

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The world is currently facing severe and growing challenges to meet the rapidly growing demand for water resources. At the global level the average amount of water per person has substantially dropped from about 43 000 cubic meters per year in 1850 to about 9000 cubic meters per year in 1990 (Gleick, 1995). This results from the rapid population growth, which is not matched by an equivalent growth in the development of new water sources. New sources of water are increasingly becoming expensive to exploit; hence, the potential for expanding water supply has become limited. This problem is most visible in developing countries where national, regional and seasonal water scarcity poses a severe threat to economic development and poverty reduction. This threat is further exacerbated by the increasing cost of exploring new water supply sources, wasteful use of the already developed water supply, degradation of soil in irrigated areas, depletion of groundwater, water pollution, subsidies and other distorted incentives that govern water use, and inequitable access to water or its benefits by women, the poor and other disadvantaged groups (Rosegrant *et al.* 2002b).

The appropriate response to these threats requires the formulation of water management policies such that can maintain growth in agricultural production, facilitate the efficient and equitable inter-sectoral reallocation of water, reverse the ongoing degradation of water in irrigated land and water-related ecosystems, safeguard the rights and increase the incomes of the poor and socially excluded groups to the benefits from efficient water use

and improve the effectiveness of water use in rainfed agriculture (Rosegrant *et al.* 2002a).

These policy issues and concerns have led to water reforms in many countries.

1.2 ALTERNATIVE WATER ALLOCATION MECHANISMS

There are various strategies and principles used in allocating scarce water resources among the various sectors. Dinar *et al.* (1997) identified four major water allocation mechanisms which are generally practiced in different countries. These are marginal cost pricing, public allocation, water markets and user-based allocation mechanisms.

The first mechanism discussed by Dinar *et al.* (1997) is the marginal cost pricing, which involves an allocation strategy that equates the marginal value of water to the unit cost of water allocation. Sectors that have higher marginal values than the unit cost of water should be allocated more water than those with lower marginal values and higher unit costs of water supply. Economic efficiency or optimal water allocation is attained at the point where the ratio of the marginal value to the marginal cost (unit price) of water is the same for all sectors and is equal to unity (Beattie and Taylor 1993). This means that efficiency in inter-sectoral water allocation is achieved when the marginal benefit of a cubic unit of water is equal to the marginal costs of supplying that cubic unit. Although this mechanism is theoretically efficient and can easily be combined with pollution/effluent charges or taxes to solve the problem of externalities, it is difficult to define and correctly estimate the marginal costs of water allocation over time.

The second mechanism, which is the public water allocation strategy, is used when the state determines the quantity of water to be reserved for environmental sustainability and

other priority use, while it allocates or distributes the balance water among different sectors of the economy. Public allocation mostly dominates industrial, municipal, agricultural and recreational sectors in many countries. The state's role is particularly strong in inter-sectoral water allocation as it is the only institution that has jurisdiction over all sectors of water use (Dinar *et al.*, 1997). In addition to its objective of protecting the poor and the vulnerable population, sustaining environmental needs and providing a given level of water to meet minimal needs of the receiving sectors, public allocation also maintains prior legal rights which are based on historical facts. However, public water allocation can lead to waste and misallocation of water, and in many cases, does not support user participation. Most countries or river basins have some form of public allocation of water resources.

The third mechanism is the market-based allocation of water, which is referred to as “exchange of water-use rights”. In a pure market-based allocation the demand for and the supply of water resources dictate the quantities to be traded as well as the unit price of water in the market. In such a situation water is reallocated from low to high marginal value uses; hence, makes the allocation mechanism efficient. However, market-based water allocation mechanisms sometimes require public intervention to define the original allocation of water rights, create the institutional and legal framework for trade and invest in the basic infrastructure to allow water transfers with low transactions costs.

The major advantage of the market-based allocation mechanism is the empowerment of water users to consent to any reallocation of water and compensation of any water transfer. This mechanism also induces water users to incorporate the full opportunity cost of water in their marginal cost analysis. It therefore allows users to easily and quickly respond to

changes in commodity prices and water values. However, a purely market-based allocation mechanism often prices out of the water market the critical and most vulnerable population whose basic survival strategies depend on livelihoods that require the use of the resource.

