estimation methods. A large percentage of the farmers had low water use efficiency scores; 17 percent of farmers had efficiency scores below 1 percent, while 35 percent of farmers had their efficiency scores between 1 and 10 percent. 21 percent of the irrigation farmers were water use efficient. The average overall water use efficiency was 0.31 (31 percent) indicating large inefficiencies in irrigation water use. Accordingly these findings suggested that, if all other inputs were held constant, it would still be possible to attain the current outputs using averagely 69 percent less irrigation water. This is in line with findings of Frija et al., (2011) and Speelman et al., (2009). Following Speelman et al., (2009), the results further suggested that, if efficiency was to improve, it would be possible to re allocate the excess water used into other water demands without negatively affecting farm production. The results showed that irrigation water use efficiency was low and barely reflected efforts of the current water policy reforms. We argue that water policy implementation is still a ‘work in progress’ yet to attain its goals for the Olifants basin among many other basins of South Africa.

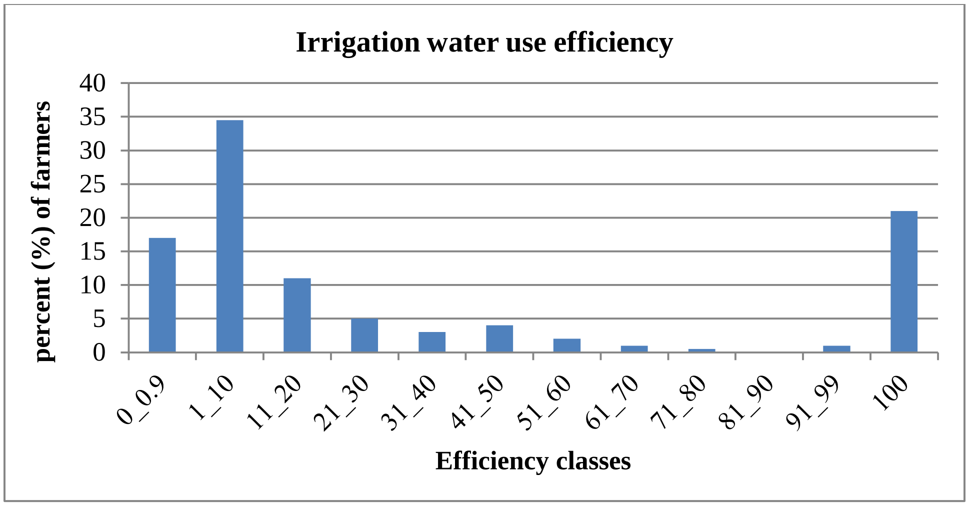


Figure 3.4: Sub vector water use efficiencies

Source: own compilation

3.5.2.2 Tobit results

The tobit regression results in Table 3.7 indicate that compulsory licensing positively influenced irrigation water use efficiency. This was an interesting result for water policy reform in South Africa, indicating a positive step towards attainment of the water reform objectives. This finding implies a call towards more widespread implementation of compulsory licensing in order to foster irrigation water use efficiency. The positive significance of compulsory licensing on WUE was attributable to the incentive it gives to farmers as an entitlement to water hence more efficient water use (Burness & Quirk, 1979). Compulsory licensing is a water right and just like any other property right, it fosters security of ownership and encourages farm level investments and efficiency (Wang, 2010; Frija et al., 2009; Speelman et al., 2008).

The results further show that farmers with more years of schooling were likely to be more water use efficient. This was in line with the findings of Dhungana et al., (2004), Binam et al., (2004) ,Wang, (2010), who found that farmers above a certain threshold of schooling years were more likely to be efficient in their farming activities. Our findings thus support Schultz (1964) hypothesis that, education improves the ability to perceive, understand, and react to new endeavors and nurtures farmers managerial skills. Schooling improves access to information from a variety of sources such as newspapers and instruction manuals (Rosenzweig, 1995)

Technical assistance has in the past been regarded as a positive driver of water use efficiency (Frija et al., 2009); Binam et al., 2004; Bozoğlu & Ceyhan, 2007). This study examined technical assistance received by farmers and in reference to the sources of such assistance. A surprising result was that, farmers who obtained their technical assistance from the DWAF were less efficient in water use compared to farmers who obtained their technical assistance from private companies, WUAs and their fellow farmers. This could mean that DWAF is not as efficient as the private companies and WUAs in disseminating technical information to irrigation farmers. This was in line with the findings of Binam et al., (2004) who attributed it to bureaucratic inefficiency, poor program design and generic inherent weaknesses in public operated systems. More so, the top down approach used by government systems is ineffective in improving farmer knowledge and more participatory approaches are preffered.

Crop choice significantly affects water use efficiency and previous studies recommend growing crops that have higher profit returns per unit (m^3) of water used (Speelman et al., 2008; Njiraini & Guthiga, 2013). The findings from this study indicate that vegetable and cereal crop growers were less water use efficient. However, comparison of crops in terms of profit per unit (m^3) of water used was beyond the scope of this study.

Table 3.7: Effects of water policy on irrigation water use efficiency: Tobit results

Variable	Coefficient	Standard error	P value
WUA-membership(1=yes,0=no)	0.073	0.064	0.258
Compulsory Licensing compliance(1=yes,0=no)	0.389***	0.133	0.004
Region- Middle Olifants	0.002	0.118	0.921
Region- Lower Olifants	-0.116	0.129	0.370
Leadership in WUA(1=yes, 0=no)	0.048	0.164	0.770
Gender(1=male, 0=female)	-0.035	0.064	0.587
Years of schooling	0.011*	0.006	0.057
Main occupation-small scale	0.098	0.131	0.457
Main occupation-other	-0.010	0.175	0.955
Farming years	0.002	0.002	0.449
Farm size- ln farm size	0.000	0.000	0.266
Landclaims (1=yes,0=no)	0.012	0.117	0.916
Income- ln income	-0.002	0.016	0.921
Water cost- ln water cost	-0.021	0.013	0.118
Technical assistance (1=DWAF,0=others)	-0.246**	0.100	0.015
ICT tool	0.020	0.058	0.732
Perenial crop growers (1=yes,0=no)	0.006	0.123	0.963
Cereal crop growers (1=yes,0=no)	-0.169*	0.087	0.054
Vegetable crop growers (1=yes,0=no)	-0.282**	0.113	0.014
Irrigation method- drip	-0.085	0.157	0.588
Irrigation method-flood	-0.084	0.171	0.623
Irrigation method-other	-0.025	0.249	0.922
Irrigation method-sprinkler	-0.016	0.162	0.922
_cons	0.717**	0.333	0.033
N=179	R^2 =0.216	P=0.0001	

Source: Own compilation

3.5.3 Effects of water policy on irrigation water quality: Multinomial Logit (MNL) results

We estimated a multinomial logit model (MNL) to assess the factors influencing water quality used in irrigation farming in the Olifants basin. Among them, we included water policy factors to assess their effectiveness on water quality status amid the NWA implementation process. Table 3.8 gives the results of the MNL regression. The dependent variable (water quality) was a multivariate variable with four possible quality categories as outlined by DWAF and perceived by the farmers in this study. These are namely: (Ideal (good) - the water has no effect on the user in any way, acceptable (moderate)-slight to moderate problems exist, tolerable (bad)-moderate to severe problems encountered and unacceptable (very bad) - highly unusable water). The acceptable (moderate) category is used as a base category hence we describe the results for the remaining three categories. Estimation of the MNL regression model used maximum likelihood procedures. The chi statistic (p-value < 0.0000), suggests that the model fit the data well and is highly explanatory.

Ideal water quality

For the ideal water quality category, the number of farming years, occupation and farming of cereals significantly explain water quality. More farming years negatively affected good water quality while involvement in activities other than farming and growing of cereal crops also negatively related to good water quality.

Tolerable water quality

Farmer location, occupation, cereal, and perennial crop farming significantly influenced tolerable water quality. Results indicate that, irrigators from the middle and lower Olifants were less likely to use water of tolerable quality compared to their upper Olifants counterparts. Respondents who were engaged in other nonfarm activities were more likely to use water of tolerable quality compared to the commercial irrigation farmers. Farmers growing perennial crops were less likely to use water of tolerable quality in comparison to those who did not engage in perennial crops farming. Cereal crop farmers on the other hand were more likely to use water of tolerable quality unlike none cereal growers.

Bad water quality

The results indicate that farmers compliant to compulsory licensing, those involved in WUAs/informal water use groups, and the leaders in these groups were less likely to use very bad quality water. This was in line with Shah, (2002) who reported positive and significant effects on water use, under cooperative irrigation management in WUAs. The study results further indicate that farmers who paid high costs for their water were less likely to use bad quality water; we suggest that given their ability to pay higher costs for higher water quantities used, these farmers could be in a position to treat their water for farming activities before use. The exporting farmers in the study region were indeed observed to treat their water beforehand for their farming activities. The results further show that, small-scale farmers and individuals involved in other non-farm activities were more likely to use water of bad quality compared to their large scale counterparts. Additionally, the results indicate that farmers with large farm sizes were less likely to use bad quality water; these were mainly the commercial scale farmers. Khalkheili & Zamani, (2009) suggested that large-scale landholders have more stakes to loose hence the incentive to find alternative coping strategies.

Farmers with more schooling years and farming experience were less likely use bad quality water probably because they had discerned ways of differentiating and coping with different water qualities for their farm activities given their knowledge and experience. We further found that farmers faced with tenure insecurities were less likely to use bad quality water and this could be due to their minimal investments in farming activities thus not much water used in agriculture. Shah, (2002), and Adger & Luttrell, (2000) suggest that insecure property rights limit farmers from making any major investments in their farming activities. Our results also indicate that recipients of technical assistance information about water policy from DWAF and extension agents were more likely to use water of bad quality, which was a surprising result from this study. However, this could point out to weak extension services or the fact that, the policy process has not yet attained full implementation and desirable results. Farmers in the middle and lower Olifants were more likely to use water of very bad quality compared to those in the upper Olifants region. This was attributed to their location in the downstream part of the basin; Cardenas, (2009) suggested that location of water users along a river basin is a determining factor in the appropriation of the resource. Lastly, our results show that cereal growers were less likely to use bad quality water.

Table 3.8: Effects of water policy on irrigation water quality: MNL results

	Ideal quality			Tolerable quality			Unacceptable quality		
Variable	**Coeff**	**Se**	**P**	**Coeff**	**Se**	**P**	**Coeff**	**Se**	**P**
Region-middle Olifants	1.142	1.181	0.334	-2.368*	1.270	0.062	6.780***	2.594	0.008
Region-lower Olifants	0.135	1.297	0.917	-1.612*	0.958	0.092	7.422***	2.732	0.007
WUA-membership (1=yes,0=no)	-0.807	0.514	0.116	-0.238	0.694	0.731	-4.953***	1.862	0.008
Compulsory Licensing compliance (1=yes,0=no)	0.971	1.201	0.419	1.795	1.215	0.140	-7.625***	1.820	0.000
Leadership in WUA (1=yes,0=no)	0.742	0.914	0.417	-0.297	0.828	0.720	-3.915**	1.554	0.012
Gender (1=male,0=female)	0.232	0.457	0.613	0.896	0.574	0.119	-0.732	1.148	0.524
Years of schooling	-0.041	0.045	0.367	0.019	0.053	0.725	-0.168*	0.107	0.096
Main occupation-small scale	-0.683	0.819	0.405	0.457	1.593	0.774	10.738***	2.936	0.000
Main occupation-other	-0.094*	1.201	0.058	2.974*	1.645	0.071	17.951***	4.428	0.000
Farming years	-0.050**	0.022	0.022	0.012	0.020	0.571	-0.082**	0.039	0.039
Land claims (1=yes,0=no)	0.885	0.836	0.284	-0.465	1.298	0.720	-18.504***	1.455	0.000
Technical assistance (1=DWAF,0=others)	-0.096	0.869	0.912	1.281	0.864	0.138	3.245**	1.504	0.031
ICT tool for water management (1=yes,0=no)	0.285	0.461	0.536	0.145	0.589	0.805	-0.530	0.999	0.596
Water cost-ln water cost	0.000	0.000	0.405	-0.000	0.001	0.882	-0.923***	0.190	0.000
Perennial crops grown (1=yes,0=no)	-1.013	1.140	0.374	-1.508*	0.879	0.086	-0.226	1.698	0.894
Cereal crops grown (1=yes,0=no)	-0.972*	0.514	0.058	1.879**	0.911	0.039	-2.268**	1.009	0.025
Vegetable crops grown (1=yes,0=no)	0.911	0.925	0.325	1.102	0.844	0.192	5.617*	3.124	0.072
Farm size-ln farm size	0.003	0.002	0.185	0.001	0.002	0.516	-0.211***	0.057	0.000
Income-ln income	-0.025	0.125	0.860	-0.053	0.099	0.592	-0.161	0.120	0.179
_cons	1.228	2.355	0.602	-3.004	2.453	0.221	-23.803***	7.855	0.002
N=179	R^2 = 0.263			P = 0.0000					
N by water category: Acceptable=60	Ideal=52			Tolerable=31			Unacceptable=36		

Source: Own compilation

3.6 Conclusions and policy recommendations

IWRM is now a popular approach to address issues of water management given rising water scarcity. However, literature lacks enough evidence of the effect of the proposed water principles on water use and its management. Some mixed outcomes exist while the effects of some of the associated policies remain unknown. In the beginning of this chapter, we examined the organizational structure of institutions involved in management and implementation of the 1998 South African water Act. This was in effort to shed light on who influences the activities of the water policy process, the governance structure for the actors, rules setting procedures, institutional interactions, and possible challenges of water policy implementation. The South African government has set up three main tiers of water management at the national, regional, and local levels. The water management tiers are under the jurisdiction of the water minister through DWAF, CMAs, and WUAs respectively. However, despite the stipulated roles for each of the bodies, so much power was still vested with the minister of water affairs who had authority over most water activities at all the three levels (Bourblanc & Blanchon, 2013). Power struggles, among other factors remained adamant and seemed to be the obstacle in the way of the NWA implementation (ibid). We recommend streamlining of the organizational structures involved in water management in order to address challenges facing the current water reforms.

