An Estimation of the Value of Water in the Commercial Forestry: Two Case Studies from KwaZulu-Natal, South Africa.

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DECLARATION

I declare that this dissertation is my own work and has not been submitted for a degree in any other university.

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ABSTRACT

The aim of this dissertation is to estimate the value of water in the commercial forestry in selected areas of Kwazulu-Natal. Furthermore, the essay focuses on two species:Eucalyptus grandis and Pinus patula. The estimation of the value of water is done using two types of water and they are evapo-transpiration (ET) and stream flow reduction (SFR). ET water is used because it has been discovered that there is a loss of water due to afforestation. On the other hand, SFR water is used because the existence of trees means that the water that is supposed to flow to the streams does not, as it is absorbed by the trees. Moreover, the essay develops two methods that can be used to estimate these two types of water in the commercial forestry. The methods are the residual method and the marginal valuc product (MVP) method. In the casc of the residual method, the results are diverse. This means that the values of water for eucalyptus using the ET water, ranges from 05 cents to 23 cents. With the pinus patula, the values of water ranges from 01cents to 03 cents. This is clear that the value of water for eucalyptus grandis using the ET water is higher than the pinus patula.
The value of water using the MVP method using the ET water is decreasing. This means that the values of water starts from higher values to the lowest. This is due to the fact that we are estimating the marginal product. The values start from 72 cents and go down to 28 cents in the case of eucalyptus grandis. The values for the pinus patula start from 26 cents and go down to 12 cents.

When estimating the value of water using SFR water, we do not use the residual method. We use the MVP method instead. The values obtained show that eucalyptus grandis values are higher than those of the pinus patula. They start from R5.10 cents and go down to R2.77 cents for eucalyptus grandis and from R2.39 to R1.03 for pinus patula. The methods used show that the economies of scale are present, because when we add more water, the value falls. Furthermore, The law of diminishing marginal returns is present because when we add more water; the values reach a maximum point and then start to fall. These two factors comply with the economic theory.

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CHAPTER 1
INTRODUCTION

1.1.Background

Recently, the scarcity of water has been felt in the country. Lee, (2000) states that only 3 percent of water available for consumption. This percentage can be used by at least seven sectors. The sectors are agriculture, industry, recreation and esthetics, waste assimilation, hydropower, navigation and municipalities. If we are to divide this quantity of water among all these sectors it becomes clear that water is a scarce resource. As a result, there are sectors that must reuse water because of the shortage. This shows clearly that water is a scarce resource.

Furthermore, it has been discovered that the agricultural sector uses more water than any other sectors. As Gibbons (1986) says about 50 percent of water, available is used by this sector. If the agricultural sector uses 50 percent of water it becomes clear that the other sectors must share the other 50 percent of water. This necessitates regulations in the use of water by this sector.

Within the agricultural sector, there is forestry. Forestry uses more water than other crops. This is due to two factors: Firstly, South Africa has an area of about 122.1 million hectares (ha) of land of which 1.5 million ha of land is used for the plantation of commercial forestry (Gasana, 1999). Furthermore, there is also 2800 ha of land used by the farmers to grow small plantations of poplar, which supplies wood for matches (www.dwaf.pwv.gov.za.whitpap.htlm). As this sector uses more land for afforestation, it is obvious that it also uses more water. As a result, in 1986 it was estimated that the commercial forestry uses 1.2 billion cubic metres of water. This water is about 30 percent of water that can be used by the urban sector and the industrial sector or can be about one-tenth of water for the growing of other agricultural crops. Again, this water would have been used for the growing of other crops or have entered streams and rivers (www.dwaf.gov.za.whitpap.htlm). This shows that this sector uses more water than other sectors.

Secondly, there is an increase in the demand for forest products. To meet this increase, the government has decided to increase the plantation of trees by 17000 ha per year (www.dwaf.pwv.gov.za.whitpap.htlm). This increase is also due to the fact that not all provinces are rich in the plantation of forests. The following provinces are fully engaged in the plantation of natural forests. They are Eastern Cape (about 140 000ha), KwaZulu – Natal (KZN) (about 91 200 ha), Western Cape (about 60 000ha), Northern Province (about 35 000) and finally Mpumalanga Province (35 000ha). In the case of industrial/commercial forestry, Mpumalanga Province is leading with 624 000 ha of land followed by KZN with 534 000ha of land. Northern Province, Eastearn Cape and Western Cape have far lesser quantity of hectares planted (www.dwaf.pwv.gov.za.whitpap.htlm:11). An increase in the demand for forest products is coupled by an increase in the use of water for afforestation. As a result, Bosch, *et al,* (2000) state that the demand for timber is expected to increase by 80 percent in the year 2010.

The regulation of water makes the valuation of water used in this sector very crucial because it allows the foresters to know exactly, the value of water used in this sector. The valuation could show that there is an efficient use of a resource because it equates marginal benefit of an extra resource with the marginal cost.

1.2.Problem Statement

Water is an environmental resource that has many uses. For instance, the well functioning of the agricultural sector is based on the availability of water. Again, recreation and esthetic sector needs water for its survival. However, it is clear that although water has many uses, it is a finite resource. This trend of the scarcity of water is recent because previously, there was an unlimited supply of water. There are at least five factors that show that water is a scarce resource.

The first factor that shows that water is a limited resource is the quantity of water available for consumption. In fact, the existence of 'oceans and seas' does not mean that this country has infinite supply of water. Ali (1979) states that water covers 70 percent of the earth's surface of which only 2 percent is fresh water. This fresh water can be found stored as ground water, glaciers or ice caps. Lee (1999) recently estimated the quantity of fresh water on earth and confirmed what Ali has said by stating that only 2.5 to 3 percent of water is available to human being as fresh water.

The second factor that contributes to the problem of water is a wide spread occurrence of dessication. This refers to the shrinkage of sea or ocean. For instance, in the United States (US), the Aral Sea shrunk (Winpenny, 1994). The shrinkage of the sea caused several problems. Firstly, there was a decline in the fishing industry because there was a lack of fish caught in the sea. The secondary effect of this problem is that it contributed to environmental problems as the presence of fish represent the well functioning of the sea. Secondly, the dust storms increased rapidly as there was no water in the sea. Lastly, there was wide spread salt deposition. The problem with salt deposition is that it is difficult to grow crops if the water that is going to be used for irrigation is concentrated with salt. The yield is then reduced. The problem of dessication can be traced in other countries as well here in South Africa. As a result Nanni (1970) states that the waters or rivers which used to thrive exist no longer exist. Some of these water bodies dried out partially while others were permanently dried out. This shows that this country has a problem of water shortages.

The third factor is due to the fact that most of the time evaporation is greater than precipitation (www.pwv.dwaf.gov.za). Whenever evaporation exceeds precipitation, it means that the country would have water shortage problem because more water is lost through evaporation and is not generated adequately. The plantation of trees, for instance, has been witnessed that it involves the loss of water through evaporation.

Another factor that contributes to the scarcity of water is the way in which the aquifers operate. The rate of pumping them is higher and, they are depleted quickly. Cairns (1995) suggests that if the plantation of trees is 50 percent of hectares (ha), then the water from the aquifers would be reduced by 2-5 metres. Therefore, the plantation of forests tells us that there would be the reduction in the supply of water due to the aquifers. Moreover, in the winter season there would be a substantial shortage of water due to the weather. Since water is a common property, the market forces of demand and supply do not operate to show that water from the aquifers is a scarce resource. This makes them deplete quickly.

What worsens the situation is that some aquifers are not reversible. If one uses them inefficiently, they are reduced. This can be a problem because it shows that there is no potential for sustainability in this resource. It needs to be treated with caution otherwise there would be a permanent loss of it. If it gets lost, the households, farmers and others who use it would suffer. The effect of it in the long run is that the future generation would not extract water from them. For instance in the United States (US), an aquifer was supposed to live for a period of hundred years but it was pumped in such a way that it ended up living for 40 years (Winpenny, 1994). This shows that there was an overuse of this resource. It also shows that this resource is not reversible or re-usable.

Finally, South Africa has a problem of climatic conditions. The weather of this country varies greatly. There are regions that have high rainfall and those with low rainfall. Recently, there is a wide spread occurrence of floods. The floods are then followed by droughts (www.pwv.dwaf.gov.za). This shows clearly that water is a scarce resource and the country is experiencing problems with the supply of water. In the case of aquifers mentioned above, it is difficult for them to recharge quickly because of the weather of this country.

The five factors stated above shows clearly that water is a scarce resource and the supply of water is limited. Therefore, there are challenges facing the government of this century.

Firstly, the government has to provide proper sanitation and clean water for all South African citizens. This involves even the rural areas. This means that the supply of water has to be increased. The problem is that there is limited quantity of water and the water sector is experiencing problems as stated above.

Secondly, there must be the protection of environmental resources and indigenous forests (www.pwv.dwaf.gov.za). Recently, there has been accelerated environmental awareness. People are now not expected to exploit or abuse environmental resources. Forests are not the exceptions as they are environmental resources. Furthermore, forests are used for recreational and research purposes. However, the protection of indigenous forests is a problem because they are grown in places that are moist (Nanni, 1970). It means that they have greater influence on water resources from the catchments. This is clear that the government is faced with a challenge of protecting environmental resources and indigenous forests on one hand and on the other hand, the use of water by this species must be regulated because the streams are reduced for their existence. Furthermore, some water is evaporated and not being absorbed again by the trees.