The fourth mechanism, which is the user-based allocation, requires collective-action-institutions to make decisions on water rights. An example includes the former irrigation boards in South Africa. This mechanism's major advantage lies in its flexibility to adapt to water delivery patterns that meet local needs. On the one hand the allocation process becomes quite easy if those directly involved in water usage have adequate information on local conditions. On the other hand, the successful operation of user-based allocations depends on a transparent institutional structure, which may be absent especially in developing countries.

All these four water allocation mechanisms aim at promoting economic efficiency, social equity and environmental sustainability.

1.2.1 Efficient water allocation

The allocation of an input is economically efficient if there is no other feasible allocation of that input that would make some sectors better-off without making others worse-off (Browning and Zupan, 2006). Hence, water allocation efficiency is a situation in which water is allocated among sectors, firms or individuals such that no further reallocation would provide gains in production or consumption to some firms, sectors or individuals without simultaneously imposing losses on others (Young 1996). Economic efficiency in

water allocation or reallocation is also concerned with the amount of wealth that can be generated by a given quantity of water.

The equimarginal and the marginal cost-pricing principles are the two preconditions required to attain water allocation efficiency. The equimarginal principle requires that the marginal benefits of water should be the same for all users or sectors (Agudelo, 2001). Thus efficient water allocation means that the benefits from using an additional cubic unit of water in one sector should be the same for all the sectors. Once this is achieved, further redistribution of water resources can make no sector better off without making another worse off. The implication of this principle is that resources should be allocated in such a way that all the users and consumers derive equal value in using additional units of the resource.

The marginal cost-pricing principle requires that the benefits derived from the use of an additional unit of water should be equal to the cost of supplying the same unit of water. This means that the unit price of the resource should be the same as the marginal value of that resource. Thus, to efficiently manage a given quantity of water resource, it should be provided at the lowest cost and allocated in a way that makes the marginal benefits of users equal in all the economic sectors of a country, region or water management area (DWAF, 1998). Under efficiency consideration more water should be allocated to the sectors with higher marginal values of water than those with lower marginal values.

1.2.2 Equity

Equity objectives are particularly based on the principle of fairness of allocation across different economically diverse groups in the population of a country or water management area. This may not be compatible with the efficiency objective. Equitable water management requires that everyone has equal access to sufficient and affordable safe water to meet their basic needs or to the benefits generated from the use of a specific water resource (DWAF, 1998). This means that water allocation or reallocation should not only be concerned with deriving maximum benefits from the use of the resource, but also with how the allocation process improves the standard of living of the most vulnerable population. Most of the studies that have discussed the issue of equity in the past have concentrated on equity in access to water, which in most cases compromises the efficiency considerations of water allocation. Equity to the benefits from the use of the resource also needs considerable attention as a viable alternative to equity in access.

1.2.3 Sustainability

A sustainable water management strategy entails the use of the resource such that the resource stock is not depleted and that sufficient water is reserved for environmental needs. This may also be referred to as inter-generational equity where in the current generation's use of water resources or the benefits derived from using it does not compromise the future generations' use of the resource or its perceived benefits.

The attainment of efficient, equitable and sustainable water management requires weighing up the different social, economic and environmental objectives in the water management area.

1.3 WATER ALLOCATION REFORM IN SOUTH AFRICA

South Africa is in the process of implementing water reforms outlined in the 1998 National Water Act (DWAF, 1998). This legislation is internationally recognized as the most promising legal framework to address the country's water management problems. The framework is intended to repeal the 1956 Water Act which was based on the riparian principle, in favour of one that recognizes water as a national asset. DWAF (2005) stipulates the principle that "the national government is the custodian of the nation's water resources, as an indivisible national asset, and has ultimate responsibility for, and authority over water resource management, the equitable allocation and usage of water, the transfer of water between catchments and international water matters". This statement shows that South Africa has public inter-sectoral water allocation mechanism, based on the principles of efficiency, equity and sustainability. The framework for water allocation reform in South Africa provides detailed strategies and approaches to promote equity, sustainability and efficiency in water use. It recognizes that there are still significant inequities in access to and use of the country's water resources, as well as inequities in the distribution of the benefits that accrue from water use. The implementation of water allocation reform is designed to support government's poverty eradication strategies and economic development objectives (DWAF, 2005). The strategies for and objectives of water reforms in South Africa have been formulated into guidelines and approaches which are discussed below.