Secondly, we reviewed several of the stipulated water policies in the Act and highlighted on their past, present, benefits, costs, and possible challenges to implementation. Apparently, none of the investigated water policies was in full operation in the Olifants basin at the time of this study. We found that some progress was manifest for water pricing and compulsory licensing while formation of WUAs seemed partial in operation. However, some discrepancies in water pricing existed between water users and the water authorities that indicated flawed implementation. Water trade was non-operational for the Olifants' basin farmers while payment for effluent discharges by industry and mining is yet to kick off.

Thirdly, the study used regression methods to examine the effects of water policies among other factors', on water use quantities, quality and water use efficiency in irrigation farming in the Olifants basin. Water use efficiency was assessed using DEA methods and the results indicated that irrigation farmers in the Olifants were water use inefficient; the average water use efficiency was only 31 percent suggesting major room for improvement and water re allocation. Various demographic, socio economic and institutional factors influenced water use quantities, efficiency, and quality. The OLS results showed that, involvement in WUAs, occupation, farm size, level of income, water costs and crop choice significantly influenced water use quantities of farmers. The Tobit results showed that compulsory licensing, schooling years, technical assistance, and crop choice influenced water use efficiency. The MNL results on the other hand indicated that, compulsory licensing, involvement in WUA, and water costs among other factors negatively influenced the use of bad quality water. Use of ideal water quality was explained by farming experience and cereal farming while tolerable water quality, was significantly explained by farmer location, main occupation and crop choice.

We conclude that the array of factors influencing the various aspects of irrigation water use, should guide policy towards better water management; this is especially so for the examined water policy reform factors of compulsory licensing, WUAs and water pricing. For example, the highly significant positive effect of compulsory licensing on water use efficiency highlights the importance of water rights and lays emphasis on water reforms. The water rights ensure farmers have entitlement to the water they use and promote water use efficiency. Current water prices on the other hand do not seem to encourage water saving as farmers comfortably pay the corresponding costs for higher quantities of water used. We recommend a review of the current tariffs and strict implementation of the same. Other factors such as technical assistance point to the needed improvement in extension service and alternatives of information dissemination. Schooling points to the importance of capacity building though it is a difficult target for policy in the short run. In the short term, farmers can best learn from the practices of their efficient counterparts, possibly through extension tools such as farmer field days.

Chapter Four

4. Impacts of water pricing and water rights on farmers' welfare

4.1 Introduction

In many parts of the world, irrigated agriculture is a pathway into developing competitiveness in the agricultural sector and encouraging rural development (Bazzani et al., 2005). However, conflicts arise due to water scarcity and existing competition between sectors and users. The increased worldwide water scarcity and its associated negative impact on agricultural production has therefore been the center of attention among policy makers and scholars (Yanget al., 2003). Various Integrated Water Resource Management (IWRM) policies have in return been suggested to address the water scarcity situation and streamline irrigation water use (Yang et al., 2003; Speelman et al., 2009). IWRM strategies are envisaged to bring major changes in water resource management and more so, in irrigation farming. Water rights and water pricing are such policies under IWRM, highly prioritized in the policy agenda of many water-scarce countries such as South Africa. The policies are envisioned to regulate water scarcity in various ways and eventually improve water use efficiency and conservation (Yang et al., 2003; Varela-Ortega, 1998). South Africa, having been ranked among the World's water scarce countries by UNESCO-WWAP, has made attempts to control the existing and foreseen water shortages through implementation of the country's Water Act (Muller & Schreiner, 2009). The implementation process has however been slow and laden with numerous challenges (Muller & Schreiner, 2009). Nevertheless, the stipulated reforms in the water Act are expected to have major impacts on water management, welfare of resource users and other aspects of the South African economy (Hassan & Thurlow, 2011; Muller & Schreiner, 2009; Diao et al., 2005; Speelman et al., 2009).

Appropriate water pricing tariff structures would be a way forward to meeting the social, political, and economic water goals amid scarcity, competing uses, and rising populations (Rogers, Silva, & Bhatia, 2002). Proponents of water pricing policy argue that it creates awareness of water scarcity to farmers and creates incentives for them to move towards more efficient water use (Frija et al., 2011). It results in reduced quantities of water demanded and efficient water reallocation to populations previously not served hence nurturing equity (Molle et a., 2008). When the water price reflects the true cost of water, it fosters sustainability in water use because users assign it to the most valuable uses and this reduces demands on the resource base (Rogers et al., 2002). Increases in water prices also lead some farmers to lease out their land to better investors while others invest in better water-saving technologies (Frija et al., 2011; Molle et al., 2008). Additionally, water pricing fosters managerial efficiency through increased revenues which can be used for improvement of water infrastructure and capacity building of stakeholders

(Molle et a., 2008). Despite the many benefits accruing to water pricing, this policy tool is unlikely to be feasible for all stakeholders especially resource poor farmers (Speelman et al., 2009). Water pricing may lead to reduced yields and food insecurity due to abandoned production, which results in lost revenues, financial vulnerability and risk associated with possible alternatives (Molle et al., 2008 ; Speelman et al., 2009; Gomez-Limon., 2004 ; Speelman et al., 2009; Yang et al., 2003). These mixed results of water pricing in literature give room for more context specific analysis to inform policy and decision-making especially in countries undergoing water reforms such as South Africa.

Water rights, on the other hand, have increasingly received recognition for their importance in water management. This is because properly defined water rights enhance the value of the water resource through fostering water productivity, equity in water allocation, optimization of benefits from investments in water supply, and improvement in rural livelihoods thus poverty alleviation (Speelman et al., 2010). On the contrary, non-clear water rights result in high transaction costs of water use decisions and inhibits water use efficiency (Speelman et al., 2010). In South Africa, water rights instituted through compulsory licensing act as strategies towards efficiency, equity, and sustainability in water use. Despite the envisioned benefits, research on the possible impact of compulsory licensing on water users welfares is lacking. Previous studies have mainly focused on the inequities of the compulsory licensing process such as insecurity of water licenses and limited transferability (Backeberg, 2006; Gillitt et al., 2005).
It is evident that water pricing and water rights policies/principles play important roles as instruments to address water scarcity issues. Knowledge and understanding of their contribution and impact on water savings and on people's incomes is important for present and future policy analysis and decision making (Varela-Ortega, 1998). Therefore, following Roibás et al., (2007), we argue that the suitability of any policy for natural resource management depends on the gains or losses in welfare it generates to the target populations.

Current literature from different parts of the world contains a mixture of varying impacts of different water policies on people's welfare. In Italy, for example, Bartolini et al. (2007) found that water pricing had a lower effect on welfare compared to policies of agricultural market scenarios such as world and regional markets. Water prices only worked to reduce water use for the annual less water intensive crops. Berbel & Gómez-Limón (2000) found a negative impact of water pricing on farm income, crops grown, and employment in the short run for Spanish irrigation farmers. Similar findings were reported by Riesgo & Gómez-Limón (2006) for the Douro basin of Spain where a water pricing policy reduced farmers' incomes. In northern china, water pricing had failed to incentivize water conservation due to a shift towards high value yet water intensive crops (Yang et al., 2003). Frija et al., (2011) reported endangered small-scale farmer livelihoods due to increases in water prices in Tunisia. The small-scale farmers resulted to using more land and less water while their technically efficient large-scale counterparts could easily afford higher water prices. Similarly, water price increases adversely affected smallholder farmers in Limpopo, South Africa which in turn affected their ability to pay for water rights reforms (Speelman et al., 2010). In the Northwest province of South Africa, small-scale farmers responded to water price increases by reducing quantities of water used in farming. However, the price increases were not sustainable because the farmers could not afford thus negatively affecting their farm profits (Speelman et al., 2009). In the Jordan valley, Molle et al., (2008) reported that water pricing was only effective in recovering the operation and maintenance costs incurred for water management. Moreover, findings from Seville, Spain indicated that water price increases resulted in less welfare losses compared to supply cuts. Nevertheless, water prices still caused welfare losses (Roibás et al., 2007). Irrespective of the mixed water pricing outcomes, most of these studies recommended a favorable water price applied in combination with wider agricultural policies in order to reduce adverse effects on small-scale farmers. Rogers et al., (2002) suggest that water pricing can only attain its foreseen goals if water resources management takes place in an integrated approach whereby the legal, economics, and environmental facets complement each other. Research on the impact of water rights on water users' welfare is however lacking in literature.

Previous studies assessing the relationship between water policies and water users' welfares focus on either single policies, one type of farming, or use case study approaches which make it difficult to generalize policy recommendations for wider areas. The current study seeks to broaden the scope by simultaneously assessing the impacts of water rights and water pricing on the welfare of both large-scale and small-scale farmers' in the Olifants basin, using a representative farm approach. The current study bases on the Expected Utility Theory (EUT), which incorporates uncertainty in farmer decisions rather than pure profit maximization like in previous studies. Additionally more crops are considered for the analysis and differentiated between large scale and small scale farmer crops. Section 4.2 outlines the empirical framework ,4.3 describes the data used, 4.4 discusses the results while section 4.5 concludes.

4.2. Empirical Framework

4.2.1 Expected Utility Theory (EUT)

Two major approaches have previously been used to assess welfare impacts of policy: econometric models that rely on time series data, and mathematical programming models that are based on cross sectional data (Sadiddin, 2009). The former are advantageous because the supply and demand functions indicating market equilibriums and prices help to understand the overall behavior of the agricultural sector and its sub sectors. However, difficulties associated with econometric methods lie in data problems. Firstly, there is usually need to obtain own and cross price elasticities of supply functions estimated. Secondly, the process requires sufficient degrees of freedom in the time series data used – this is difficult to obtain especially for developing countries (Hazell and Norton, 1986 quoted in Sadiddin, 2009). Thirdly, using econometric models to analyze current and alternative policies is troublesome due to economic structural changes such as policy or external shocks. This implies that it is usually almost impossible to base the policy analysis on extrapolations from historical data when considering newer policies (Hazell and Norton,1986). Fourthly, econometric models require assumptions of competitive markets which does not necessarily apply for many commodities especially in the developing world (Sadiddin, 2009). Lastly, the case of household modelling is not applicable to the commercial farming sector which does not consume its own output (Taylor & Adelman, 2003).

Mathematical programming models overcome these problems because they are based on cross sectional data with a high level of detail. The supply functions provide the necessary information to estimate derived demand functions of inputs; therefore allowing tracing impacts of policy on both outputs and derived demand of agricultural inputs such as water and labor (Hazell & Norton, 1986). However, it is important to carefully choose the objective function and the constraints since they greatly impact on the results of mathematical programming (Sadiddin, 2009). To represent the cross effects present in the agricultural sector, which is usually hard to capture with econometric models, mathematical programming models are combined with a representative farm approach, which allows reducing the amount of data needed. A representative farm approach is important because outcomes of a policy are dependent on reactions of individual actors which are in turn influenced by farm structure in terms of resource endowments, technology, geographical location, and many other forms of classification (Hazell & Norton, 1986; Sadiddin, 2009; Walter, 2010). The representative farm approach further increases ability of the mathematical programming to measure aggregate impact of policy for specific regions depending on their characteristics such as location and resource endowments.