Finally, the government is faced with a huge problem in the case of the commercial forestry. There is a projection of an increase in the demand for timber products. The government decided to meet this increase by adding about 17 000 ha per year (www.dwaf.pwv.gov.za.whitpap.htlm). This increase is also due to the fact that not all provinces are fully engaged in the plantation of forests. However, the following provinces are fully engaged in the plantation of natural forests and they are: Eastern Cape (about 140 000 ha), KwaZulu-Natal (KZN) (about 91 200 ha), Western Cape (about 60 000 ha), Northern Province (about 35 000) ha). In the case of the industrial/commercial forestry, Mpumalanga Province is leading with 624 000 ha of land, followed by KZN with 534 000 ha of land. Northern Province, Eastern cape and Western cape have far lesser quantity of ha planted (www.dwaf.pwv.gov.za.whitpap.htlm). An increase in the demand for forest products means that more water would be used by this sector. This is a challenge because water is a scarce resource and the demand has to be met.

Furthermore, afforestation strengthenes the economy of the country because in 1993/94, industries dealing with forest products contributed about 7.4 percent to the output of the country in the manufacturing sector. Furthermore, exports earned about R1,28 billion in net foreign exchange. This sector has created more jobs for rural people, over one million people are employed to this sector (www.dwaf.pwv.gov.za.whitpap.htlm). This shows afforestation is important in this country. As there is a projection of an increase in the demand for timber products as well as a shortfall of demand for timber products, it means that more revenues would be derived from this sector. The problem of unemployment would also be alleviated as more people will be employed in the country. However, the environmental costs are also enormous.

All economic commodities are attached with prices to show that they are scarce. It is clear that human wants are unlimited yet, resources are scarce so they are forced to make choices. The role of choice in the allocation of resources is important because it reveals that the resource in question is limited when dealing with its quantity as well as the cost of supplying it (Pearce, 1993). To this end, the use of a resource has to show that there is an opportunity cost foregone. For instance, the use of water in the commercial forestry would have been used in the growing of other agricultural crops. Because there is an opportunity cost foregone, the value of water in the commercial forestry must reflect this. Another factor is that if water remains a common/ free good, it means that there would be no efficient allocation of it. An efficient allocation of a resource allows the marginal benefit (MB) from the last unit supplied to be equal to the cost of supplying that unit. The problem is that most of the time MB is greater than marginal cost (MC). Whenever an economic price is charged, MB=MC. To develop this economic price and also reveal that water is a scarce resource and that there is an opportunity cost foregone in the use of water for the plantation of trees, it is clear that there must be an estimation of the value of water in the commercial forestry. This means that there must be different methods developed to value water in the commercial forestry.

1.3. The Objectives of the Study

An economic price can only be achieved if the value of water is estimated. So, the major objective of the study is to estimate the value of water in the commercial forestry.

More specifically, the aims of the study are as follows:

1. To review the literature on different regulations and acts passed to regulate the use of water in the commercial forestry..
2. To review the literature on different methods that can be used to value environmental resources as well as water used in the commercial forestry.
3. To reveal the kinds of water used in the commercial forestry. This means that there would be two sources of water that would be dealt with and they are: evapotranspiration (ET) and stream flow reduction water (SFR). These two sources of water are used in this essay to estimate the value of water. There are two methods developed to estimate the value of water in the commercial forestry and they are the residual method and the marginal value product (MVP) method.

1.4.The Need for the Study

There are several reasons why the study needs to be pursued.

Firstly, an estimation of the value of water in the commercial forestry has never been undertaken in South Africa before.

Secondly, there must be a shift from concentrating on supply augmentation to demand management. Demand management allows for the treatment of water as an economic commodity rather than as a public good. This allows for marginal benefits of using an extra quantity of water to be equated to marginal cost of gaining that quantity. Eventually, economic efficiency is achieved. It is important that MB=MC. Previously, MB<>MC, which symbolizes a misallocation of resources.. In this study we want to equate MB with MC. Furthermore, the absence of demand management has caused the water sector to loose about 50 percent of water in many former black townships (**www.dwaf.gov.za**). This is characterised by leaks, low level-payments and institutional problems

The availability of funds from the estimation of water would be used for water resource management, water development costs and waterworks costs. Resource management ensures that the regulations stipulated for the water sector are followed. On the other hand, water developments are concerned with the developments that are undertaken by the water sector to achieve equitability and also to ensure that proper planning for them is followed. All works related to water could be done if the estimation of water is undertaken because funds would then be available for them.

Finally, the study is very important because foresters would be expected to grow trees of high value instead of that of low value. Previously, there was no selection of crops because water was free or charges a very low price (Winpenny, 1994). The plantation of trees with high value would help not to deforest some forests. There are rumors that if deforestation takes place, more water would be released to other sectors (Versfeld, 1996). However, an estimation of the value of water would help the decision-makers when taking any decision pertaining to water and its allocation.

1.5. The Scope of the Study

An estimation of the value of water in the commercial forestry would focus on two species, and they are: eucalyptus grandis and pinus patula. The reason behind this is that about 56 percent of land is used for the plantation of eucalyptus grandis and 32 percent of land is used for the plantation of pinus patula (**www.pwv.dwaf.gov.za**). Another factor is that these two species reduce stream flow more than other species as they account for a larger portion of the land. There are two methods that would be used to estimate the value of water in the commercial forestry namely: the residual method and the marginal value product (MVP) method.

However, we will rely on the secondary data for the development of these methods. Furthermore, we use only KwaZulu-Natal (KZN) sites as samples. This means that the study is only restricted to this province but anticipating the results would be the reflection of other sites in the country as a whole.

1.6. The Organization of the Study

Chapter 1 is an introduction, while chapter 2 first looks at the relationship between water and the commercial forestry. This relationship is captured by discussing evapotranspiration as well as stream flow reduction. These two sources would be used to estimate the value of water. Furthermore, this chapter reviews the literature on different regulations and permits to regulate the use of water in the commercial forestry. It also reviews the literature on different methods that can be used to estimate the value of environmental resources.

Chapter 3 develops the conceptual model in estimating the value of water in the commercial forestry. It also deals in depthly with the two methods of analysis in this study: the residual method and the MVP to be used to estimate the value of water in the commercial forestry. Chapter 4 analyses and discusses findings from estimation. Finally, in the last chapter 5, summary and conclusions are provided.

CHAPTER 2

LITERATURE REVIEW AND VALUATION METHODS

2.1. Introduction

Afforestation in South Africa is increasing rapidly because of an increase in the demand for forest products and the involvement of many people, especially, rural people in this industry. This increase is coupled by an increase in the demand for water. Since water is a finite resource, it is wise to develop regulations for its use in the commercial forestry. As a result, the government, policy-makers passed regulations and policies in-order to regulate the use of water in the commercial forestry in South Africa. So, it is important to look at the water use in the commercial forestry. In discussing the water use in the commercial forestry we first look at the relationship between water and the commercial forestry. This means that we discuss two sources of water in the commercial forestry, which are evapo-transpiration as well as stream flow reduction. Furthermore, one has to review the literature of the regulation of water in the commercial forestry. The regulation of water in the commercial forestry is in two folds.

The essay looks at different regulations and laws before the twentieth century. Secondly, it reviews the literature after the twentieth century, which is the current situation that suggests one of the solutions to the water-problem, that is, the valuation of water. This leads to a discussion various methods that can be used to value all environmental resources more especially, water.

2.2. The Water Use in the Commercial Forestry

The South African Farmers have discovered that the plantation of trees threaten water supply (Nanni, 1990: 9). This can be attributed to the fact that more water is lost due to the plantation of forests. Furthermore, the regulations passed by the government show that more water is lost as a result of afforestation. It will be of interest to look at the relationship between water and the commercial forestry, as well as the literature review on the regulation of water in the commercial forestry.

2.2.1. The Relationship between Water and the Commercial Forestry

A study done by Peter Dye et al (2001) reveals that the water used in the commercial forestry can be in the form of evapo-transpiration (ET) and stream flow reduction (SFR).

Evapo-transpiration (ET)

In the case of forestry, ET comes from the loss of water from the stands of trees when compared with other crops. This means that when afforestation takes place, water is evaporated and is also transpired by the leaves. The water that comes from the leaves is being re-absorbed by the tree. However, not all water is reabsorbed. Some is then lost because of these processes. Nanni, (1970), states that a tree that gets enough water and is kept in green leaves transpires at least 1500 litres of water on average, daily. This means that afforestation means that water is lost without actually used for any positive outcome. On the other hand, a tree that gets at least 1100 mm of water per annum usually vaporises an amount of ten litres a day. This also shows a significant loss of water due to the plantation of trees.