1.3.1 Guide lines for water allocation reforms in South Africa

The South African Department of Water Affairs and Forestry proposed in 2005 that water allocation process should:

- i) Primarily redress the past imbalances in water allocations to the Historically Disadvantaged Individuals (HDI). This means that priority should be given to the poor and less privileged in the allocation of the available water resources.
- ii) Have capacity-building programmes that support the use of water to improve livelihoods and to facilitate the productive and responsible use of water. This implies that both equity and economic growth objectives should be simultaneously addressed in the water allocation process.
- iii) Contribute to the broad-based-black economic empowerment and gender equity, by facilitating black and women-owned enterprises access to water.
- iv) Respond to local, provincial and national planning initiatives, and South Africa's international obligations and regional SADC initiatives. South Africa is a vast country with huge differences in regional water availability. It also has shared rivers. These regional differences and commitments to international obligations in allocating water resources must be taken into consideration in water resource management.
- v) Be undertaken in a fair, reasonable and consistent manner, such that the existing lawful uses will not be arbitrarily curtailed.
- vi) Give effect and support to the protection of water resources as outlined in the National Water Act, by promoting the phased attainment of both developmental and environmental objectives.
- vii) Introduce innovative mechanisms that can reduce the administrative burden of authorizing water use, while still supporting its productive uses, and the effective management and protection of water resources (DWAF, 2005)

In summary, the guidelines for water allocation among the different sectors and users in South Africa are meant to promote efficiency, equity and sustainability.

1.4 PROBLEM STATEMENT

Water scarcity is increasingly becoming a pressing problem in developing countries. The demand for the world's water resources is rising rapidly, challenging its availability for food production and putting global food security at risk. Agriculture, upon which the majority of the world's population depends, competes with industrial, mining, domestic and environmental uses of the scarce water supply (Rosegrant *et al.*, 2002a). With increasing population growth, urbanization and the need to increase agricultural production, the demand for the scarce water resources is raising a growing concern about increasing the efficiency of water use. The number of countries facing the problem of water scarcity and insufficient water supply is rising. At the global level, while per capita availability of water is declining, water withdrawals are projected to increase more rapidly especially in developing countries (Webb and Iskandarani, 1998; Rosegrant *et al.*, 2002). Therefore, the concept of water scarcity has received considerable attention in the last decade (Seckler *et al.*, 1998).

Generally, water scarcity raises two critical questions for development policies: i) to what extent can water resources be efficiently, equitably and sustainably allocated and used? and ii) what are the possible ways or means by which water scarcity can be alleviated or mitigated in support of further development? The answers to these questions will provide essential tools for water managers to design appropriate water development policies and allocation strategies. Previously, much concern has been

about the agricultural (irrigation) sector to use water efficiently and release more water for other inter-sectoral needs. With the increasing concerns about the growing demand for water given the projected inelastic supply of the resource, efficient water use is now viewed as an inter-sectoral phenomenon, which can only be addressed from an integrated water resource management perspective.

In South Africa, as the economy grows, the competition for water among agriculture, mining, industry, domestic and environmental uses increases, while the long-run supply of water is projected to be inelastic. The rapid increase in the demand for water also increases externality problems. These factors increase the value of water; hence, the benefits from efficient water allocation among the user sectors. In the past, while attention was mainly focused on the development of new water resources, the efficiency and equity considerations were not given much attention as a viable alternative strategy to solving the problem of water scarcity. With the current water situation, the Department of Water Affairs and Forestry is looking for ways to ensure the most beneficial utilization of water in the country. These include the reallocation of water from lower to higher-value uses over time. Thus, the benefits from and the necessity of demand-side water management has significantly increased in importance.

While irrigation water requirements in South Africa account for about 62 percent of the total water requirements, agriculture accounts for less than four percent of the gross domestic product (GDP), and employs about 11 percent of the total number of employees in the country. Conversely, the mining and manufacturing sectors, which contribute about eight percent and 23 percent respectively to the GDP and employ

about seven per cent and 19 percent of the total number of employees, account for only 15 percent of the total water requirements. Urban water requirements account for 25 percent of the total water use in the country (DWAF, 2004). Thus, there is an economic reason to reallocate water from agriculture to the non-agriculture sectors to promote sustainable economic growth and employment in the country.

From the economic perspective, the issue of reallocating water from low to high-value uses often emerges as rational under efficiency considerations. In most cases however, efficiency considerations alone fail to consider the backward and forward linkages among sectors, primary factors of production and institutions and the other non-economic uses of water, which if incorporated into the valuation framework addresses the issues of equity and sustainability. The question therefore is, not only how much does a particular sector contribute to the GDP, but how can a given quantity of water be used such that the standard of living of the critical mass of people is improved, both in the short and long-run. This addresses the issue of efficiency as well as equity and sustainability; hence, justifies the inclusion of social and environmental values of water into the economic valuation framework.