Mathematical programming models have previously been used to address problems in the irrigation sector whereby assumptions are usually made with regard to farmers' objectives (Bazzani et al., 2005; Berbel & Gómez-Limón, 2000a; Bartolini et al., 2007). Previous studies have maximized farm profit – captured as the farm gross margins – subject to constraints such as land, labor, and water use in attempt to derive the impact of agricultural related policies on farm incomes and welfare (Berbel & Gómez-Limón, 2000a; Bazzani et al., 2005). However, maximising farm profit fails to incorporate risk and uncertainty faced by farmers. This study incorporates uncertainty of farmer decisions by maximizing farmers' utility of expected income subject to production constraints. Physical and financial constraints, uncertainties arising from variations in yields, prices, and policy, are all important in a farm's decision-making process (Sadiddin, 2009). Farmers try to balance the possibility of negative outcomes rather than maximize profits due to uncertainty (ibid). It is therefore important to include risk and/or uncertainty in farm modeling to match farmer behavior.

The Expected Utility Theory (EUT) developed by Von Neuman and Morgestern (1944) is one of the most established decision theories in economics. This theory predicts that risky or uncertain prospects are ranked by their expected utility (Hazell & Norton, 1986; Sadiddin, 2009). It is based on four axioms fulfillment of which does not restrict the utility function of the decision maker to a particular functional form but rather leaves it open to suit choice of that which best describes farmer behavior or computational ease when dealing with a large number of farmers. The four axioms are:

(i) Ordering **-** whereby a decision maker faced with two risky prospects a and b, chooses one of them or remains indifferent between the two

(ii) Transitivity whereby if there is a third option c and the decision maker prefers b to c, then it's likely that they prefer a to c or indifferent between the two choices

(iii) Continuity which states that if there exists three lotteries a, b and c and a is preferred to b while b is preferred to c, then there should be a possible combination of a and c such that a decision maker is indifferent between this mix and b

(iv) Independence which states that if an individual prefers a to b and there exists a third risky outcome c, a lottery giving a and c is preferred to b and c (Harderker et al., 2004 cited in Sadiddin, 2009).

The mean variance analysis approach, which presumes that farmers base their choices on expected incomes and the associated variances, is widely used for the execution of the expected utility theory (Hazell & Norton, 1986; Sadiddin, 2009). It assumes that expected utility of farm income is measureable through certainty equivalence. Certainty equivalence is equal to the expected farm income (Gross Margin) less income variation. Previous studies (Backeberg, 2006; Gillitt et al., 2005) in South Africa indicate that, less investment in irrigated agriculture is associated with uncertainty stemming from insecure water licenses and prices. Therefore, following Sadiddin, (2009), the current study employed the mean variance analysis approach to approximate the EUT. Other alternative theories such as prospect theory and cumulative prospect theory criticize the EUT on basis of choice behaviours that may violate either of the four axioms giving rise to unpredictable preferences. However, these alternative theories combine perceptions and preferences which both affect behavior under risk or uncertainty through a mean variance; which is what the EUT does. This then implies that non of the alternative theories are empirically superior to the EUT.

4.2.2 The Mathematical Programming Model

This study used farm-level models (taking into consideration farm characteristics) to simulate farmer reactions towards different water prices and compulsory licensing fees. Scenarios help to depict what is feasible at the farm level rather than for prediction purposes, i.e. the scenarios give insights about the future. The mathematical programming techniques result in optimal cropping mixes and farm activity combinations for the two types of representative farms studied (small scale and large scale). Models set up signify each of the representative farms. Characterization of farmers into representative homogenous farms allows to reduce bias found in fully aggregated models (Gómez-Limón & Riesgo, 2004). This is because the two categories of farmers are dissimilar with regard to farm sizes, level of investments, crops grown, farm technologies, and income. Each farm type maximized the expected utility of agricultural income subject to constraints of land, labor, and water. The year 2013 is the reference year for the data in this study and acts as the baseline. Water tariffs and compulsory license fees simulations are therefore conducted, and compared to baseline results

A representative farm maximizes the expected utility of farm income CE in the objective function *4.1*, subject to land *(4.13)*, labor *(4.14)*, and water *(4.15)* constraints. CE is the certainty equivalence of the corresponding expected farm income (GM) measured in South African Rand (ZAR). GM is the Gross Margin and the measure of expected farm income in ZAR. RAC is the absolute Risk Aversion Coefficient incorporated to estimate the uncertainty in making farm decisions. It is assumed to take a value for which the optimal solution gives cropping mixes as close as possible to the observed data. Var is the variance of farm income in ZAR, which is a product of farm output($Q_j Q_k$) and the covariance of prices (σ_{jk}) calculated in equation *4.3*.

$$Max\ CE = GM - RAC * Var \qquad (4.1)$$

Equation *4.2* calculates the farm gross margin as the total farm revenue (R) in ZAR less the farm variable costs (VC)

$$GM = R - VC \qquad (4.2)$$

$$Var = \sum_j \sum_k Q_j Q_k \sigma_{jk} \qquad (4.3)$$

The farm output of the j-th product (Q_j) in Kgs was estimated as:

$$Q_j = \sum_y \sum_c X_c * Y_{c,j,y} \qquad (4.4)$$

Where, X_c is the level of cropping activity chosen in the optimal solution to represent the cultivated area of the c-th crop in Ha. $Y_{c,j,y}$ is the unit yield coefficient representing the amount of j-th product obtainable from one unit of the c-th cropping activity in Kgs/Ha in year y. Therefore, equation *4.4* gives the total output produced for each product in year 2013.

The farm revenue given in equation *4.5*, was estimated as a product of the j-th farm output and the expected price (Ep_j) of the j-th product in ZAR. The expected price (Ep_j) on the other hand is estimated by multiplying the price ($Ps_{j,n}$) of the j-th product (ZAR /Kg) when the n-th state of nature takes place, by the probability of the n-th state of nature taking place ($prob_n$). Ten states of nature(s_n), were assumed (each with a probability of occurrence) in order to generate a matrix of prices for each product output as a way to introduce uncertainty into the model. Equation *4.6* gives the expected price for each product useful in calculating farm revenue.

$$R = \sum_j Q_j * Ep_j \qquad (4.5)$$

$$Ep_j = \sum_n Ps_{j,n} * prob_n \qquad (4.6)$$

The covariance of prices(σ_{jk}) of the k-th and j-th products in ZAR was calculated by the variance – covariance matrix of the product prices given in equation (*4.7*); the obtained covariance of prices was used to calculate the variance of the total farms' income earlier in equation *4.3*.

$$\sigma_{jk} = \sum_n \left(Ps_{j,n-}Ep_j\right) * \left(Ps_{k,n-}Ep_k\right) * prob_n \qquad (4.7)$$

The total variable costs are given as:

$$VC = F_{c1} + I_c + L_c + W_f \qquad (4.8)$$

Where F_{c1} is the cost of seeds, fertilizers, and other chemicals in ZAR, I_c is the total cost of water in ZAR, L_c is the cost of hired labor in ZAR and W_f is the licensing fee in ZAR per farming household. Equations 4.9 through to 4.12 are the variable cost components.

$$F_{c1} = \sum_c \sum_f X_c * In_{f,c} * Pr_{f,c} \qquad (4.9)$$

$$Ic = \sum_t \sum_c X_c * Dq_{c,t} * Dp \qquad (4.10)$$

$$L_c = \sum_t \sum_c X_{c,t} Hlab * Wh \qquad (4.11)$$

$$W_f = Licensing\ fee \qquad (4.12)$$

Where, X_c is the level of cropping activity chosen in the optimal solution to represent the cultivated area of the c-th crop in Ha. $In_{f,c}$ are the physical inputs unit requirements (seeds, fertilizers, chemicals) for the f-th input of the c-th cropping activity in Kg/Ha. $Pr_{f,c}$ are the input prices defining price of the f-th input used for the c-th cropping activity in ZAR /kg. Dq_{ct} are unit requirements of water for the c-th cropping activity in the tth month in M^3. Dp is the price of water in ZAR / M^{3,} $Hlab$ is the amount of hired labor (workers) while Wh is the wage rate for hired labor in ZAR /worker.

The inequality constraints for the model are given in equation *4.13* through to *4.15*.The land constraint is given as:

$$\sum_c X_c * Lr_c \leq L \qquad (4.13)$$

Where, Lr_c is the unit requirement of land for the c-th cropping activity in Ha, and L is the total farm size in Ha. It means that the total cropped land must not exceed the total farm size. The labor constraint is given as:

$$\sum_c X_c * Labr_{c,t} \leq Flab_t + Hlab_t \qquad (4.14)$$

Where, $Labr_{ct}$ is the unit requirement of labor for the c-th cropping activity in the tth month, and $Flab_t$ is the family labor available in the tth month. This implies that the total labor use per month must not exceed family labor and additional hired labor available. Lastly, the water quantity constraint is estimated as:

$$\sum_c X_c * Watr_{c,t} \leq Wat_t \qquad (4.15)$$

Where $Watr_{c,t}$ is the unit requirement of water for the c-th cropping activity in the tth month, in m^3 per Ha. Wat_t is the irrigation water available in the tth month in M^3. The equation indicates that the amount of water used in a month must not exceed that which is available for use in that given time period.

4.3 Data

A field survey of the Olifants elicited data from large-scale/commercial and small scale irrigation farmers in the basin. We define small scale as farms operating on less than ten hectares while the large-scale farms were operating on land areas above ten hectares (Kloos, 2010). Chapter two of the thesis outlines the sampling procedure. Data used included physical inputs quantities, input prices, output quantities, output prices, land requirements for crops, wage rates, water licensing fees, water tariffs, and the risk aversion coefficient. We identified the crops grown by the two farming typologies and for each, calculated averages for all the data required. Large-scale farmers' crops included citrus, maize, grapes, onions, peas, wheat, summer vegetables, and winter vegetables. Small-scale farmer crops on the other hand included maize, mangoes, onions, peas, potatoes, and vegetables grown in summer and winter. Small-scale water use estimations based on capacities of pumps used to draw water from the rivers and the frequency of irrigation in non-metered cases. Local experts and extension agents further verified the small-scale water used quantities. Since some small-scale farmers do not pay the normal water tariff price to DWAF, we used the cost of fuel and electricity incurred for pumping water; we divided this by the cubic meters of water used to obtain price per cubic meter of water used by the small-scale farmers. Large-scale farmers reported their water use quantities and prices, with further verification from the respective irrigation boards. Labor was expressed in terms of man-days used per cropping activity while wage rates were averages of money paid per employee per month.

Yields and their prices were the averages of yields and prices respectively given by farms. Variability in prices of outputs introduced uncertainty in the model. We used the gauss-hermite quadrature method to generate a matrix of prices for each output assuming ten states of nature, each having an attached probability of occurrence. The assumption on prices is a lognormal distribution to ensure that they take non-negative values. The result is a set of ten prices for each product and their associated probability. We assumed land and machinery costs as fixed costs.

4.4 Results and discussion

4.4.1 Model Validation

Model validation is important in any empirical analysis as it improves model performance and problem insight (McCarl & Spreen, 2011). A model can either be validated by construct or by results; construct validation assumes that the model is properly built based on previous research and theory but does not involve any testing. Validation by results compares model solutions to the real observed outcomes. Therefore, in any validation process, construct precedes results validation. However, both remain subjective as it remains the modeler's decision on the validity of tests, criteria for the tests, what outputs to validate and data choice. Nevertheless, a validated model reveals its strengths and weaknesses which are important to users (McCarl & Spreen, 2011). Sadiddin, (2009) suggests that a mathematical programming model is only suitable for prediction purposes once validated to ensure that it replicates the observed data as close as possible. The validation process targets at getting the results of the optimal solution as close as possible to their observed equivalents for the variables chosen. In this study, we compared the quantities of outputs produced by farms, to the optimal level quantities attained by the model farms for the two farming typologies. We used the risk aversion coefficient for this purpose. Our model incorporated uncertainty into farmer behavior by assuming that the expected utility of farm income incorporates absolute risk aversion to portray farmers' behaviors towards uncertainty. Thus, a higher risk aversion coefficient indicates a more risk averse farmer.

McCarl & Spreen, (2011), show numerous ways to estimate the risk aversion coefficient. For this study, we estimated the risk aversion coefficient such that the difference between the optimal model solution and observed farmer behavior was minimized (Hazell & Norton, 1986; McCarl & Spreen, 2011; Sadiddin, 2009). Therefore, we solved the model for the two farm types using an iterative process and selecting numerous values of risk aversion coefficients (0.05,0.01,0.001,0.005,0.0001) until we arrived at values that gave the optimal solutions closest to the observed data as indicated in Table 4.1 below.