Again, in the study by Dye *et al* (2001), it states that areas that have plenty of rainfall are able to yield more than those areas that experience drought. However, the areas that yield more also transpire and vaporize more water. This shows that more rainfall means more loss of water that can be used in other crops. Therefore, afforestation has an effect on the water sector and it needs to be considered more closely so that the loss of water can be reduced.

Stream Flow Reduction (SFR)

Basically, the plantation of trees means that natural vegetation is replaced. Most of the time the natural vegetation that is usually being replaced by forests is grassland. This is a problem because grassland is reduced which is able to allow more water to flow to the rivers and to the catchments. For instance, in the Mpumalanga province, forests replace 25 percent of the grassland (www.dwaf.gov.za/whitpap.htlm). This means that most areas are afforested and the grassland is removed. The removal of grassland means that more land is used for the growing of trees. The secondary effect of this is that streams are reduced because forests absorb more water than grass. Dye,*et al,* 2001) confirms this in his study of seven sites about the relationship between water and the commercial forestry. He gave us the following results:

Table 1.1: The relationship between Water and the Commercial Forestry

SPECIES	Location	MAP (mm)	Grassland (mm yr^{-1})	Forest ET (mm yr^{-1})	Stream Flow Reduction (mm yr^{-1})
E.grandis	Kwambonambi	1102	661	904	243
E. grandis	Tanhurst	962	618	820	202
E. grandis	Kia-Ora	822	568	726	158
E. grandis	Baynesfield	834	572	735	163
Pinus patula	Usutu	1124	667	916	249
Pinus patula	Richmond	1025	638	859	221
Pinus patula	Greytown	786	553	701	148

Source: Dye,*et al,* (2001)

The results above show the effects of afforestation on the streams. The column labelled MAP is 'mean annual precipitation' that represents the quantity of rainfall received in each site. The second column shows how much water used by the grassland. The column labelled 'stream flow reductions' shows how much water is reduced due to afforestation as compared to natural vegetation, which is grassland in this case. This means that grassland absorbs, in Kwambonambi, 661 yet forests absorb 904. The difference is 243, which is the reduction of stream flows due to afforestation. For example, if afforestation replaces grassland, Armstrong, *et al,* (1996) state that the plantation of pines allow more rainfall to be absorbed by the plant, unlike grassland. Furthermore, pines are grown the whole year. In the case of grassland, most of them are not grown through out the entire year. Like for instance, grasses in the Afromontane areas are mainly found in winter. This shows clearly that afforestation, and especially pines, reduce stream flows greatly.

Most of the time afforestation takes place near by the catchments. Broadly speaking, catchments are described as places where by social, economic and physical systems inter-act. These systems contain people, agriculture, industry, communications services and recreational services. Most of the time afforestation takes place in the places that are above catchments described above. This means that afforestation indirectly affect catchments (Bosch, *et al,* 1990). It becomes difficult for other systems to perform adequately their tasks because trees are absorbing more water. As afforestation takes place in the upper parts of the places, the streams are reduced greatly because all the water that was supposed to flow to the streams no longer does that.

At this juncture it is wise to look at the catchment in specific terms. This can be traced back from the 19th century where the government of South Africa realised that mountainous places are only suitable for the plantation of forests. But when the country experienced the drought, the government was forced to implement water catchments near by the mountains. The catchments are used to store water. However, the existence of forests in the mountains means that the forests use the water that comes from the rain. In fact, this water is supposed to flow to the rivers and catchments. This makes the stream flows to be reduced. Thus Peter Dye, *et al,* (2001) state that water that is used for afforestation is in the form of stream flow reduction (SFR) because of the reduction in the streams. Forests absorb water for the growing of timber and other forest products.

As there is a projection of an increase in the demand for timber, it means that the catchments would be reduced greatly. There is then, a strong and urgent need for the regulation of afforestation in South Africa because water is a scarce resource and it needs to be treated with caution.

2.2.2 The Regulation of Water in the Commercial Forestry in South Africa.

South Africa has, for a long time, been trying to regulate the use of water in the commercial forestry. The first period is before the twentieth century and the second period is after the twentieth century, which is the current situation. This has been shown by many regulations and laws passed before the twentieth century.

2.2.2.1 The Regulation of Water Before the Twentieth Century

Afforestation in South Africa can be traced back in the 1400 AD where in the Western Cape, there were forests and shrubs planted. But the regulation of forestry is recent. For instance, in 1652 when van Riebeeck came to South Africa there was a high demand for timber at the Table Mountain and Hout Bay. This demand was due to the fact that timber was used for the building of ships and houses. The exploitation of timber resources continued in this century although the population was not very large. As a result in 1888 the Cape Forest Act was passed to restrict the extraction of forest products. The acts were used in the regulation of the use of water but not to restrict the use of water by the commercial forestry. This is confirmed when the British government in the 1900s emphasised that water is a common property so all the members of the society must use it. The Department of Forestry was entitled to regulate the use of water by issuing the riparian rights. However, the members of the society did not welcome these rights. As a result, in 1912 an Irrigation and Conservation of Water Act was passed. This act was passed mainly for the use of water for irrigation. In that time the weather contributed a lot to the problem of water.

Again, in 1956 the Water Act was passed. This act was mainly for the improvement of irrigation system in the country. It also emphasised the abolition of the riparian rights. Moreover, the act divided water into different categories like, public water, private water, normal flow and others. This means that there was some form of discrimination in the use of water. There are several problems attached to this act that led to its abolishment. Firstly, many people issued permits to farmers. This involves the minister, the court, and the irrigating water board. This makes it impossible to regulate the use of water in this regard. Secondly, the act did not emphasise on the management of water catchments. This was a big mistake of not managing the use of catchments because many farmers could increase their plantation of forests near by the catchments as there was no act regulating this. As a result, the water act of 1956 had to be abolished.

In 1968 and 1969 the Forest Act and Soil Conservation Act were passed, respectively. The two acts were used to improve the conditions in the management of water catchments. However, there were problems with the use of these acts because of the agencies. The agents did not have the same prescription about the use of water and the land. This means that they did not have a uniformity in the way they deal with the farmers. At some instances they have overlapping powers and this also created problems.

Eventually, the two acts were abolished and in 1970 the Mountain Catchment Areas Act was passed. This act emphasised the use of water that is secured by a sustained flow of water (Ackerman, 1976). Furthermore, this water must not have salt depositions because salts reduce the yield in the crops.

The problems with the Mountain Catchment Areas Act are that:

(a) It failed to protect water because of the existence of corruption amongst the regulators.

(b) This act was unable to stop the construction of buildings, that confirms development in the country or the construction of resorts.

(c) The act assumed that it is possible for all agricultural crops to be cultivated or grown. It fails to acknowledge that there must be the selection of crops that are planted. Gibbons (1987) states that the agricultural sector uses more water because they grow crops of low value. She suggests that if farmers were charged higher for water, they would be forced to shift from the growing of low value crops to that of high value. This reveals that the Mountain Catchment Act has to be replaced by some other acts because it is not economically efficient. Furthermore, it is not true that the agricultural sector can grow crops near the water catchments because they are economically efficient. The mountain catchments rather, can be used for recreational purposes and for other purposes.

This shows again that this act has to be abolished. There is a strong need for a new act that would be able to address all the problems discussed above.

The regulations discussed above were passed but the government was not very strict in implementing them. However, in 1972 the regulation of afforestation became the main issue to the government. As a result a policy of afforestation permit system (APS) was passed. Before the formation of APS, the regulation of afforestation was hindered by the high demand of timber during the two world wars in 1917 and in 1939. Furthermore, the drought that occurred in the 1960s hindered strong regulations for afforestation. Eventually, APS was formed to regulate the plantation of forests by issuing permits to foresters. This system was an amendment act of 1972 acts no 46. The Chief Directorate of Forestry in the government was expected to issue permits to the foresters.

Bosch, *et al,* (1990: 43) highlight the rule that govern the issue of permits by the Chief Directorate of Forestry. They say:

> *If afforestation will reduce the means annual runoff of a catchment beyond a specified minimum level, a permit is not granted. Otherwise planting is permitted, provided that streams, vleis and other open bodies of water are not afforested.*

There are issues that need to be considered when dealing with the permits for afforestation. Firstly, the extract above states that government specify a minimum level of runoff that cannot be exceeded otherwise permits for afforestation would not be issued. Because afforestation takes place in the upper parts of the catchments, there are three classes that were linked to the reduction of stream flows. Firstly, there is class 1, which does not allow the reduction of runoffs at all. If a farmer applies for a permit and fall under class1 areas, that farmer is not issued with a permit. Secondly, class2 areas allow for the reduction of Mean Annual Runoffs (MAR) of five percent. Finally, class three areas allow for the reduction of MAR of 10 percent (Bosch, *et al,* (1990). The argument that was raised is that the government allows a large area of afforestation because of the reduction of stream flows.

The government scheduled a limited quantity of water that the farmers can reduce. If the farmers exceed the quantity set by the government, they are expected to pay a penalty. Recently, afforestation was declared a stream flow reduction. This means that a charge has to be imposed on water for afforestation. Permits are used to regulate this. If a farmer does not have a permit, it means that that farmer is not allowed to grow trees.