A number of studies in South Africa have tried to estimate the value of water in different sectors. Louw (2001) evaluated the impact of a potential water market on the efficient utilization of water in the Berg River basin. The study used a mathematical programming model to determine the true value of water. The estimated figures showed significant differences in the marginal value of water in different locations in the basin. However, the study estimated the marginal value of water for all industrial

activities as a single sector. Therefore, the estimated marginal values for industries cannot be used as reliable base for workable policy decisions, because the demand for and the value of water vary from one industrial sub-sector to the other. For example, demand for or the value of water in agro-based industries (food and beverage manufacturing) is quite different from that of vehicle manufacturing.

In a different study, Farolfi and Perret (2002), through the use of standard environmental economics and an agent based simulation model analyzed the impact of reallocating water from farmers to mining sector in the Steelpoort sub-basin of the Olifants. While the study's use of a simple model is highly recommended for policy purposes, the use of only two sectors (irrigation and mining) when other sectors like different industrial sub-sectors, construction and services exist in the same study sub-basin is a major limitation. The model also used restrictive assumptions about water demand and output supply behaviour of competing users. In a related study, Hassan and Farolfi (2005) improved the initial model, by including industries and taking into consideration the ecological reserve. However, the study did not still consider the economy-wide benefits of water, which include the forward and backward linkages among the sectors as well as feedbacks from institutions. A recent study by Moolman *et al.* (2006) estimated the marginal revenue function of water for six irrigated crops in South Africa. The findings indicate that there are differences in the marginal revenue for different irrigated crops and in different locations and that the estimated marginal revenues can be used for intra-sectoral water allocation policies. While this is a good development in water management studies, focus on only a few crops and one production sector limits the policy relevance of the study. All the above studies

contributed to the literature in water resources research in South Africa, but neglected the economy-wide contributions of inter-sectoral water use in the country.

Hassan (2003) estimated the economy-wide benefits from water-intensive industries in the Crocodile River Basin, using a quasi-input-output analysis. The study analyzed the contribution of irrigation agriculture and cultivated plantations in the Crocodile Catchment. While the study made a useful contribution to the understanding of water's contribution to economic development at a river basin level, the analytical framework was limited to the primary production impacts. Issues such as the contribution of water to household income generation, employment and output beyond the primary production sectors are not addressed in a traditional input-output analysis. Hence, this approach understates the full potential contribution of water to economic development and changes in households' welfare. Also, the study focus on the agricultural sector alone, while excluding other vital sectors like industrial sub-sectors, mining and the services sectors, which contribute more to the GDP and employment in the country's economy than agriculture, is major limitation to the policy relevance of the study.

The gaps and limitations of the above studies and the need to include feedback from factor inputs, institutions and the rest of the world in an analytical framework that assesses the economy-wide contribution of water to economic growth, poverty reduction and redressing the racial and income disparities in South Africa, necessitate a study that can include all the major production sectors and sub-sectors into the economy-wide water valuation framework. These issues and concerns require a detailed modeling technique that critically analyzes the structure of sectoral water uses

in South Africa, with the view to recommending policies that maximize economic and social welfare benefits in the country. However, to effectively accomplish such a study, there is the need to understand the inter-sectoral demand for and the marginal value of water at both global and country specific levels, hence, the inclusion of global sectoral water demand estimation as the springboard for the country-specific water demand analysis.

1.5 THE OBJECTIVES OF THE STUDY

This study is designed to analyze the global and country specific (South Africa) sectoral demand for water and to analyze the efficiency and equity effects of inter-sectoral water reallocation strategies/ mechanisms based on the estimated marginal values in South Africa. Specifically, this study is designed to:

- i) estimate the global and South African sectoral water demand elasticities and marginal values,
- ii) update the existing South African social accounting matrix (SAM) and use the SAM approach to analyze the contribution of water to various inter-sectoral activities,
- iii) using the market water allocation mechanism, investigate the impact of different sectoral water reallocation scenarios on households' welfare in South Africa.
- iv) using the computable general equilibrium approach investigate the impact of global change on households' welfare in South Africa and
- v) based on the simulation results, recommend policies that would promote water use efficiency and equity in South Africa.