Table 4.1: Mathematical programming model validation

Smallscale crops	Risk aversion coefficient_0.0001		
crop name	**observed output data**	**optimal solution**	**percent change**
Maize	2442,32	2342,32	-4,09
Mangoes	2468,80	2468,80	0,00
Onions	2887,60	3287,60	13,71
Peas	800,00	800,00	0,00
Potatoes	343,77	343,77	0,00
VegS	2315,93	2315,93	0,00
vegW	1104,92	1104,92	0,00

	Risk aversion coefficient _0.0001		
Largescale crops	**observed output data**	**optimal solution**	**percent change**
Citrus	25000,00	24316	-2,74
Grapes	21298	20307	-4,65
Maize	2500,00	2531	1,24
Onions	18500,00	18033	-2,52
Peas	3137,21	3049	-2,81
Wheat	3219,38	3016	-6,32
VegS	12500,00	12158	-2,74
VegW	36022,50	35273	-2,08

Source: Own compilation

4.4.2 Impact of increasing water Tariffs on farmers' welfare

The effect of water pricing on welfare and other resource use is expected to differ by region given spatial diversity between regions and types of cropping patterns (Berrittella & Rehdanz, 2005 ; Diao et al., 2005). In this section we discuss the impact of water pricing and compulsory licensing on farmers welfares and water demand in the Olifants basin. Farm gross margins and certainty equivalents are used to show the changes in farmers' incomes due to changes in water prices and compulsory licensing fees. The year 2013 was our baseline year solved using the currently incurred water prices. Subsequent water price and license fees simulations were then performed in comparison with the baseline results to assess their impact on farm welfare and irrigation water demand. We calibrated our model starting at intervals of 50 percent price increases following the envisaged DWAF water prices.

The results (Table 4.2) indicate that gross margins of a small scale farmer declined by about 2.7 percent due to a 3000 percent increase in water price. This was equivalent to about 3 percent decline in the expected utility of income for small scale farmers. The increase in water tariffs further increased small scale farmers total farm production costs from 0.6 to 39.8 percent. The results show that similar increases in water tariffs for the largescale farmers resulted in lower impacts on their farm welfares and gross margins compared to their small scale counterparts. The decline in largescale farmers' expected utility of income and gross margins ranged from 0.02 -1.57 percent. The rise in water tariff costs for the largescale farmers accounted for about 2.25 percent of increase in total farm production costs which was far less compared to the 39 percent increase in production costs for the small scale farmers. This gave the impression that existing water tariff costs were insignificant for largescale farmers production costs, a finding that was corroborated by our expert interviews and FGD's results.

Table 4.2: Impact of water pricing on farmers' welfares

Smallscale farmers										
Tariff_ZAR	**%increase in tariff**	**Certainty equivalence**	**Change in welfare**	**%change in welfare**	**Grossmargin (GM)**	**Change in GM**	**%change in GM**	**Total prodn' costs**	**Change in total costs**	**%change in total costs**
0,44	Baseline	**332072**			**373988**			**25277**		
0,66	50	331920	-152	-0,05	373836	-152	-0,04	25429	152	0,6
0,88	100	331768	-304	-0,09	373684	-304	-0,08	25581	304	1,2
1,1	150	331616	-456	-0,14	373532	-456	-0,12	25733	456	1,8
1,32	200	331464	-608	-0,18	373381	-608	-0,16	25885	608	2,4
1,54	250	331312	-760	-0,23	373229	-760	-0,20	26037	760	3,0
1,76	300	331160	-911	-0,27	373077	-911	-0,24	26188	911	3,6
2,2	400	330857	-1215	-0,37	372773	-1215	-0,32	26492	1215	4,8
2,64	500	330553	-1519	-0,46	372469	-1519	-0,41	26796	1519	6,0
5	1036	328923	-3149	-0,95	370839	-3149	-0,84	28426	3149	12,5
10	2173	325471	-6601	-1,99	367387	-6601	-1,77	31878	6601	26,1
15	3309	322018	-10054	-3,03	363934	-10054	-2,69	35331	10054	39,8
Largescale farmers										
Tariff_ZAR	**%increase in tariff**	**Certainty equivalence**	**Change in welfare**	**%change in welfare**	**Grossmargin (GM)**	**Change in GM**	**%change in GM**	**Total prodn' costs**	**Change in total costs**	**%change in total costs**
0,36	Baseline	**997647**			**1995409**			**512504**		
0,54	50	997454	-193	-0,02	1995023	-386	-0,02	512647	143	0,03
0,72	100	997261	-386	-0,04	1994637	-772	-0,04	512791	287	0,06
0,9	150	997068	-579	-0,06	1994251	-1158	-0,06	512934	430	0,08
1,08	200	996875	-772	-0,08	1993865	-1544	-0,08	513078	574	0,11
1,26	250	996682	-965	-0,10	1993479	-1930	-0,10	513221	717	0,14
1,44	300	996489	-1158	-0,12	1993093	-2316	-0,12	513364	860	0,17
1,8	400	996103	-1544	-0,15	1992321	-3088	-0,15	513651	1147	0,22
2,16	500	995717	-1930	-0,19	1991549	-3860	-0,19	513937	1433	0,28
5	1285	992676	-4971	-0,50	1985467	-9942	-0,50	516191	3687	0,72
10	2663	987333	-10314	-1,03	1974781	-20628	-1,03	520136	7632	1,49
15	4034	982005	-15642	-1,57	1964124	-31285	-1,57	524052	11548	2,25

Source: Own compilation

Figure 4.1 depicts the impact of rising water tariffs on the expected utility of income. It is evident that though the change in welfare is minimal, the smallscale farmers are more adversely affected by a rise in water tariffs compared to their largescale counterparts. This result is in line with the findings of Speelman et al., (2010) Speelman et al., (2009) and Frija et al., (2011) who reported adverse effects on small scale farmers' welfares and livelihoods due to increase in water prices.

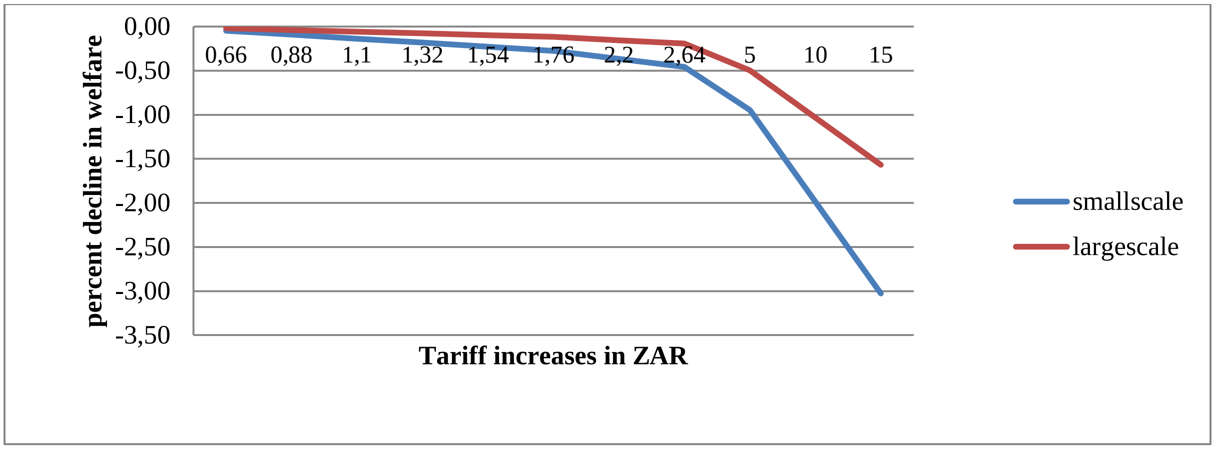


Figure 4.1: Impact of rising water tariffs on farmers welfares

Source: Own compilation

4.4.3 Impact of increasing water Tariffs on irrigation water demand

The results indicate that water demanded for irrigation is somewhat inelastic for the two types of farmers investigated (Figure 4.2). Specifically, the small-scale farmers, water demand remains unchanged given tariff price rises. We attribute this to the nature of the less water intensive crops they grow and tendency to shift to rain fed crops as suggested by (Gómez-Limón & Riesgo, 2004; Berrittella & Rehdanz, 2005). The responsiveness of farmers' water demands to changes in irrigation water prices is a function of many factors as suggested by Yang et al., (2003). Some of these include prevailing market conditions, lack of enforceable water rights, availability of substitute crops, possibility of opportunities outside agriculture, farmer self-sufficiency, freedom of decision making in production, and rural-urban economic development. For example, involvement of farmers in water management and decision making, results in higher responsiveness to price changes (Yang et al., 2003). Theoretically, increasing the price of a resource is expected to create incentives for better management and improve economic efficiency and welfare by triggering demand (Yang et al., 2003). However as observed in our study findings, this does not always apply for agricultural water use (Yang et al., 2003). Previous studies have indicated that water pricing results in economic, environmental, and social impacts but only when the elasticity of water demand is reactive to water price changes (Berrittella & Rehdanz, 2005). Inelastic water demand curves as observed for the small-scale farmers in this study have little impact on water use behavior. However, the price changes affect farmers' incomes (ibid). In cases of very inelastic water demand curves, water pricing would only be suitable for ensuring full water cost recovery rather than water conservation (Bartolini et al., 2007). Nevertheless, the prices should not be too high to be met by the system (ibid).

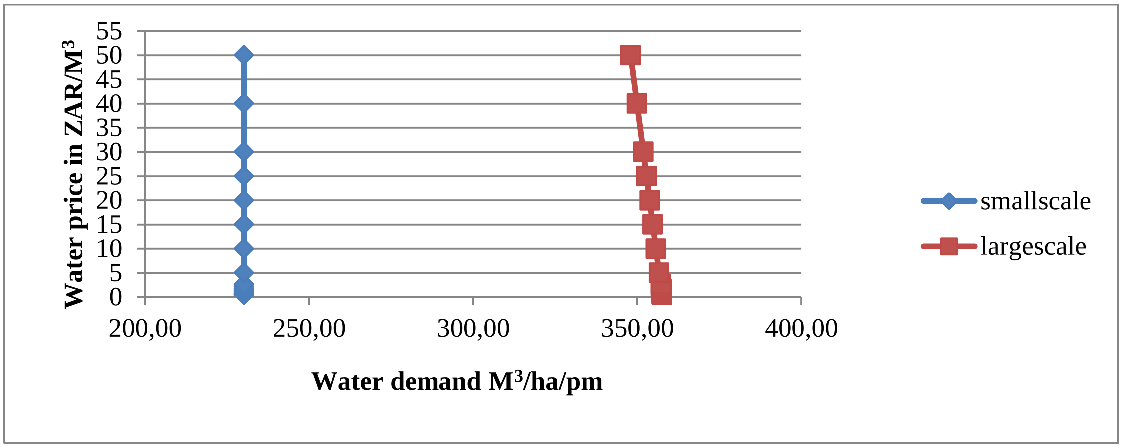


Figure 4.2: Small scale and large-scale water demand with increase in prices

Source: Own compilation

The results further indicate that the large-scale farmers' water demand is moderately elastic (Figure 4.2 and 4.3). We observe slight reductions in quantities of water demanded by the large-scale farmers albeit at very high prices. This implies that farm income would have to decline significantly higher before affecting water demand and consequently conservation. Following Schoengold et al., (2006) we argue that this could be as a result of overly subsidized water prices which do not give rise to much significant responses in water demanded due to price changes. Additionally, Frija et al., (2011) and Speelman et al., (2009) suggest that when water costs are insignificant in relation to total farm production costs like for the case of largescale farmers in this study, the quantity of water demanded remains less responsive to price changes. Gómez-Limón & Riesgo, (2004) and Berrittella & Rehdanz, (2005) suggest that the small changes in the quantity of water demanded can be attributed to a shift in crop choices to less water intensive ones which are less profitable, adoption of improved irrigation technologies that save on water and less land put into production.

The results further indicated a reduction in the quantities of outputs produced by the largescale farmers, at higher water prices as water use declined. In such a scenario, the resulting lost incomes due to reduced output production in the agricultural sector may be seen as a transfer of revenue to other sectors since the water saved maybe put into productive use in other sectors such as industry, recreation, and urban uses

(Gómez-Limón & Riesgo, 2004 ; Berrittella & Rehdanz, 2005). However, if the water saved is put into less valuable uses, this would imply less efficient allocation of resources due to water pricing. Figure 4.4 indicates the resulting individual fall in quantities of output produced by crop as water tariff prices increase. Figure 4.5 indicates the average reduction in quantities of outputs over all crops as water tariff prices increase. Results further indicated a slight gradual decline in labor and land allocated to the cropping activities as water prices increased and water use declined.