The implementation of acts and different regulations is linked to the increasing demand for water and more especially, to the increase in the demand for water in the commercial forestry. If the water sector is not regulated it means that it would be difficult to meet an increasing demand for water.

2.2.2.2. The Current Situation

Usually, the agricultural sector uses 50 percent of total water utilization for irrigation (www.dwaf.gov.za). This figure shows that this sector uses more water than any other sector for its operation. This sector must regulate its use of water to show that there is an opportunity cost of the use of water for irrigation. Recently, the forest sector is faced with a substantial rise in the demand for timber and forest products. An increase in the demand for timber means that the demand for inputs would also rise. For instance, in 1980, the water used for commercial forestry was 1284 million m^3/a. The water that is used for afforestation is expected to go up to 1700 m^3/a by the 2010. This tells us that 32% of water would be used for afforestation (Bosch, *et al*, 1990). This means that there would be more water used by the forestry sector.

An increase in the demand for forest products means that stream flows would be reduced greatly. This is due to the fact that more plantations of forests would take place. The existence of forests means that run-offs would eventually be reduced. Furthermore, the water catchments would run short of water and the aquifers would not be recharged because there is less water available. Therefore, the costs of an increase in the demand for timber and forest products are that there would be a reduction in the water supply.

An increase in the demand for timber and forest products can be attributed to an increase in demand for forest products in other countries. This means that there is an increase in exports for timber products. In 1994 timber products earned the South

African economy R707 million in foreign exchange earnings and is projected to increase greatly (www.dwaf.gov.za). This shows that South Africa is earning more for their forest products.

The demand for forest products is expected to increase even further because a shortfall is foreseen in the future. This means that the demand for forest products would be greater than the supply of timber and forest products. The government is then, expected to make means of meeting this demand. However, the manner to meet the projected demand has to be considered because if there is an increase in the demand for forest products, it is obvious that there would be an increase in the demand for water and other inputs (www.dwaf.gov.za). In the case of water, the government must have in mind that water is a limited resource so it needs to be treated as an economic commodity. This is a problem because it still not clear to many people that water must be treated as a commodity. The government is then forced to regulate the use of water.

The regulation of water is somehow difficult because the government has recently decided to involve rural households in the production of timber and other forest products. The reason behind this decision is that in most parts of the country the rural areas are experiencing poverty. In-order to fight poverty; they are to grow forests for commercial purposes. Furthermore, the private companies decided to implement these policies as Sappi has a project grow, which is used for the development of small growers (Cairns, 1995). This tells us that there would be an expansion in the plantation of forests. It is clear that the government is facing a challenge in this century of regulating the plantation and the use of water on one hand, and of fighting poverty on the other hand.

The government has taken major actions to regulate afforestation. The solutions involve the passing of acts and also the amendments of some acts. For example, the government has passed the National Water Act no36 of 1998 to regulate afforestation. There are also a number of developments that are taken by the government to deal with the issues mentioned above.

Firstly, the government is entitled to issue permits for the plantation of trees. Previously, there were no strict rules in the issuing of permits. However, recently, the government has decided to slow down the permits issued to the farmers (www.dwaf.gov.za). This is a strong policy because there is an increase in the demand for forest products and this increase has to be reconciled by an increase in the supply of forest products. The government has decided to abolish the minimum level of reduction of run-offs of permits in-order to issue permits but is now using the economic terms in the provision of permits (www.dwaf.gov.za). In economic terms it means that there must be the consideration of the opportunity costs in the use of water. For example, the community, the maintenance of aquatic ecosystems and others must use water in the catchments. All the users of water are competing, so there must be the means of allocating water in an efficient manner so that all the users are 'better off'.

A licence must be issued for the use of water for afforestation. This would reduce the number of people who gain high profits because they do not pay for other costs. Furthermore, the licence also contains the enforcement of the property rights. Enforcement is important because it restricts the use of a natural resource. The farmers are not expected to plant forests that are above the land they are given. If they do this, they violate the use of property rights.

Secondly, the government is expected to promote advance education and training in the forestry (www.dwaf.gov.za). This means that the people in this sector are to be educated about issues that are related to forestry. They can be educated on water management and other issues. This makes it easier for the government to regulate the use of forestry if all the stakeholders have a clear picture about forest issues. The education has to be extended to the members of the society; and to the farmers on how to use water in an efficient manner. This would save great funds if the community is educated about the use of water and the importance of conserving water for future use.

Thirdly, the farmers as the solution goes, are expected to pay a minimum price for the use of water and for the reduction of streams. The money they are to pay would cover most of the things, like to show that the use of water in the commercial forestry has high opportunity costs, for water resource management and for the achievement of equitable and efficient allocation for the use of water (Gildenhuys, 1999). This would enable the water sector to reconcile supply with demand management. Previously, the water sector has been concerned with the supply of water to all the communities. Due to the problems experienced by this sector, it makes them to think of ways of dealing with the conservation of water and of managing the demand for water.

The fourth factor is that an equitable allocation of water means that all citizens of South Africa must have an access to clean water and must be provided with proper sanitation. This means that more water is still needed to satisfy all the members of this community. Furthermore, the rural community a makes livelihood out of forestry, as they use and sell wood as it is a form of fuel. Ministry of water affairs says that although the government is busy with electrification, it would take about 20years to provide electricity for all South African households (www.dwaf.pwv.gov.za). This means that woods for fuel are still very important. Moreover, there are small grower schemes for rural people so that equity can be found. This means that more water would be used for equitable solutions. As a result, Forester (1995) says that it would be wise to allow all rural people to grow trees for their survival so that equity is achieved (cited in Versfeld, 1996:58). It is clear that this solution would not work because, firstly, there are areas suitable for afforestation and those not suitable. If they command everyone to grow trees, there would be a shortage of land. Secondly, not all people have an interest in afforestation. Thus the value of water in the commercial forestry is important because funds would be used for different purposes.

Finally, there has to be the management of water catchment by the government. According to the National Water act no 36 of 1998: there must be agencies to control the use of catchments (www.dwaf.gov.za). These agencies are expected, according to section no 80 (a-e):

(a) to investigate and advise interested persons on the protection, use, development, conservation, management and control of the water resources in its water management area;
(b) to develop a catchment management strategy;

(c) to co-ordinate the related activities of water users and of the water management institutions within its water management area;

(d) to promote the co-ordination of its implementation with the implementation of any applicable development plan established in terms of the Water Services Act, 1997 (Act No. 108 of 1997);

(e) to promote community participation in the protection, use, development, conservation, management and control of the water resources in its water management area.

All these duties enlisted above will help in the management of catchments by the agencies. The advantage of the management of catchments is that the alien plants that grow near by the catchments would be removed so that the streams would not be reduced.

The price that is going to be charged by the water sector should be one that reveals that water is a scarce resource and it has many uses. This price can be achieved if an estimation of the value of water is undertaken. The next section deals with the estimation of the value of water, which seems to be the key to the management of water in this country.

2.3 The Valuation of Water as an Environmental Resource

The estimation of the value of water is important because it shows that there is an opportunity cost in the use of water. Furthermore, it reveals that water is a scarce resource so it needs to be treated as a commodity, not a public good. Moreover, the estimation of the value of water is a solution to the challenges facing the South African government and the whole country. The aim of this section is to discuss different methods that can be used to value water in the country. The definition of value in economic terms will be discussed first and eventually the valuation methods that can be used to value water. The essay will further look at the following factors, the assumptions of methods, the advantages and disadvantages, the methodology of estimating the value of water.

The Background of the Valuation of Environmental Resources

The valuation of environmental resources falls under a class of neo-classical welfare economics in the microeconomics. This category is concerned with the analysis of welfare of the society as a whole. This involves the interaction of human beings and the environmental resources so that welfare can be maximised.

The valuation of environmental resources is new to this category because of the existence of public goods. Previously, there was no valuation of public goods because public goods are non-rival and non-exclusive. This eventually, renders them non-tradable in markets. As a result, most of the environmental goods are known as non-markets goods as they do not involve market transactions (Folmer, *et al,* 1995: 177). This means that there is no price attached to them. Recently, all environmental resources are to be treated as economic goods in the sense that they are finite and their provision is no longer free.

Characteristics of Value

Not all environmental goods can have economic value. However, there are factors or characteristics that must be carried by environmental resources in-order for them to have value. Firstly, a resource needs to have a user value or utility. This means that there must be future flows of return from the resource. It is not easy to pay for a resource that would not give any return in the future. Secondly, a resource needs to be scarce in the supply. If the resource is not scarce in its supply, it is not possible to have a value. In the case of water, it has been seen that water is a scarce resource so water qualifies to have a value. Finally, a resource has to be appropriable. This means that for a resource to have a value it must be transferable. If a resource is not transferable, it becomes impossible to make use of it at its best. Again, water would be used efficiently if it were transferable because if one fails to use it efficiently, one has to transfer it to the other user that will use more efficiently.

The Definition of Value

There are three ways that the 'value' of environmental resources can be defined. Firstly, according to Alan Gilpin (1999); National Research Council (1997), value can be defined as the 'value in exchange'. This means that if two commodities can be exchanged equally, then they have a value. Recently, value can be seen as a price of a commodity because if one has money, it is easier to get a commodity if the value of a commodity is equal to that price. In other words, the price attached to the commodity can be seen as the substitute for the value of that commodity. This means that when one acquires an object, one has to pay for that object in exchange. This value depends on how much one is willing to pay (WTP).