1.6 HYPOTHESES TO BE INVESTIGATED

Various econometric studies have been carried out to investigate the relationship between water use as an intermediate input and sectoral output. The estimated results of these studies suggest that sectoral water demand is price elastic (Rees, 1969; Turnovsky, 1969; DeRooy, 1974; Grebenstein and Field, 1979; Babin *et al.*, 1982; Renzetti, 1988; Renzetti, 1992; Renzetti, 2002; Wang and Lall, 2002; Renzetti and Dupont, 2003). Empirical studies also show that water contributes positively to sectoral (Renzetti, 1988; Renzetti, 1992; Farolfi and Perret, 2002; Nieuwoudt *et al.*, 2004; Hassan and Farolfi, 2005; and Moolman *et al.*, 2006). The empirical evidence from these studies suggests that sectoral water allocation is efficient when water prices reflect the sectoral water marginal values of water. The empirical findings of Wang and Lall (2002) indicate that the agriculture sector has the least marginal value of water compared with the manufacturing, mining and services sectors. Based on this evidence it can hypothesize that water reallocation from the agriculture to the non-agriculture sectors in South Africa can lead to growth in sectoral output.

However, in a country where there is a wide gap between the rich and the poor, equity issues are high on the development agenda. Therefore, the benefits derived from efficient water reallocation should be distributed such that improve the standard of living of the critical population. Hence, the second hypothesis is that water reallocation from the agriculture to the non-agriculture sector can lead to an increase in the income of the critical population

The study estimates the sectoral price elasticities and marginal values of South Africa, updates the 1999 social accounting matrix for South Africa and uses both SAM

multiplier and computable general equilibrium approaches to investigate how water reallocation from the agriculture to the non-agriculture sectors affects output growth, value added, job creation, and income generation and distribution among the income-stratified households.

1.7 OUTLINE OF THE STUDY

Chapter two provides a brief review of methodologies used in the economic valuation framework for water resources, while chapter three analyzes the global inter-sectoral water demand. In chapter three, the output elasticity, marginal value and price elasticity of water are computed for agriculture, mining, energy, manufacturing sectors. Since water use in the manufacturing sector differs for different manufacturing activities, this sector is divided into sub-sectors. The study uses the GTAP and UNIDO data to econometrically determine the demand functions for the different sectors.

In chapter four, the global model is validated by using data from the census of manufacturing and agricultural activities, and water resource accounts compiled by STATSA (2004) and the time series data on manufacturing and agricultural activities, compiled by Trade and Industrial Policy Strategy (TIPS) for South Africa. The sectoral demand for water is further analyzed at the regional level to examine the extent to which sectoral marginal values of water differ from one region to the other. This is followed by updating the 1998 social accounting matrix developed by Thurlow and van Seventer (2002), to have 2003 entries and to replace the water accounts with the STATSA's 2004 water supply and use account for south Africa.. These data are used in chapter five to compute the coefficient matrix and multipliers, which are used to

analyze the contribution of water to the economy and to assess the impact of sectoral water reallocation based on marginal values on inter-sectoral output growth, factor payments, job creation and household income generation in South Africa. In chapter six, because SAM impact analysis usually overstates or understates the simulation results, the study uses the computable general equilibrium analysis (CGE) to investigate the impact of global change and water reallocation from the agriculture to the non-agriculture sectors on households' welfare.

Chapter seven presents summaries of the empirical findings in the previous chapters and discusses some policy implications of these findings. It provides a brief general conclusion and highlights the areas for further and future investigation.

1.9 LIMITATIONS OF THE STUDY

The major limitation of this study is the unavailability of regional or basin level social accounting matrices in South Africa, because it is difficult to construct basin level SAMs for the nineteen water management areas within a short period. The water situation in South Africa varies from one catchment to the other. Analyses at the national may overstate or understate regional or basin level situations. For example, while mining may be an intensive water user in one catchment, in another catchment it might be agriculture or manufacturing. However, national level analyses are used as broad examples to show how reallocation of water from one sector to another on the basis of sectoral marginal productivity of water may not always simultaneously address efficiency and equity objectives.

Another limiting factor, which might affect the results, is the aggregated nature of the agriculture sector. Agriculture, forestry and fishing are aggregated into one sector. There is the need to disaggregate this sector to rainfed and irrigated agriculture, plantation and wild forestry. For effective policy implementation, there is the need to understand the value of water in these sub-sectors as in the disaggregated manufacturing sub-sectors.