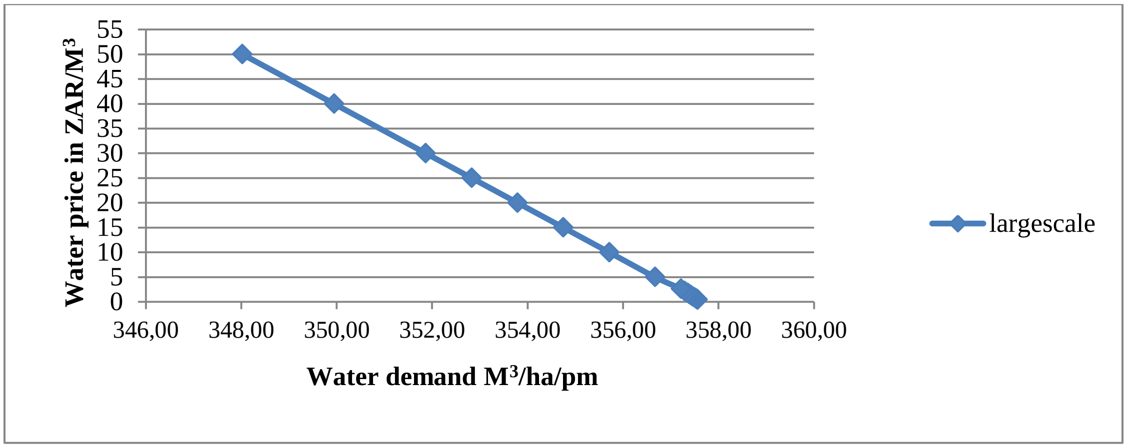


Figure 4.3: Large-scale water demand with increased prices

Source: Own compilation

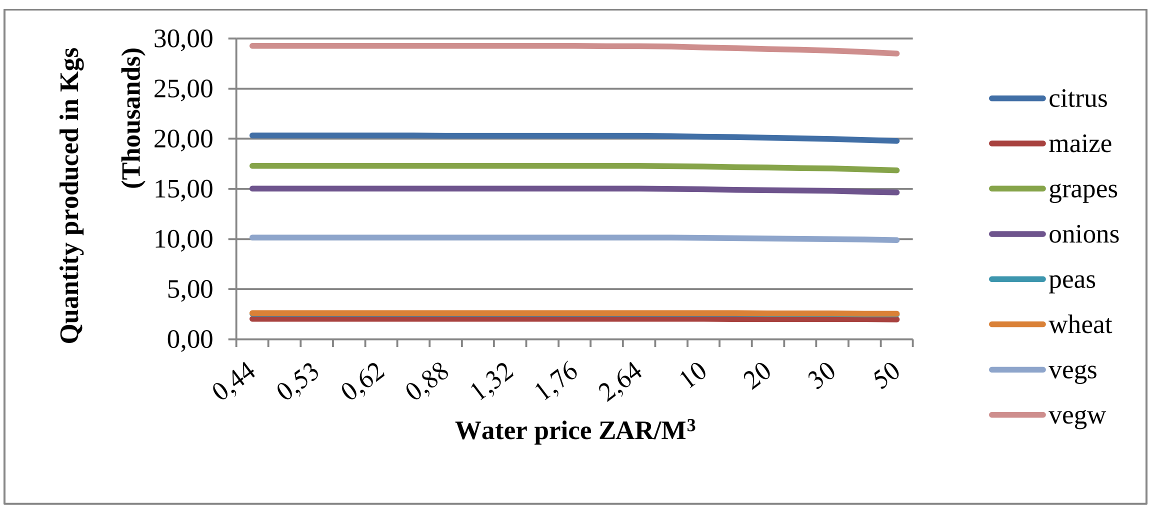


Figure 4.4: Reduced output quantities due to increased water prices

Source: Own compilation

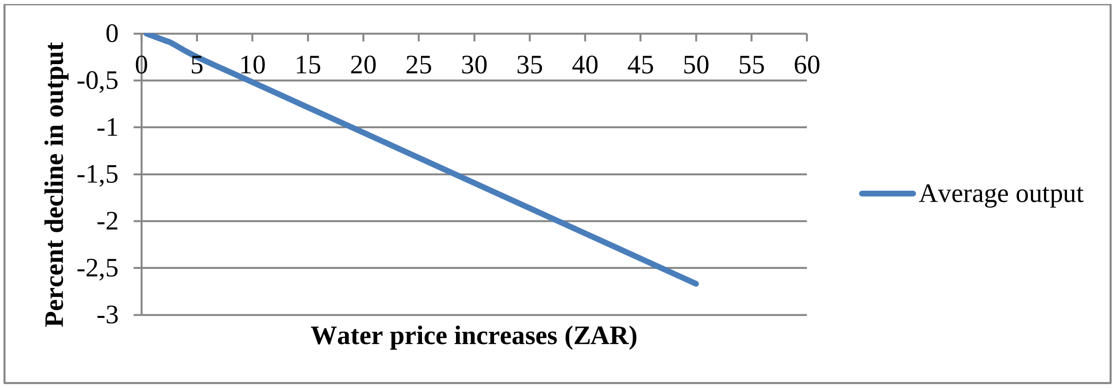


Figure 4.5: Percent reduction in average output quantities due to increased water prices

Source: Own compilation

4.4.4 Impact of compulsory licensing fee increases on farmer welfare

Current compulsory license fees in the Olifants basin are a constant charge of R 114 per farm per annum. Using this as our baseline, we vary the licensing fee by percent increases at intervals of 10 and 50 percent. Figure 4.6 shows that compulsory licensing fees increases result in smaller changes in welfare compared to water tariff increases (Figure 4.1). This is so despite the compulsory license fees being higher amounts than water tariff charges. This is due to the nature of the compulsory licensing charge being a single lump sum payment per annum unlike water tariffs, which are applicable per unit of each cubic meter of water used by farms. Specifically, the adverse effect of compulsory license fee increases is more severe on small-scale farmers' welfares, which reduce by 0.18 percent at 500 percent increase in compulsory license fees. On the other hand, large-scale farmers' welfare declines only by 0.006 percent at 500 percent increase in license fees (Figure 4.6). This implies that small-scale farmers would be harder hit by license fee increases than the large-scale farmers would. We further compare increases in compulsory license fees to total costs incurred in production activities. We report that for both categories of farmers, the compulsory licensing fees increases comprise a small percentage of the total costs of production (less than one percent). However, the compulsory license fees increases comprise a bigger part of the small-scale farmers' total production costs in comparison to the large-scale farmers' production costs (Figure 4.7).

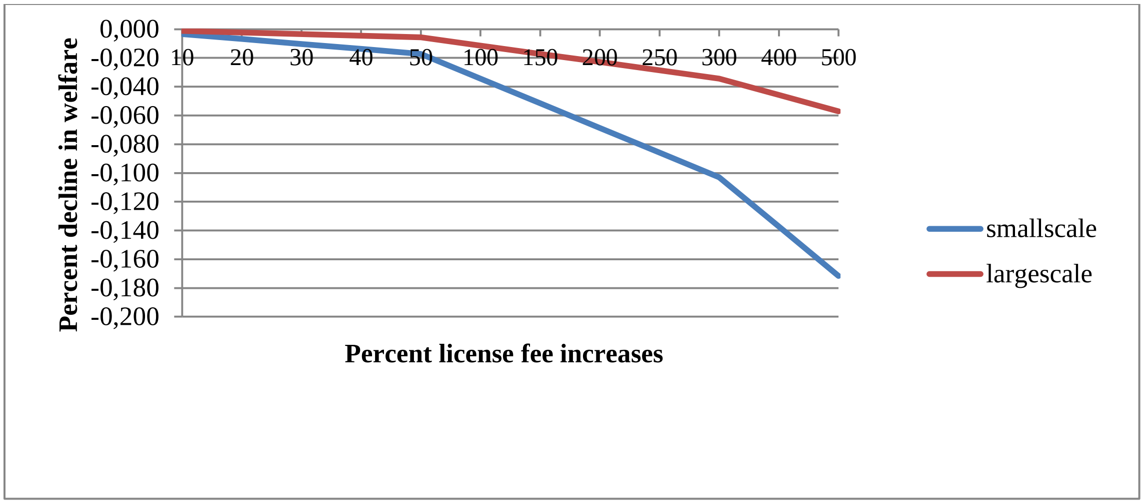


Figure 4.6: Impact of compulsory license fee increases on farmers' welfares

Source: Own compilation

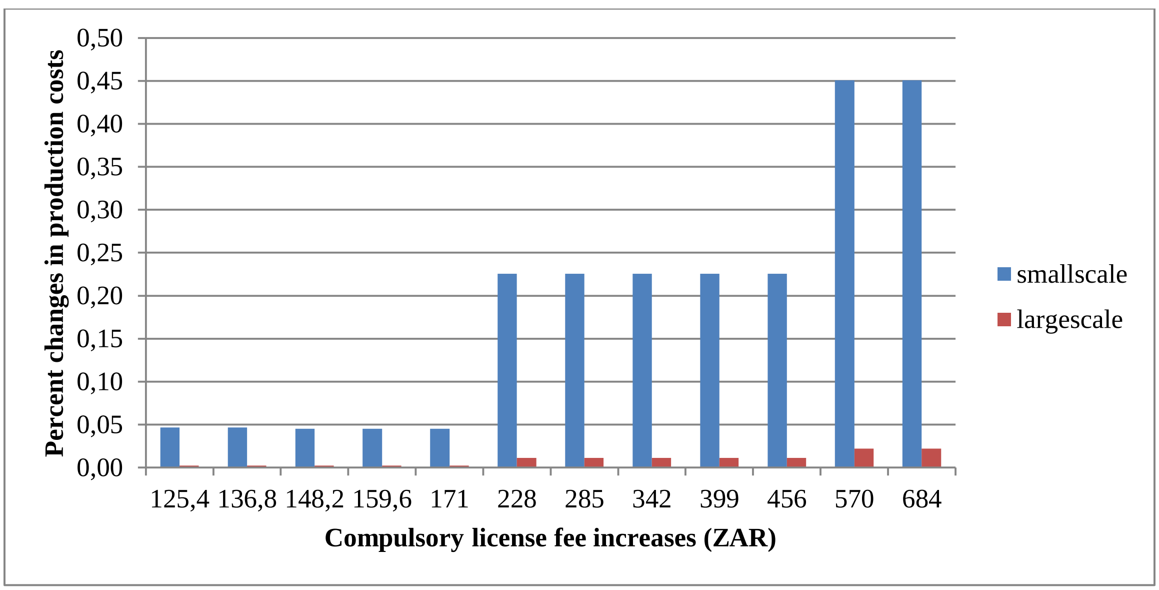


Figure 4.7: Percent changes in total production costs due to changes in license fees

Source: Own compilation

4.5. Conclusions and policy Recommendations

Welfare effects remain the basis of policy analysis (Slesnick, 1998). Reactivity of farms to changes in water prices determines if pricing policy can be used to improve water management (Bazzani et al., 2005). Findings from this study indicate a very low elasticity of water demand for the largescale farmers and an inelastic demand for small scale farmers. If the reactivity of farms is very low like in this study, the use of pricing instruments would only lead to loss of incomes without major changes in water consumption (Bazzani et al., 2005). This is because, as it is observed in this study, the change in water demanded occured only at very high prices (ibid). According to Berbel & Gómez-Limón, (2000a), this implies that water pricing single handedly applied as an instrument to reduce irrigation water use would not be effective. The impact of this would be unfavorable especially for small scale farmers in areas that are heavily reliant on irrigated agriculture for their livelihoods (Berbel & Gómez-Limón, 2000a). Water pricing therefore, would work but only if water demand is elastic and other policies are in place to support the resource poor farmers to adopt to changing water prices (Frija et al., 2011).

Economically, this study finds a moderate reduction in farmers' incomes thus welfare due to water pricing and compulsory licensing for both categories of farmers investigated. The negative impact on welfare is more adverse for the small-scale farmers than the large-scale farmers. We recommend additional policies to complement the existing water policies and support especially the small-scale farmers. Given the small elasticity of water demanded for the large-scale farmers, and the small percentage of production costs represented by water costs, we suggest a tiered pricing strategy for this category of farmers where water rates vary when amount of water used exceed certain thresholds. However, caution should be taken to avoid very high declines in farmer incomes which would reduce competitiveness of the agricultural sector thus economic sustainability (Gómez-Limón & Riesgo, 2004).