Secondly, value can be defined as the WTP that is attached to the environmental assets which is not charged the price in the open market. The National Research Council (1997) reveals that an environmental asset is any asset that is used in the production of a commodity that would have a value. For instance, aquifers are environmental assets because they are used for irrigation and, eventually, crop results.

Finally, value can be defined as the total economic value (TEV) attached to environmental resources. Economic value cannot be regarded as the only value that can be attached to environmental resources. However, they are very useful in the decision making because they bring along the pricing of environmental resources. The availability of price in the environmental resource symbolises the efficient allocation of them because they have joint uses and users. TEV involves the actual value of an asset, the option value, bequest value and the existence value.

According to Munasinghe (1995); Harrison *et al* (eds) (2000):

TEV= UV + NUV = (DUV+IUV+OV) + (BV+EV).

UV is the use values. This use values consists of DUV which is the direct use value, IUV which is the indirect use value as well as the OV which is the option value paid by a person to safeguard the asset available in the future. On the other hand,

NUV means that they have non-use values. BV and EV represent non-use values. BV stands for bequest value and it says that an environmental good must be available for the future generation. EV is the existence value and it says that an environmental good has to exist even if human beings do not need it for consumption. However, this essay is only interested in the use value of water. It does not cover non-use values.

Whenever a value is placed on an environmental resource it tells us how much the consumer is WTP for it. Like for instance, one can be willing to pay for the existence of aquifers even if this person would not make use of them.

What underlies all these values is the willingness to pay (WTP) because there can be a project that allows for growing of trees for instance, instead of preserving a place as it is. One can pay for the existence of this land and the other can pay for the future use of this land. If their willingness to pay is below the proposed project, it means that the latter would be done. So individuals are expected to pay more for natural resources so that they cannot be abused and overused.

2.4 The Valuation Methods

Previously, environmental resources were overused and abused because they were treated as public goods. Recently however, it has been discovered that environmental goods have value that can be attached to them. Water is an environmental resource and thus has a value.

There are four methods that can be used to estimate the value of water as an environmental resource. They are:

1. Opportunity Costs
2. Averting Expenditure
3. Changes in Productivity

4. Contingent Valuation Method

2.4.1 Opportunity Costs

Most of the time environmental goods have best alternative foregone. This means that these resources always have joint uses. The user has to sacrifice one thing in order to gain another. For instance, water that is used in the Commercial forestry can be used in the irrigation of other crops. This means that one has to sacrifice the irrigation of crops so that forests can be irrigated. The cost foregone is a proxy for the value of water. It sometimes happens that one proposes a project of using a dam to generate power. There must be a cost- benefit analysis to see whether power has to be generated from the dam or leave the dam as it is. If the results show that the dam can be left as it is then there is no problem. But if the results show that costs of preserving the dam are more than benefits, it is wise to look at non-use values, which are, option, bequest and existence values. After adding these non-user values, the analysts can see whether to continue with the project or not.

2.4.2 Averting Expenditures

This approach uses three ways, which are cost-based. The first method that can be found under this category is the preventive expenditure. There are two assumptions suggested by Dixon, *et al,* (1994). Firstly, this method has the data that is available for estimation. Secondly, expenditures are only concerned with primary benefits and not secondary benefits.

This method works as follows: For example, households are expected to prevent pollution from occurring rather than removing it when it has occurred already. If say, industries dump their pollutants to the river; the people who draw water from the rivers can avert these pollutants by using preventive measures like, boiling water before using them or buy disinfectants to prevent sicknesses from water. These expenditures determine the importance of an environmental resource. This tells us that the expenditures used by people to prevent pollution represent a surrogate demand for an environmental resource. The costs of preventing damages can be seen as part of the value of water.

The problem with this method is that most of the time individuals are constrained by the income rather than the demand. This makes it difficult to use preventive measures because individuals do not mitigate pollutants, as they do not have enough income to do so.

The second approach is the replacement costs. The assumptions associated with this method are that:

1. The size of the damage that has occurred can be measured.
2. It is efficient because one can calculate the costs of replacing an environmental resource. These costs are not greater that the facility that has been destroyed.
3. Again, this method is used mainly for the primary benefits and not the secondary benefits.

In the case of environmental resources that are irreversible, it is possible to replace these resources. Like for instance, if the aquifers are depleted, one can replace them with other systems of generating water. The costs of generating water from other sources acts as a proxy for the environmental damage. Ultimately, the costs incurred in the alternative are the value that can be placed on environmental goods.

The last approach that falls under averting expenditure is the relocation costs. The assumptions with this method are more or less the same as those mentioned above. Furthermore, this method functions the same as the replacement costs except that with the relocation costs, we measure the costs of moving from one area to the other because of environmental damages. For example, if the households are harmed by water pollution, the government can decide to move them from their original place to another place that is called relocation. All the costs involved in the relocation due to water pollution are taken as the value of water.

2.4.3 Changes in Productivity

The production can change physically when one value environmental resources using market price for inputs and outputs. One advantage of using changes in productivity to value environmental goods is that it is easier to adjust the prices used if there are distortions in the market.

When dealing with the valuation of water in the market using this method, it is wise to note that this method explains changes in productivity both on site and off-site. By on-site we mean the change in the output because of the estimation of the value of environmental resources. On the other hand, off-site changes deal with all the externalities, either environmentally or economically, that were not taken into account in the past. It is important to consider the off-site impacts so that we can have a full picture of the impact that the project would have on water.

Hanley and Spash (1994) suggest three ways of estimating the value of natural resources using changes in productivity. They are (1) Marginal Value Product (2) Econometric Methods (3) Programming Methods.

The first method mentioned above is the marginal value product (MVP) method. This method aims at estimating the value of environmental resource that involves the change in the production when there is a change in the water sector. In estimating MVP, firstly, we estimate the marginal physical product (MPP) of the yield. We then, multiply MPP by the selling price of a crop to obtain marginal value product (MVP) of the crop. There are two advantages of this method:

1. This method is simple and it does not need extensive data set to do it.
2. Furthermore, the consumer's surplus does not change because the price of the crop is constant.

However, this method has some problems:

1. The value of water can change if there are external forces that cause it to change. For example a change in the price of a crop. This method fails to accommodate that change.
2. Since the price of a crop does not change it means that this method fails to estimate the change in the consumer's surplus.
3. This method is less concerned with the distribution of income.
4. MVP is liable to the occurrence of the diminishing marginal return.
5. In some cases, this method does not estimate the total water used for irrigation. Like for instance in the estimation of the water for commercial forestry, water is in the form of evapo-transpiration and it is not 100% water used for irrigation.
6. Lastly, this method cannot be used for a specific crop.

The second method is the econometric method. It can also be used to value the changes in productivity due to the change in an environmental resource. Basically, this method is normative in the sense that it reflects the historical reality over a certain time period. Furthermore, it uses scientific and statistical methods to value changes in productivity. In estimating the value of an environmental resource, one can estimate a regression equation with the data collected. A dependent variable would be a water demand and explanatory variables include evapotranspiration, the cost of inputs that are complementary and those that are substitutes, and others.

There are few problems associated with this method:

1. It is impossible for one to capture new information outside the time span of the data.
2. One also has a problem with the choice of the functional form, eg. Cobb-Douglas functions.
3. There can be omitted variables. This is due to the fact that there are times when one does not include a variable yet it is needed.

The third methods that can be used to value environmental resources are programming methods. There are two types of programming methods that can be used in the valuation of environmental resources. They are Linear Programming and Quadratic Programming methods. Both of them require extensive data set for estimation. They can be done in a computer because of their complexity. The approach they use is similar because they require an objective function so that it could be clear whether we are maximizing profits or minimizing the costs. They also require the decision variables as well as the constraints. In the estimation of the value of environmental resources we only focus on the Linear Programming (LP) method.

Tewari, 1996; has used linear programming method in the study in Saskatchewan for the water demand. The results gained from that study show that it is possible and effective to use linear programming because of its simplicity.
The method that can be used to value environmental resource that can be adopted is as follows: Firstly, LP reveals the change in the output due to the change in the input. There must be the decision variables, the objective function and the constraints so that LP solution can be done.

The advantage of them is that they are able to distribute the benefits. However, the problems of this method are that:

1. If the real world operates sub-optimal because of market distortions, this makes the LP inefficient.
2. It is not easier to make predictions using the LP method. This needs to be improved as the time goes on.

The last method, in the category of changes in productivity, which can be used to value environmental resources, is the contingent valuation method (CVM). CVM is a survey technique that is used to obtain the information contained by the individuals' preferences for the good in question. The term 'contingent' refers to the valuation method, whereby the value is given to a surrogate or hypothetical market created by the researcher (OECD, 1994).

CVM can be used to obtain the values of public and private goods, but it is most suitable for the use in cases where no actual or alternative markets for a good exist or they are not well developed (Dixon *et al*, 1994). This method does not place a value on aggregate changes but rather it examines individual preferences directly, and then aggregates them according to who is affected by the change in welfare (Dixon, *et al*, 1994).