Chapter Five

5. Conclusions

5.1 Synopsis

South Africa as a water scarce country recognizes the fact that it is no longer possible to augment existing water supplies. The country has therefore intensified efforts to come up with and implement more efficient water management practices to meet growing demand from competing users and uses. The country's National water Act targets to revolutionize water management in the country through devolution from the central government to the community by establishment of catchment management areas and water user associations. It stipulates economic instruments such as compulsory licensing, effluent discharge permits, water pricing, and water trade for better water management. However, implementation of the envisaged policies continues to face challenges. Water users continue to encounter water allocation and services related problems such as poor quality and distribution. Therefore, in order to inform and guide the water policy reform in South Africa, this study found it important to examine the effects, impacts, and transaction costs of selected water policies in South Africa, specifically the Olifants basin. We presume that water management policies affect the efficiency, quantity, and quality of irrigation water use and have significant effects on the welfare of irrigation water users. Additionally, we argue that significant transaction costs characterize and could inhibit the water policy implementation and compliance processes.

Chapter two of this study followed a framework by McCann & Easter, (2004) and McCann et al., (2005) to measure transaction costs and further used OLS regression methods to assess the determinants of transaction costs. Findings indicate that sizeable transaction costs accrued to both water users and water managers (varying between 13 and 29 percent of total water budget costs over the ten year period examined). Transaction costs were high for the widely implemented policies but they fairly decreased in the course of policy implementation. Very high start-up transaction costs were associated with the non operational policies such as water trade and effluent discharge permits. We conclude that different levels of transaction costs for the different water policies existed and could be contributing factors to inefficient policy implementation and compliance. Various determinants such as water pricing, membership in WUAs and use of ICT for water management significantly influenced transaction costs incurred by water users. The study further highlighted possible transaction benefits of the water policies and recommends a more empirical approach in order to gain a deeper understanding of transaction benefits.

In chapter three, we used various regression techniques (OLS, Tobit, and Multinomial Logit) to assess the effects of water policy and other socioeconomic factors on irrigation water use. Water use efficiency was assessed using DEA methods and the results indicated that irrigation farmers in the Olifants were water use inefficient; the average water use efficiency was only 31 percent suggesting major room for improvement and water re allocation. Among the various assessed factors, we find that compulsory licensing positively and significantly influenced water use efficiency while farmers involved in WUAs were likely to consume less water for irrigation. Water pricing on the other hand did not limit irrigation water consumption because farmers were likely to pay higher prices for their continued water use. Results further indicated that farmers compliant to water pricing, compulsory licensing and membership in WUAs, were less likely to use bad quality water, suggesting that these water policies could actually foster use of good quality water. The beginning of the chapter examined the organizational structure of institutions involved in management and implementation of the South Africa water Act, in effort to shed light on who influences the activities of the water policy process, the governance structure for the actors, rules setting procedures, institutional interactions, and possible challenges of water policy implementation. Findings indicate that despite having attained some level of decentralization, so much power remained in the hands of the minister of water affairs to authorize most water activities at all the management levels.

Chapter four presents the results of the mathematical programming approaches based on the Expected Utility Theory, which was used to assess the impact of compulsory licensing and water tariffs on the welfare of irrigation water users. Rising water tariffs had a negative though minimal impact on farmers' welfares. Small scale farmers were however more adversely affected by rising water tariffs and license fees compared to their largescale counterparts. Water demanded for irrigation was somewhat inelastic to price increases for the two types of farmers investigated; the large-scale farmers' water demand was however moderately elastic as there were slight reductions in quantities of water consumed due to water price increases. An inelastic demand to price changes implies that the use of pricing instruments would only lead to loss of incomes without major changes in water consumption. Compulsory licensing fees increases on the other hand resulted in smaller changes in welfare compared to water tariff increases.

The study findings inform water policy and equip decision makers with evidence-based ideas in water management for the Olifants basin and beyond. Firstly, the various relevant factors affecting transaction costs, water use-quantity, quality, and efficiency can act as policy indicators towards better water policy reform and management. The existence of different levels of transaction costs for the different water policies is important feedback to guide water policy design in South Africa. In terms of the organizational structures, power struggles seemed to be an obstacle in the way of the NWA implementation and required streamlining. Farmers' welfares on the other hand moderately reduced due to rising water tariffs and compulsory license fees. The negative impact on welfare was however more adverse for the small-scale farmers than the large-scale farmers; this study recommends a tiered pricing strategy where water rates vary when amount of water used exceeds certain thresholds. Additionally, we conclude that elasticity of water demand is necessary for water pricing to be effective in reducing water use and enhance conservation.

5.2 Study limitations, and suggestions for future research

Limitations to this study mainly lay in the data collection process due to the sensitivity of the water and land reforms in South Africa. It was difficult to obtain responses to survey questions as irrigation water users were reluctant to attend to survey questions while ministry staff hesitated to avail information. Although focus group discussions conducted with leaders of water use groups, extension personnel, and farmers, substantiated the farmer interview responses; it would be interesting to see future research based on larger sample sizes. In the second chapter, we quantify transaction costs of the water policy process but only highlight on the possible transaction benefits. This could be a good starting point for future research on transaction benefits in water management.

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7. Appendix

7.1 The GAMS model

$title waterpolicyc2 model for the Olifants
$OFFUPPER

Sets

x fixed factors of the farming systems /land, rac /
**rac is the risk aversion coefficient*

t month
**Months of the year, many parameters are given by month*

/ jan, feb, mar, apr, may, jun, jul, aug, sep, oct, nov, dec /

c the set of crops that are cultivated
/ maize2, mangoes2, onions2, peas2, potatoes2, vegs2, vegw2 /

** c1 (c) crops for commercial farmers*
**/citrus1, maize1, grapes1, onions1, peas1, wheat1, vegs1, vegw1 /*
c2 (c) crops for smallscale farmers
/ maize2, mangoes2, onions2, peas2, potatoes2, vegs2, vegw2 /

sn the set of states of nature /1*10 /
**assumption is that farmers face ten states of nature as a way to introduce*
**uncertainty in their farming activities*

p products: each product is composed of one crop
/ maize2, mangoes2, onions2, peas2, potatoes2, vegs2, vegw2 /

ty year /2013 /

in input
/ seeds, fertilizer, insecticides /

** This set is just to allow repeating the set of products*
alias (p,pp) ;

$ontext these parameters and the following equations aim to allow:
1- the calculation of the mean prices of all products
2- the calculation of variance-covariance matrix of the prices of all products
3- the above two will allow to calculate the total revenue variance of a farm type,which will be used in calculating the certainty equivalent which is the objective function to be maximised in our model.
$offtext

parameter
mean(p) average prices of products
covar(p,pp) variance-covariance matrix of prices of various products ;

**matrix of prices calculated assuming a lognormal distribution*
**these are the prices of products in different states of nature*
table price(p,sn);

Parameter prob (sn) probability of each state of nature for prices (they sum up to one)
/ 1 0.0000043107
2 0.0007580709
3 0.0191115805
4 0.1354837029
5 0.3446423349
6 0.3446423349
7 0.1354837029
8 0.0191115805
9 0.0007580709
10 0.0000043107 / ;

mean(p) = sum(sn, price(p,sn)*prob(sn));
covar(p,pp) = sum(sn,(price(p,sn)-mean(p))*(price(pp,sn)-mean(pp))*prob(sn));

display mean, covar ;

* parameters which will be connected to their equivalents at the farm type level
parameter

famlab(c,t) *family labour availability by month*
yield(p,ty) *yields of different crops*
watereq(c,t) *water requirements per month for different crops*
laboureq(c,t) *labour requirements per month for different crops*
iinputs(in,c) *physical inputs requirements for different crops*
hlab (c,t) *hired labor per month*
landreq (c,t) *land requirements per month for different crops*
priceinp(in,c) *prices of various inputs*

*land1 *farm size per hectare for commercial farmers*
land2 *farm size per hectare for smallscale farmers*
rac *the risk aversion coefficient*
f *water license fee*
qlt *willingness to pay for quality*
*waterav1 *average irrigation water available per month for commercial farmers*
waterav2 *average irrigation water available per month for smallscale farmers*
*hwage1 *hired labor wage rate for commercial farmers*
hwage2 *hired labor wage rate for smallscale farmers*
*watprce1 *price of water by cubic meter for commercial farmers*
watprce2 *price of water by cubic meter for smallscale farmers*
*mchineryc1 *machinery maintenance and additional costs per annum for commercial farmers*
*mchineryc2 *machinery maintenance and additional costs per annum for smallscale farmers ;*

```
*model variables

variables
xcrop(c) cropping activity                (hectares)
quantity(p) quantity produced by product   (kg)
revenue  total average revenue            (R)
labcost labour cost                        (R)
water water consumption                   (cubic meter)
labour total labour employed              (workers)
hlabour hired labour employed             (workers)
flabour family labour used                (workers)
inputcost inputs variable costs           (R)
*mchinerycost  machinery maintenance cost   (R)
irrcost the costs of irrigation water      (R)
waterfee licensing fee                     (R)
totcost total variable costs               (R)
totvariance total income variance          (R)
grossmargin gross margin                   (R)
certequiv certainty equivalent             (R) ;

positive variables xcrop(c);

equations
*landbal1(t)   land balance commercial            (hectares)
landbal2(t)    land balance smallscale            (hectares)
laborbal(c,t)  labour balance                     (workers)
*watercon1(t)  water constraint commercial        (cubic meter)
watercon2(t)   water constraint smallscale        (cubic meter)

output(p)      quantity accounting by product      (kg)
arev           average revenue accounting          (R)
inpcosts       input cost accounting               (R)
*watercost1    water cost accounting commercial    (R)
watercost2     water cost accounting smallscale    (R)
*alab1         labour cost accounting commercial   (R)
alab2          labour cost accounting smallscale   (R)

cost           total costs accounting              (R)
totvar         total income variance accounting    (R)
GM             gross margin accounting             (R)
CE             certainty equivalent accounting     (R)    ;

* the equations are classified in three main groups
* the first includes the constraints equations
* the second includes the objective functions equations
* the third includes results equations
* the constraints equations

* land constraint: total cultivated area by month must not exceed the farm size
*landbal1(t)..sum(c, xcrop(c)*landreq(c,t)) =l= land1 ;
```

```
landbal2(t)..sum(c, xcrop(c)*landreq(c,t)) =l= land2 ;

* the sum of total labour used by month must not exceed the available family
* labour plus hired labour in the same month
alias (c,cc);
laborbal(c,t)..sum(cc, xcrop(cc)*laboureq(c,t)) =l= famlab(c,t) + hlab(c,t);
* the sum of irrigation water used by month must not exceed the available water
* in the same month
*watercon1(t)..sum(c, xcrop(c)*watereq(c,t)) =l= waterav1 ;
watercon2(t)..sum(c, xcrop(c)*watereq(c,t)) =l= waterav2 ;

*accounting equations to form the elements of the objective function
* this equation is to calculate the quantity produced by product
output(p)..quantity(p) =e=  sum(ty, sum(c, xcrop(c)* yield(p,ty)));

* this is to calculate the total revenue taking into account price variation
* and probability parameter
arev..revenue =e= sum(p,quantity(p)*mean(p)) ;

* this is to calucalate physical input costs (fertilizers, seeds, insecticides)
inpcosts..inputcost =e=  sum(in, sum(c, xcrop(c)* iinputs(in,c) *priceinp(in,c)));

* this is to calculate water costs (water)
*watercost1..irrcost =e= sum(t, sum(c, xcrop(c)* watereq(c,t) *watprce1)) ;

watercost2..irrcost =e= sum(t, sum(c, xcrop(c)* watereq(c,t) *watprce2)) ;

* this is to calculate the cost of hired labour
*alab1..labcost =e= sum(t, sum(c, xcrop(c)*hlab(c,t)*hwage1));

alab2..labcost =e= sum(t, sum(c, xcrop(c)*hlab(c,t)*hwage2));

* this is to calculate total costs
cost..totcost =e= inputcost + irrcost + labcost + f + qlt;

* this is to calculate the variance of the total farm revenue
totvar..totvariance =e= (sum(pp,sum(p,quantity(pp)* covar(p,pp)*quantity(p)))) ;

* this is to calculate the total gross margin
GM..grossmargin =e= revenue - totcost ;

* this is the objective function: it is the certainty equivalent
CE..certequiv =e= grossmargin - rac*totvariance ;

*landrequirements by farm type ,crop, month in ha
table landreq (c,t);

*prices of inputs by farm type,crops,inputs in R/ha
*machinery maintenance with additional costs are given in R/annum

table priceinp (in,c);
```

```
scalars
f water license fee in Rands per farm per annum /114/
qlt willingness to pay for quality in Rands per cubic meter /0.6/ ;

parameter
*   hwage1      / 3196.81 /
   hwage2       / 666.19 /
*   watprce1    / 0.36 /
   watprce2     / 50.0/
*   waterav1    / 16490 /
   waterav2     /  2500 /
*   land1       /  218.3 /
   land2        / 3.8 /
*mchineryc1 / 6229314.97 /
*mchineryc2  / 4108.61 /
*yields of crops in kgs/ha by farm type, crop, product
table yield (p,ty);

* irrigation requirements by farm type, crop,and month (cubic meters/hectare per month)

table watereq(c,t);

*labour requirements by farm type, crop,and month(workers/ha)
table laboureq (c,t) ;

*family labor availability by farm type, crop,and month(workers/ha)
table famlab (c,t) ;

*hired labor available by farm type, crop,and month(workers/ha)
table hlab(c,t);

*input requirements (quantities of inputs in kgs/ha) by farm type, crop
*citrus, mangoes and grapes seeds are given in seedlings

table iinputs(in,c) ;

Model waterpolicy farm level model /all/;

 rac = 0.0001

 solve waterpolicy using nlp maximizing certequiv;

display landbal2.l, laborbal.l, watercon2.l, quantity.l, revenue.l, inputcost.l, irrcost.l, labcost.l, totcost.l,
totvariance.l, grossmargin.l, certequiv.l ;
execute_unload 'sstariff16.gdx',landbal2.l, laborbal.l, watercon2.l, quantity.l, revenue.l, inputcost.l,
irrcost.l, labcost.l, totcost.l, totvariance.l, grossmargin.l, certequiv.l ;
execute '=gdxviewer sstariff16.gdx';
```