The contingent valuation method provides an accurate measure of an individual WTP and WTA for a given change in the welfare.
These two measures work together with a sample of consumers to measure their WTP and WTA for any change in an environmental service flows, in a carefully structured hypothetical market.

CVM is a direct method because it directly questions the individuals to place a value on a resource in question. This technique uses survey questions to obtain people's preferences, through the means of WTP and WTA, and then aggregates these amounts to a population WTP/ WTA and arrives at a total value for the resource in question (Mitchell, 1989). For the purpose of this study, the CVM allows us to arrive at a WTP for water used for irrigation in forestry.

As a technique to arrive at a total value for a resource, the CVM follows six general steps to obtain this figure (Hanley and Spash, 1993). These are:
*setting up the hypothetical market;
*obtaining the bids;
*estimating mean WTP and/or WTA;
*estimating the bid curves;
*aggregating the data; and
*evaluating the CVM exercise.

The first step in the CV process is to define the hypothetical market for the good or service under consideration. The definition of the hypothetical market determines the quality of the answers obtained by the researcher. If the hypothetical market is too complex, then the respondents may not fully understand the situation and thus give incorrect answers, and this introduces hypothetical bias (Hanley, 1989) Again, the purpose of the hypothetical market is to set up the 'reason for payment' (Hanley and Spash, 1993). The respondent should be notified of the proposed change, the expected benefits and costs of this change, as well as the reason for the valuation survey. Furthermore, information concerning who will be responsible for the delivery of the service, as well as when the service is expected to commence, should be provided. This information establishes the individual's 'reason for payment' or 'reason to accept compensation' for the proposed change in the status quo (Hanley and Spash, 1993).

The processes by which such payment will be made-if the proposal were to be accepted- should then be outlined for the individual. For example, this means of payment or bid vehicle must be stated clear. There are different kinds of payments that can be used. They involve the use of the property tax, income tax or trust fund payment. Survey questions must make it clear whether all the consumers that will be using the resource needs to make payments if the change is taking place and how the fee is going to be set. Other groups in the society pay this is important because there are cases where the group that is known as poor is not charged or if it is charged it does not pay the same amount.

The second step is the obtaining of bids. This is the actual questioning of individuals concerning their valuation of the proposed good or service, and their socio-economic characteristics, is performed at this stage of the CV process. In answering the questions asked, individuals express their WTP and/or WTA for the proposed policy. It is imperative to acquire further characteristics from individuals, so as to verify that those people who perform the CV are a truly representative sample of the population who will be affected by the change. For example, in the case of willingness to pay for water in the irrigation, one has to interview people like the farmers who use water for irrigation or the consumers who make use of a crop; not the people who have no knowledge of, or interest in that particular crop.

There are three methods that can be used to obtain the bids, (1) personal interviews, (2) telephone interview, (3) mail surveys (Hanley and Spash, 1993). The first method have the advantage of being both interactive, and of remaining plausible even in situations where the respondents may be illiterate or semi-illiterate (Hanley and Spash, 1993; OECD, *et al*, 1994). This method produces the highest quality of data but it is considerably more expensive and time-consuming than the use of other methods.

The telephonic method is relatively inexpensive and is less time-consuming, while still remaining interactive. This method allows for random telephone number selection, which aids in obtaining the WTP of that particular individual. Telephonic method is least preferred because it is difficult to convey the message over the phone, partly due to a limited attention time span (Hanley and Spash, 1993).

The mail surveys are widely used but suffer the problem of non-response bias and they are expensive (Hanley and Spash, 1993).

The questionnaire is the focal point of the Contingent Valuation Method. It is thus important to obtain meaningful answers, and minimization of biases, that the questionnaire be set out, and the correct questions be asked (Hanley, 1989).

There are three parts that needs to be addressed by the questionnaire (OECD, 1994):

The setting up of the hypothetical market of a good in question

The questions that are able to obtain individuals WTP, and

A section to where the socio-economic situation of the individual is questioned

After one has managed to obtain all the steps that have been outlined above, the next step is to obtain the WTP bids. In-order to obtain the WTP; it is imperative that one uses the bidding game (Dixon *et al*, 1994). There are four types of bidding games that can be used: A bidding game, close ended referendum, payment card, and an open-ended question (Hanley and Spash, 1993). Suggesting higher and higher amounts to the interviewee until his or her maximum WTP is established plays the bidding game. The closed referendum method presents the individual with a single WTP value and the individual must give a yes or no answer. The payment card technique, present the respondent with a range of WTP values, to which the respondent must select the one that closest represent his or her WTP. The final option is the open-ended question, which offer no WTP value and the respondents must give their value.

Thirdly, after the bids have been obtained of individuals concerning their WTP and/or WTA, the next step is to calculate the mean WTP and/or WTA for the sample (Hanley and Spash, 1993). Here the data must be analysed so as to remove outliers in the data. These outliers are from the protest bids, where the respondent has refused to give his/her WTP, or give 'less-than-meaningful' values. This can be in the form of a very large WTA, or a zero or negative WTP. These values are then removed from the data, as they arguably bias the data from the correct mean (Hanley and Spash, 1993).

Once the mean WTP has been established, the resource is valued at a price per person. This calculation provides preliminary estimates of 'total value', as well as the percentage of population that is willing to buy a good or service at a given price. Thus the price of an environmental resource has been arrived at.

The fourth step deals with the estimation of the bid curve. This section of the CVM exercise extrapolates the determinants of the WTP measure, usually regressed against the relevant population that is either directly affected by the change, or that falls within a particular political boundary of the change, income, education, age and some environmental quality (Hanley and Spash, 1993). These variables give important information about the correlation of, say, income and WTP, thus suggesting WTP being related to ability to pay. In estimating the bid curve, it is possible to predict changes in WTP due to some change in environmental quality, holding the other variables constant or using the demand theory and common sense. If the theory is supported, then this fact can give significant strength to the accuracy and validity of the results (OECD, 1994).

Once the mean WTP has been estimated, the next step, which is the fifth step, is to aggregate the sample bid for the whole population of those affected by the proposed change. There are three issues that need to be taken into account (Hanley and Spash, 1993):

choice of the population;

method of moving from sample mean to population mean; and

choice of the time period over which to act.

The choice of the correct population is basically the population that is affected by the proposed change. For example, those people who were not interviewed but have an option value of the price of water need to be taken into consideration. The method of moving from the sample mean to the population mean in-order to obtain the population mean is possible if one simply multiply the average sample bid calculated above by the number of people affected by the proposed change. This however, introduces certain biases, which will be discussed later. The other option is to use regress the data using the method of Ordinary Least Squares and thereby obtain the population mean. Each variable is given relevant population figures, and this is used as the relevant population (Hanley and Spash, 1993).

The final section of the CVM should include an evaluation of the technique. This can include the various anomalies in the data and how these anomalies were dealt with. This step also includes the accuracy and reliability of the survey that has been appraised subject to the problems surrounding the CVM.

There are at least three advantages of the CVM.

1. CVM is able to estimate the conceptual model using the direct questioning of the individuals that would be affected by the policy.

2. It makes all the members of the community to be part of decision- making.

3. This method does not only looks at the user values but it extends itself to non-user values where it deals with existence value and bequest value. This makes the method very popular.

Although, this method has some advantages, there are several problems attached to this method. These problems are known as 'biases' and 'errors'. These biases are as follows:

The first problem is the hypothetical bias. This bias can be found in bidding games as well as in the survey techniques in general (OECD, 1994). Here, people can be asked questions and these people do not give correct answers to the questions asked. This makes the estimates to be overestimated or underestimated. Again, the manner in which questions are asked can lead to hypothetical bias.

The second bias associated with this method is the strategic bias. It sometimes happens that people decide to act strategically (OECD, 1994). These people can reflect according to what the interviewer will do with their answers. For example, if they feel that they will be expected to pay the amount they have been asked, they can underestimate their true response. But, if they see that high answers will bring about changes that will coincide with what they want, they tend to overestimate the amount they are WTP.

There are different methods that may be used to reduce strategic bias:

1. The interviewer states clearly that all individuals will have to pay an average of the estimates.
2. The interviewer must insist that the respondents should provide a true value on an environmental resource.
3. The individuals overstate their WTP if they see that the project will go ahead if the values are a bit higher. This can be reduced by the policy that is able to influence the results. One thing they may do is to remove all the outliers.
4. An interviewer can use a referendum (yes/ no), whereby the bids are increasing until the respondent tells the truth.

The third problem is the design bias. Design bias refers to all the biases that the presentation of the questionnaire may induce and this bias may affect the responses of the individual (Hanley and Spash, 1993). There are two types of biases associated with the design bias, they are:

(1) choice of bid vehicle and (2) starting point bias (Hanley and Spash, 1993).

The bid vehicle affects how a person values his or her WTP due to the fact that some types of payments are viewed better than the one that has to be made. For example, farmers would rather pay money into the welfare fund rather than paying for water. Starting point bias affects the value of WTP when the current actual fee charged is greater than zero. It has been assumed that people are adverse to price increase than being charged for something that was free (Hanley and Spash, 1993).

The fourth bias that is found when dealing with this method is the sample bias. The study that has been conducted has to pick up the sample from the population to obtain a WTP. In the case of paying for water, the analysts have to pick up the sample that is directly affected by the proposed project. The fact that this sample was chosen, and not from a random selection of people, can introduce sampling bias and the sample size may also affect the CVM if it is sufficiently small (OECD, 1994). This bias can directly affect the validity of the WTP measure.

The fifth problem with CVM is the interviewer bias. If an in-person interview is taking place, it becomes easier for the enumerator bias to occur. This is due to the fact that not all interviewers are identical in their approach when they are presenting the hypothetical market and bidding process. This leads to 'Compliance bias' where the interviewees answer the questions in a manner that pleases the enumerator.

The selection bias is the final problem that is associated with CVM method. If there are non-zero but very large bids, the estimator needs to select whether to accept these estimates or not. This means that we have committed a bias in our estimates. Again, it has been realised that WTP is expected to follow a normal distribution. The problem is that we do not accept negative bids, and these bids are replaced by zero-values, so there is a potential to skew the distribution to the right.

2.5. Summary

The relationship between water and the commercial forestry has made it very clear that there must be ways of regulating the use of water in the commercial forestry. This is due to the fact that more water is lost when afforestation takes than when the plantation of other crops like the natural vegetation takes place. The government has realised that forest products use more water because of the existing regulations. This involves the passing of laws and the amendment of other acts. However, the solution to the value of water suggested by the economist is to value water that is used in the commercial forestry. As a result, this chapter presented different valuation methods that can be used to value water as an environmental resource. It is true that there are problems associated with the use of these methods but they can be used to value water. For instance, the opportunity cost method reveals that water has to be valued because it has joint uses. What underlies all these methods is the willingness to pay (WTP) for environmental resources.

WTP allows individuals to make decisions according to their limited income. One cannot use more water if s/he is not prepared to pay.

CHAPTER 3

THE VALUATION OF WATER IN THE COMMERCIAL FORESTRY: THE CONCEPTUAL FRAMEWORK.

3.1. Introduction

The previous chapter revealed that there are various methods that can be used to estimate the value of water. Thus, the main aim of this chapter is to focus on water that is used in the commercial forestry. Even in the case of water used in the commercial it is still imperative that there must be an emphasis on the demand management, where water is treated as a scarce resource. If water were treated as a scarce resource, the value of water would show that it has joint uses. Furthermore, the demand management has managed to discuss different methods that can be used to value environmental resources, and to be specific; it has managed to value water. Now, the aim of this chapter is to estimate the value of water that is used in the commercial forestry. The valuation of water in the commercial forestry shows that water is a scarce resource so; it must charge an economic price. In the case of the commercial forestry, which reduces stream flows and also contributes to the reduction of water that would have been used for other purposes, it is wise to charge an economic price. The aim of this chapter, basically, is to estimate the value of water using different valuation methods in the commercial forestry.

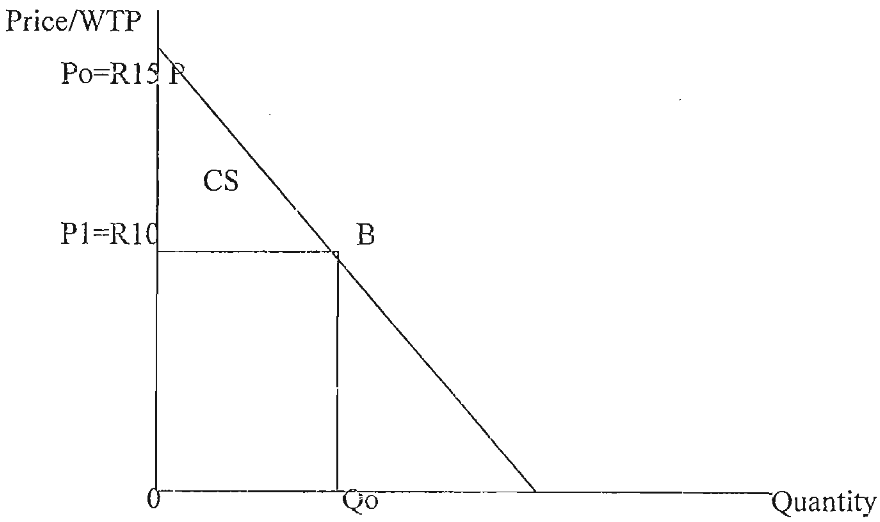
3.2. The Valuation of Water in the Commercial Forestry in South Africa

There are two methods that can be used to value water in the commercial forestry. These methods are: the residual method and the marginal value product (MVP) method. Before one discusses these two methods of estimation it may be prudent to develop a conceptual method that acts as our framework in our study.

3.2.1. The Conceptual Model

In-order for us to estimate the value of water in the commercial forestry, we need to develop a conceptual model which is derived from a demand curve. This means that if a price of water increases, the demand for water would decrease. The demand curve below thus, is downward sloping. This demand curve also reveals how much one is willing to pay (WTP) for water. If the price of water increases, the individuals would be forced to reduce their consumption of water. This means that their WTP is constrained by income and whether water is their necessity or a luxury good.

Figure 3.1 The Derivation of WTP using the Demand Curve



Source: Estimation

The diagram above illustrates the derivation of WTP. Area OPBQo measures the total WTP of water as an environmental resource. In other words, this area shows the maximum value of the environmental good. If the price of water is at, say, P1 and is R10 yet the consumer is willing to pay up to R15=Po, it means that this consumer has a consumer surplus of R5. Consumer surplus can then be defined as the difference between the willingness to pay and the actual price one pays.

3.2.2. The Residual Method

This is the first method that can be used to value water in the commercial forestry. It uses the farm costs to estimate the value of water. It does this by adding the costs (fixed costs and variable costs). If all these costs are added together, a total revenue is calculated, which is the selling price multiplied by the yield. We then, subtract all the costs from the total revenue to get a profit. The profit obtained is then divided by the quantity of water, as we did not add the cost of water when calculating the total cost. The value we get is called the residual because the farmer is able to pay all non-water costs and what remains can be used for the cost of water. The cost of water is the value of water and it shows the maximum amount the forester is prepared to pay for water in the commercial forestry (Gibbons, 1986: 29).

The residual method uses two sources of water. They are evapo-transpiration (ET) as well as the stream flow reduction (SFR). However, the residual method estimates the value of water using the ET water only.

3.2.3. The Marginal Value Product Method (MVP)

As has been discussed in the previous chapter, this method is simple and easy to grasp. Firstly, when estimating the MVP method, we estimate the marginal physical product (MPP) of the yield, which is a change of a yield for an extra unit added. We then, multiply MPP with the selling price of the crop to get marginal value product (MVP). In- order to estimate an area under the demand curve using MVP method, we use integration.

Secondly, it should be noted that the MVP method is distinct from the residual method because the former estimates the value of water using two sources of water which are the stream flow reduction (SFR) and the ET water yet, the latter uses the ET water only. Furthermore, this method does not use actual yield to estimate the value of water but the predicted yield.

The MVP of water used in the commercial forestry is expected to decrease. This makes sense because as the price of water increases, the demand for water goes down.

3.3. Data Sources and Computer Packages

The data that we use to estimate the value of water in the commercial forestry is taken from different sources.

Firstly, the costs that are going to be used to estimate the value of water in the commercial forestry are taken from the Forestry Economics Services of 1996. This book gives one all the costs that one needs in-order to estimate the value of water in the commercial forestry. These costs include fixed costs and variable costs.

Secondly, there are two species that this essay deals with: eucalyptus and pinus patula. The eucalyptus consists of two sites and they are, Kwambonambi and Kia-Ora. Kwambonambi is found in Zululand and Kia-Ora in Natal Midlands. Furthermore, Kwambonambi has higher yield than Kia-Ora yield. It also uses more water than Kia-Ora. This should be the reason why it yields most. On the other hand, pinus patula has also two sites used for estimation. These sites are Usutu and Richmond. Both of them are found in Natal Midlands. The yields for these sites are lower than the eucalyptus sites yet, they use more water than eucalyptus sites.

The third factor about the data is that there are two sources of water and they are: evapo-transpiration (ET) and stream flow reduction (SFR). The ET water is higher than the SFR water. This shows that the value of water would not be the same because the quantity of water is totally different. As has been stated above, the value of water using the residual method is estimated on ET water only. On the other hand, MVP method is estimated using SFR water and ET water.

Fourthly, when estimating the value of water using the residual method, we use the actual yield. However, when estimating the value of water using the MVP method we use the predicted yield. This means that we estimate the following function:
$Y=f(a + bX - cX^2)$. This function can be interpreted as Y is the yield (dry mass), X is the quantity of water and X^2 is the square of water. The a is the constant and b & c are

coefficients. The function above has been estimated in this manner: we regress Y against X and X^2 using the stata program and an Ordinary Least Squares (OLS) for estimation. All the sites were regressed and the results are obtained at the back in appendix A2. The results show that all the estimations are statistically significant at 5 percent level. After estimating the regression, we then estimate predicted values (new yield). This new yield is used in the estimation of the value of water using the marginal value product (MVP) method.