7.2 Survey Questionnaire

THE ROLE OF INSTITUTIONS, POLICY, AND ICT IN WATER MANAGEMENT IN THE OLIFANTS BASIN

February 2014

Confidentially

This survey collects detailed information on water use in the Olifants WMA from Large scale and small-scale farmers, industry and miners. The data will not only be important for the project but it will also comprise a PhD thesis from the University of Bonn, Germany in collaboration with University of Pretoria . The survey seeks to examine the role of different water policies and community involvement in water conservation, evaluating the impact of the different water policies on commercial and small-scale holders' welfares, examining TCs and the potential role of ICT in water management. Results from this study will be used to inform and guide water policy reform in South Africa. Herewith it is guaranteed that any information obtained from this survey that relates to any identifiable business will not be revealed. The data will be used for research purposes only!

Q1	Enumerator names	
Q2	Date of interview (dd. mm. yyyy)	
Q3	Interview start time (hh. mm)	
Q4	Interview end time (hh. mm)	

		Codes
	Province	1= Gauteng, 2= Mpumalanga, 3= Limpopo
	Region	1= Upper 2= Middle 3= Lower

MODULE A- RESPONDENT AND SITE IDENTIFICATION*NB: the respondent should be the household head/spouse or the firm manager/owner. They should also engage in water use activities in their farm/firm operations*

A1	Name of respondent	
A2	Position held (A2 codes)	
A3	Telephone number (with dialing code)	
A4	Email address	

A2 Codes; 1-household head, 2- spouse, 3-firm owner ,4-firm/farm manager, 5-other(specify)

A5. What is the distance to the nearest market center from your farm (km) (i)where you buy inputs......................(ii)where you sell outputs............

A5a. Name of market………………………………………………………………………………

A5b. Transport cost to market by public transport(a) to and fro……………………(b) by private means……………………

A5c. Distance to the nearest internet facility (i) outside the firm/farm(estimate in km)………………………………(ii) within farm………………..

A5d. Distance to nearest electricity hook up (estimate in km)……………………………………………………....

A6. Are you a member of any Water User Association (WUA) or group? 1=Yes…………..0=No……………… ***(If No, proceed to A8***)

A6a. If yes, what is the name of the WUA/group…………………………….

A6b. When did you join? (Year)...

A6c. When was the WUA established?........................years of operation since establishment.................................…......

A6d. How many members are you in the WUA?............................Of these, how many are 1=male.....................2=female…………………………...

A6e. What are the requirements for a new member joining your association? 1=size of land owned, 2=location of their land, 3= pay membership fees 4=type of water use activity they undertake/sector, 5= language, 6= others (specify)

A6f. What is the minimum and maximum number of ha required for each member?
1=minimum………………………..2=maximum…………………………..

A6g. Do you hold any leadership position in your group? 1=Yes…………..0=No………………

A6g1. If yes, which one? 1=chairperson, 2=vice chairperson, 3= secretary, 4=treasurer, 5= other (specify)

A6h. What are the group activities? 1=manage water allocation, 2=Maintain canal infrastructure, 3=monitor the water quality, 4= conflict resolution, 5=monitor water entitlements, 6= others (specify)

A6i. How do you benefit from being a group/WUA member? *(Circle the relevant benefits in the box below)*

1=Get water subsidy	5=Get help with marketing produce	9=Credit facilities from the WUA
2=pool efforts to address water quality	6= Get help with access to inputs	10= Lobbying for better water policies
3=easier lease/trade of water rights	7=Combined management of canal/dam infrastructure	11= It's a channel to voice problems
4=Obtain advice and planning farm activities	8= Capacity building/link with institutions e.g. DWAF	12= Others(specify)

A6j. Are there emerging/small scale farmers in your group? 1=Yes…………..0=No………………

A6k. If yes, how many by gender? 1=male.....................2=female…………………

A6l. What are the difficulties faced in including new members? 1= When they cannot afford membership fees, 2= when they cannot afford the water use charges, 3= language differences, 4= sector differences, 5= gender differences, 6= others (specify)

A7. How is information pertaining to group activities communicated to members? Through, 1= radio, 2=TV, 3=phone, 4=email addresses/website, 5= newsletters, 6= Pamphlets, 7= meetings, 8= newspaper articles, 9= others (specify)

A8. Observe and note race of respondent 1= white, 2= blacks 3= colored

MODULE B – Demographic characteristics

B1. How many people constantly live, eat and cook in your household?.....................................

B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13
Respondent (B2 codes)	Gender 1=male, 2=female	Age(yrs)	Years of schooling (total years)	Literacy (B6 codes)	Marital status (B7 codes)	Main occupation (B8 codes)	Years of farming (how many years have you been in operation)	Has working phone (1=Yes ,0=No)	Has email address (1=Yes ,0=No)	Has TV (1=Yes, 0=No)	Has radio (1=Yes, 0=No)

B2 Codes	**B6 Codes**	**B7 Codes**	**B8 Codes**
1. household head 2. spouse 3. firm owner 4. farm/firm manager	1. cannot read or write 2 .can sign, write name only 3. can read only 4. can read and write	1. Married living with spouse 2. Married but spouse away 3. Divorced/separated 4. Widow/widower 5. Never married 6. Other, specify	1. commercial farmer>10 ha 2. small scale farmer<10 ha 3. farm/firm worker 4. miner 5. Others (specify)

MODULE C-INFORMATION AND COMMUNICATION (*to be answered by both water managers and users*)

Please complete the table below for ICT based means of information access (applicable to owners/users from demographic table B10-B13)

C1	C2	C3 *(info access is 2 way)*	C4	C5	C6	C7	C8
ICT tool	Info accessed using tools in C1 1=National news 2=Entertainment 3=communication with friends and relatives 4=water management info 5=Other work related info 6= Other (specify)	Specify any info accessed in C2 that is related to water management activities (list) 1=reports/issues of water quality 2=water storage, supply &distribution 3=water trading activities, licensing & payment for water 4= water costs issues 5= water conflict issues 6=water/canal infrastructure 7= other (specify)	Info reliable 1=Yes, 0=No	Info easy to use 1=Yes 0=No	Initial cost of buying the equipment	Cost of getting information from this source	How does the cost of using this information source compare to your usual source of information? **(C8 Codes)**
Radio							
TV							
Phone (call/text)							
email address							
Other(specify)							

C8 Codes: 1. Same 2. Lower 3. Higher

What are your major sources of information on each of the following policy options?

C9	C10	C11	C12	C13	C14	C15	C16
Policy option	In the past year, did you need information about**[]** 1=Yes, 0=No	Information Source (C11codes)	Means of information access (C12codes)	How timely was this means of information access (C13codes)	How were the means of information access (C12) important in your decision to comply to [] (C14codes)	Number of times information was accessed using this means in the past year	Cost of each access
Compulsory licensing							
Water tariffs/use charges							
Effluent discharge permits							
Water trade							

C11 Codes	C12 Codes	C13 Codes	C14 Codes
1 DWAF 2.WUA group 3. extension Agents 4. Private Company 5. Other farmers 6. Agricultural training centre 7. Other(specify)	1. Visit by DWAF agent 2. Visit by WUA /group staff 3. Newspaper/magazine 4. Radio 5. Television 6. Mobile phone (SMS) 7. Mobile phone (Voice) 8. Internet/email 9. Agricultural training centre 10. neighbours 11. others (specify)	1.not timely 2.timely 3.very timely	1.not important 2.important 3.very important

MODULE D-LAND HOLDING

D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D10a	D10b
What is your total farm size(ha)	Area owned (ha)	Area rented in (ha)	Total area under cultivation/ other use (ha)	Year started activity/cultivating on this farm	Irrigated area (ha)	dry land/ rain fed area (ha)	Current purchasing rate of land (Rands/ha)	Current renting rate of land (Rands/ha)	Are there any claims on your land 1=Yes, 0=No	If yes, what kind (D10a codes)	How do you go about the claims (D10b codes)

D10a codes	D10b codes
1=land claims 2=water claims 3= Other (specify)	1=go to courts 2= resolve out of courts 3= other (specify)

MODULE E-FARM/FIRM PROFILE AND PRODUCTION ACTIVITIES (*only section E5,E6,E7,E8,E9, E17, E18, E19, E20, E21, E22 apply to non-agricultural industry and mining*)

Crops grown: their resource requirements, their resource costs and their respective yields and prices in the year 2013 ***(NB; convert T to Kgs i.e. 1T=1000kg)***

E1	E2	E3	E3a	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14
Crop name (E1 codes)	Parcel size(ha)	Season grown (E3 codes)	How long does this crop stay in the field? (months)	Irrigated; (1=Yes, 0=No)	Water source (E5 codes)	Amount of water used (m^3)/ha/ /month	How much did you pay for this water(monthly tariff) R/m^3	What was the water quality type (E8 codes)	How much would you be willing to pay for this water quality rather than what you actually paid R/m^3	Irrigation method used (E10 codes)	Total Seeds used (kg, T/ha)	Seed costs (Rand/ha)	Total fertilizer (kg,T/ha)	Total fertilizer cost (Rand/ ha)

E1 Codes

1=Citrus,2=peas,3=grapes,4=maize,5=wheat,6=avocadoes,7=mangoes,8=vegetables,9=cashcrops,11=groundnuts , 12=potatoes, 13= onions, 14=others(specify)

E3 codes	E5codes	E8 codes	E10 codes
1=summer 2=winter 3=Autumn 4=spring	1 = dam 2 = river 3 = borehole 4= rainfall 5 = others(specify)	1=**Ideal** (good): the user of the water is not affected in any way 2=**acceptable** (moderate): slight to moderate problems are encountered 3=**tolerable** (bad): moderate to severe problems are encountered 4=**unacceptable** (very bad): the water cannot be used under normal circumstances.	1=Drip 2=sprinkler 3=flood 4=others(specify)

Resource table continued… ***E17, E18, E19, (also apply to non-agricultural industry and mining)***

		E15	E16	E17					E18						
Crop name (E1 codes)	Season (E3 codes)	Total insecticides, herbicides/ fungicides(l/ha)	Insecticides herbicides fungicides costs (Rand/ha)	Total Labor requirements(man days/ha/ month) Total Labor costs (Rand/month/worker)					Other variable costs (Rand/[]crop/ha) if not available/crop, give total cost for all the crops						
				E17a. Family labor (how many)	E17b Permanent labor (how many)	E17c Permanent labor costs (R/month/ worker)	E17d Temporary labor (how many)	E17e Temporary labor costs (R/month/ worker)	E18a Irrigation equipment maintenance	E18b Fuel	E18c Machinery maintenance	E18d Additional transport costs	E18e Electricity	E18f Total cost of Insurance	E18g Others (specify)

E19. Annual Capital costs by month (monthly interests) incurred in the production process for year 2013

Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec

Resource table continued…Crops yields/output and their respective prices (per crop/ha)… ***E20, E21, E22 apply to nonagricultural industry and mining***

		E20			E21			E22		
Crop name (E1 codes)	Season (E3 codes)	**season 1 Yields (T, kg/ha)**			**season 2 Yields (T, kg/ha)**			**season 3 Yields (T, kg/ha)**		
		E 20a. Qty produced	E20b. Qty sold	E20c. Price/T, kg)	E21 a. Qty produced	E21b. Qty sold	E21c. Price/T, kg)	E22a. Qty produced	E22b. Qty sold	E22c. Price/T, kg)

MODULE F-WATER MANAGEMENT ACTIVITIES

F1. Is your irrigation water metered or is there another possibility of measurement? 1=Yes……..0=No……. ***(If no provide an estimate for amounts used where required in previous questions of water quantity requirements)***

F2. Is your water use registered? 1=Yes…………..0=No………………

F2a. If yes, what amount……………………………….m^3 /year or how many boreholes registered?..

F2b. Where registered……

F2c. What is the tariff…………………………………Rand/m^3 /month

F2d. Do you pay this monthly tariff? 1=Yes…………..0=No……………………..

F2e. Do you consider the current applied water tariffs appropriate?

1=Yes…………..

0=No (too much)…………how much would you be willing to pay per cubic meter………………………….

0=No (too little)…………....how much would you be willing to pay per cubic meter…………………………

F3. Do you pay separate fees for effluent discharge? 1=Yes…………..0=No……………….

F3a. If yes, how much…………………………………Rand /month

F4. Are you of the opinion that water is a public good and should be provided free? 1=Yes…………..0=No…………

F5. Is your water licensed? 1=Yes…………..0=No………………..

F5a. If yes, how much/how many quotas do you currently hold?…………………………………m^3

F5b. After how long are the water licenses reviewed?..years

F5c. Do you consider this review period adequate/sufficient? 1=Yes………….

0=No (too short)………………..What should it be……………………..years

0=No (too long)………………..What should it be……………………..years

F6. Have you in the past sold or bought your water quota 1=Yes…………..0= No…………***If yes, fill in table below. If no go to* F7**

F6a	F6b	F6c	F6d	F6e	F6f	F6g
Water transaction sold/bought	1=Yes, 0=No	When(year)	Quantity sold/bought	price(rand/m^3)	Reasons for sale/buying Reasons for non sale/ non buying 1=changes in crop combination 2= Restriction of water quotas 3=reduce area planted 4=Put more land under production 5=Drought 6= Others (specify)	In case of restrictions in current water quotas, what would be your strategies (F6g codes)
1=Sold Permanently						
2=Sold Temporarily						
3=Bought Permanently						
4=Bought Temporarily						

F6g codes 1=change in crop combination, 2=buy quotas, 3=reduce area planted, 4= others (specify)

F7		**F8**	**F9a**	**F9b**	**F10c**
What are the Problems/ challenges you face in your water use activities (Circle accordingly)			If yes, indicate limitations ***(circle accordingly)***	Available currently	How much would you Need
1. High water costs		Are your production activities limited by input availability? 1=Yes, 0=No	1. Arable land (ha)		
2. expensive equipment			2. Labor(man days)		
3. expensive operation and maintenance costs of equipment			3. Water supply(m^3)		
4. inadequate water supply			4. Fertilizer (kg, T)		
5. inadequate water distribution within WUA			5. Water quality(E8 codes)		
6. Poor water quality			6. Others(specify)		
7. Poor service in water supply					
8. Water restrictions in dry periods					
9. Administrative delays					
10. Water storage difficulties					
11. none					
Others (specify)					

MODULE G-TRANSACTION COSTS (*to be answered by both water managers and users*)stakeholders face low costs ** stakeholders face high costs***

G1	G2	G3	G4		
policy	**TC type**	Activities under each TC type (ask for costs, only where applicable to that policy) *any additional activity not listed should be included*	Time of occurrence and costs incurred		
			G4a early implementation	G4b full implementation	G4c establishment
Compulsory licensing	*Support and administrarion	notices and hearings discussions meetings follow-ups travel costs telephone costs			
	**Contracting	Additional information costs decision cost arranging for finance negotiating travel costs telephone costs			
	*Monitoring/ detection	outcome/compliance transfers travel costs telephone costs time used costs			
	*Prosecution/enforcement	conflict resolution			
Water tariffs/use charges	*Support and administrarion	notices and hearings discussions meetings follow-ups travel costs telephone costs			
	**Contracting	Additional information costs decision cost arranging for finance negotiating travel costs telephone costs			

	*Monitoring/detection	outcome/compliance travel costs telephone costs time used costs			
	*Prosecution/enforcement	conflict resolution			
Effluent discharge permits	*Support and administrarion	notices and hearings discussions meetings follow-ups travel costs telephone costs			
	**Contracting	Additional information costs decision cost arranging for finance negotiating travel costs telephone costs			
	*Monitoring/detection	outcome/compliance(quality) travel costs telephone costs time used costs			
	*Prosecution/enforcement	conflict resolution			
Water trade	*Support and administrarion	notices and hearings discussions meetings follow-ups travel costs telephone costs			
	**Contracting	bargaining costs checking market prices identifying buyers Additional information costs decision cost arranging for finance negotiating travel costs telephone costs			
	*Monitoring/d	outcome/compliance			

	etection	transfers travel costs telephone costs time used costs			
	*Prosecution/enforcement	conflict resolution			
Formation of water use groups	*Support and administrarion	notices and hearings discussions meetings follow-ups travel costs telephone costs			
	**Contracting	bargaining costs additional information costs decision cost arranging for finance negotiating travel costs telephone costs			
	*Monitoring/detection	outcome/compliance travel costs telephone costs time used costs			
	*Prosecution/enforcement	conflict resolution			

MODULE H-INCOME SOURCES AND ASSETS

H1	H2	H3	H4	H5		H6	H7
Asset name	Does the hhd/firm currently own **[]** (1=Yes, 0=No)	Quantity owned	Year of purchase	Asset value (If you sell **[]** today in its present condition, how much would you get for it		**Sources of income** ***1. Own farm*** (computed from agricultural yields in E20, E21, E22)	What was the yearly income from this source
1. Ox-plough						1a. Cash crops	
2. Ox-cart						1b. Food crops	
3. Chemical Sprayer/pump						1c. Fruits and vegetables	
4. Wheel barrow						1d. Livestock and products	
5. Bicycle							
6. Tractor							
7. Plough						2. Work at other farm	
8. Harrow						3. Work at non farm enterprises	
9. Planter						4. Salary employment	
10. Reaper						5. Service delivery	
11. Other tractor drawn equipment (specify…….....						6. Cash transfers	
12. Store for farm produce						7. Other(specify)	
13. Livestock kraal							
15. Radio/radio cassette						8. Total yearly income	
16. Mobile phone							
17. Television (TV)							
18. Computer/Internet							
19. Water pump							
20. Generator							
21. Refrigerator/freezer							
22. Landline phone							
23. Air Conditioner							
24. Sofa seats/coach							
25. Cooker							
26. Own house							
27. Other….....................							

WATER MANAGERS' QUESTIONNAIRE

MODULE A: RESPONDENT AND RESPONSIBILITIES IDENTIFICATION

A1	Name of respondent	
A2	Position held	
A3	Telephone number (with dialing code)	
A4	Email address	
A5	Gender (observe)	

A6. What are your responsibilities as a water manager? Circle accordingly	A7. If not, who is responsible for this activity in A6?	A8. Which area are you responsible for 1=upper, 2=middle, 3=lower 4= other	A9. How many managers are you in that area	A10. What Problems/aspects of concern do water users face in irrigation or other water use activities (Circle accordingly)	A11. How do you address/respond to each in A10? 1. Visit the water user 2. Visit the WUA /group 3. Newspaper/magazine 4. Radio 5. Télévision 6. Mobile phone (SMS) 7. Mobile phone (Voice) 8. Internet/email 9. seasonal training 10. pass info thru neighbours 11. others(specify)	A12. How long does it take to respond to the problems in A10? 1=seconds (how many) 2=minutes (how many) 3=days (how many) 4=months (how many) 5=years (how many)
1. Monitor water payments & costs				1. High water costs		
2. Monitor water trade/transfers				2. expensive equipment		
3. Monitor and review licenses				3. expensive operation and maintenance costs of equipment		
4. Monitor water supply				4. inadequate water supply		
5.Monitor and distribute water				5. inadequate distribution within WUA		
6. Monitor water quality/permits				6. Poor water quality		
7. Monitor/provide general service				7. Poor service in water supply		
8. Restrict water in dry periods				8. Water restrictions in dry periods		
9. Office administration				9. Administrative delays		
10. Monitor Water storage				10. Water storage difficulties		
11. Others (specify)				11. Others (specify)		

MODULE C-INFORMATION AND COMMUNICATION

Please complete the table below for ICT based means of information access

C1	C2	C3	C4	C5	C6	C7	C8
ICT tool	Info accessed using tools in C1 1=National news 2=Entertainment 3=communication with friends and relatives 4=water management info 5=Other work related info 6= Other (specify)	Specify any info accessed in C2 that is related to water management activities (list) 1=reports/issues of water quality 2=water storage, supply &distribution 3=water trading activities, licensing & payment for water 4= water costs issues 5= water conflict issues 6=water/canal infrastructure 7= others (specify)	Is the Info accessed in C3 reliable (1=Yes, 0=No)	Info easy to use (1=Yes, 0=No)	Initial cost of buying the ICT tool in C1	Cost of getting information from this source	How does the cost of using this information source compare to your usual source of information? **(C8 Codes)**
Radio							
TV							
phone							
email address							
Other(specify)							

C8 Codes: 1. Same 2. Lower 3. Higher

What are your major sources/channels of information on each of the following policy options?

C9	C10	C11	C12	C13	C14	C15	C16
Policy option	In the past year, did you need information about**[]** (1=Yes, 0=No)	Information Source (C11 codes)	**Means** of information access (C12 codes)	How timely was this means of information access (C13 codes)	How were the means of information access (C12) important in your follow up activities of [](C14codes)	Number of times info was accessed using this means in the past year	Cost of each access
Compulsory licensing							
Water tariffs/use charges							
Effluent discharge permits							
Water trade							

C11 Codes	C12 Codes	C13 Codes	C14 Codes
1 DWAF 2.WUA group 3. Extension Agents 4. Private Company 5. Other farmers 6. Agricultural training centre 7. Other(specify)	1. Visit by DWAF agent 2. Visit by WUA /group staff 3. Newspaper/magazine 4. Radio 5. Television 6. Mobile phone (SMS) 7. Mobile phone (Voice) 8. Internet/email 9. Agricultural training centre 10. neighbours 11. others(specify)	1.not timely 2.timely 3.very timely	1.not important 2.important 3.very important

MODULE G-TRANSACTION COSTS (*stakeholders face low costs ** stakeholders face high costs)

G1	G2	G3	G4		
policy	**TC type**	Activities under each TC type (ask for costs, only where applicable to that policy)	Time of occurrence and costs incurred		
			G4a early implementation	G4b full implementation	G4c establishment
Compulsory licensing	**Support and administration	notices and hearings discussions meetings follow-ups travel costs telephone costs			
	*Contracting	Additional information costs decision cost arranging for finance negotiating travel costs telephone costs			
	**Monitoring/ detection	outcome/compliance transfers travel costs telephone costs time used costs			
	**Prosecution/ enforcement	conflict resolution			

Water tariffs/use charges	**Support and administration	notices and hearings discussions meetings follow-ups travel costs telephone costs			
	*Contracting	Additional information costs decision cost arranging for finance negotiating travel costs telephone costs			
	**Monitoring/ detection	outcome/compliance travel costs telephone costs time used costs			
	**Prosecution/ enforcement	conflict resolution			
Effluent discharge permits	**Support and administration	notices and hearings discussions meetings follow-ups travel costs telephone costs			
	*Contracting	Additional information costs decision cost arranging for finance negotiating travel costs telephone costs			
	**Monitoring/ detection	outcome/compliance(quality) travel costs telephone costs time used costs			
	**Prosecution/ enforcement	conflict resolution			
Water trade	**Support and administration	notices and hearings discussions meetings follow-ups			

		travel costs telephone costs			
	*Contracting	bargaining costs checking market prices identifying buyers Additional information costs decision cost arranging for finance negotiating travel costs telephone costs			
	**Monitoring/ detection	outcome/compliance transfers travel costs telephone costs time used costs			
	**Prosecution/ enforcement	conflict resolution			
Formation of water use groups	*Support and administrarion	notices and hearings discussions meetings follow-ups travel costs telephone costs			
	**Contracting	bargaining costs additional information costs decision cost arranging for finance negotiating travel costs telephone costs			
	*Monitoring/detection	outcome/compliance travel costs telephone costs time used costs			
	*Prosecution/enforcement	conflict resolution			

NB: ***Please request for proposed budgets, financial accounts, government reports to further aid the transaction costs identification***