Fifthly, since the sites used are not found in the same place, their selling price is not the same. In the case of Kwambonambi, the selling price for this site is 188.43, for Kia-Ora is 180.15 and for pinus patula is 132.21. Different selling prices mean that the value of water would not be the same.

Finally, the estimation of the value of water can be done using the Microsoft computer package. However, to estimate the predicted values for the use in the MVP method, we use the Stata program.

3.4. Summary

The estimation of the value of water that is used in the commercial forestry can be done using the residual method and the MVP method. Both methods have problems when employed for valuation. However, it is true that they are able to estimate the value of water in commercial forestry. The use of ET and SFR water in the estimation of the value of water make the results not be the same. This can be attributed to the fact that we do not use the residual method in the estimation of the SFR water. This makes sense because with the residual method there has to be the use of cost budget while with the MVP method we do not use the costs it is only the selling price that is important. The fact that the residual method uses the actual yield to estimate the value of water whereas, the MVP uses the predicted yield makes the results not be the same.

CHAPTER 4

ANALYSIS AND DISCUSSION OF FINDINGS

4.1. Introduction

The previous chapter revealed that there are two methods that can be used to estimate the value of water in the commercial forestry in South Africa. The two methods are: the residual method and the marginal value product (MVP) method. If we manage to estimate the value of water it becomes easier to charge a price to water because one knows exactly the value of water used for the plantation of trees and the costs of all inputs used. There are two species used to estimate the value of water in the commercial forestry and they are eucalyptus grandis and pinus patula. The sites used fall under hardwood and softwood categories. That is, eucalyptus grandis are hardwoods and pinus patula are softwoods. This chapter aims at discussing results obtained from the estimation of the value of water. The analysis is done in this manner: firstly, there is the discussion of the results from the use of the evapo-transpiration (ET) water. In discussing ET water we first look at the residual method then the marginal value product (MVP) of the eucalyptus grandis. After discussing the eucalyptus grandis, I discuss the results for pinus patula using ET water. Secondly, I present and discuss stream flow reduction (SFR) water using the MVP method. It should be noted that the values for the residual method are lower than those of the MVP method.

4.2. Evapo-transpiration

This is the first type of water that has been used to estimate the value of water in the commercial forestry. There are two methods that can be used to estimate the value of water. The two methods are residual method as well as marginal value product method.

4.2.1. Eucalyptus grandis

In estimating the value of water in the commercial forestry, we start with the eucalyptus grandis. There are two species used and they are Kwambonambi which is found in Zululand and Kia-Ora found in Natal. Both species were estimated using two methods and the first method we will present the results is the Residual method then it would be the MVP method.

4.2.1.1. The Residual method

This is the first method that can be used to estimate the value of water in the commercial forestry.

Table 4.1: Kwambonambi Residual Results

YIELD (Y)	Water (m3/ha)	TR-TC(profits)	Profits/m3	Capi@10%
3	9930	-2211.29	-0.2226878	-2.226878147
39.6	27390	22233.66	0.08136751	0.813675064
86.9	38240	7966.62	0.20833209	2.083320868
130.4	50850	13243.60	0.26044452	2.604445231
154.3	62590	16142.91	0.25791521	2.579152101
172.1	68110	18302.23	0.26871577	2.687157686
177.7	73440	18981.57	0.2584636	2.584636029
187.7	80820	20194.67	0.24987215	2.49872148
207.2	90700	22560.21	0.24873442	2.487344212
226.4	104310	24889.36	0.23860957	2.386095676

Source: Estimation

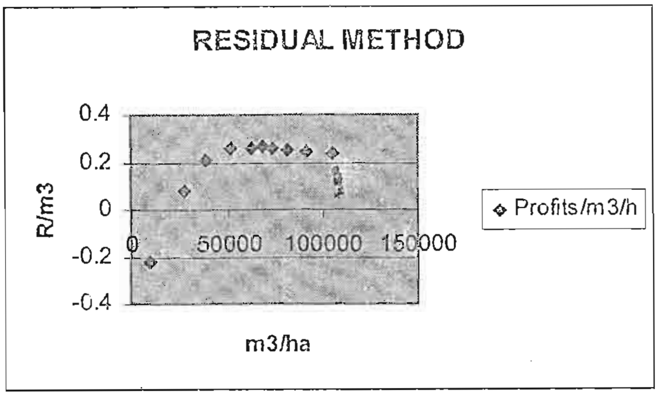
Table 4.2: Kia-Ora Residual Results

YIELD (Y)	Water (m3/h)	TR-TC(profits)	Profits/m3	Capi. @10%
8.8	18510	-1531.32	-0.082729	-0.8272912
22.9	26090	-143.45	-0.005498	-0.0549839
41.4	32940	1677.50	0.050926	0.5092599
61.7	41350	3675.63	0.0888907	0.8889071
64.3	45750	3931.55	0.0859355	0.859355
68.9	53100	4384.33	0.0825674	0.8256736
75.6	59260	5043.81	0.0851132	0.851132
83.6	68150	5831.25	0.0855649	0.855649
101.8	79310	7622.67	0.0961124	0.9611239
115.4	88820	8961.32	0.1008931	1.0089306

Source: Estimation

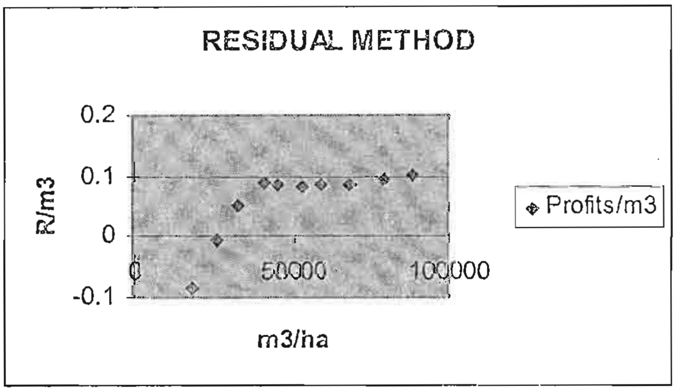
The results from the two tables above show that for Kwambonambi site the value of water start by increasing then reach a maximum point then start to decrease. However, in the case of Kia-Ora results show that the value of water for this site is ever increasing. Furthermore, this species shows that the value for water for Kwambonambi is higher than that of Kia-Ora. In the case of Kwambonambi, the values start from minus 22 cents to plus 24 cents. This shows that the value of water is higher when compared to that of Kia-Ora. This site has values that range from minus eight cents to plus ten cents. Since the values of water vary, it is imperative that the graphs can be shown below to see the relationship between the value of water and the quantity of water.

Figure 4.1 Kwambonambi Residual Curve



Source Estimation

Figure 4.2 Kia-Ora Residual Curve



Source: Estimation

The two graphs above show how the two species differ. In the case of Kwambonambi site, the value of water starts by increasing then reaches a maximum point then start to decrease. However, with the Kia-Ora site, the values are increasing. This shows that there is no trend formed in the two sites.

4.2.1.2. The Marginal Value Product (MVP)

The aim of this sub-section is to estimate the value of water using the MVP method. It should be noted that MVP method does not use the actual yield but the predicted yield for estimation.

Table 4.3: Kwambonambi MVP Results

Predicted Yield	Water (m3/ha)	Value=(b-cx)*price
-5.314435	9930	0.720916
55.24902	27390	0.678146
88.87897	38240	0.651568
124.1065	50850	0.620679
153.1759	62590	0.591921
165.6015	68110	0.578399
176.8454	73440	0.565343
191.1906	80820	0.547265
208.1717	90700	0.523063
227.3948	104310	0.489724

Source: Estimation

Table 4.4: Kia-Ora MVP Results

Predicted Yield	Water (m3/ha)	Value=(b-cx)*price
11.47121	18510	0.391259
26.25618	26090	0.379665
38.77777	32940	0.369188
53.06103	41350	0.356326
60.05514	45750	0.349596
71.00501	53100	0.338354
79.47525	59260	0.328933
90.56303	68150	0.315336
102.5816	79310	0.298267
111.1538	88820	0.283722

Source: Estimation

The results above show that the value of water is decreasing. This is due to the fact that we are estimating the value of water using the marginal product. Whenever we add one extra cubic meter of water, the value of water falls. Furthermore, the results show that the value for water is higher for Kwambonambi than for Kia-Ora. In the case of Kwambonambi the value of water starts from 72 cents and falls down to 49 cents. On the other hand, Kia-Ora values ranges from 39 cents and falls down to 28 cents.

4.2.2. Pinus Patula

There are two sites used to estimate this kind of species. They are Usutu and Richmond.

4.2.2.1 The Residual Method

Table 4.5: Usutu Residual Results

YIELD (Y)	WATER (m3/h	TR-TC(profits)	Profits/m3	Capi.@10%
1.1	19650	-2405.58	-0.12242153	-1.2242153
4.1	32400	-2247.57	-0.06936954	-0.693695
22.1	46450	-1299.51	-0.0279766	-0.279766
46.9	57760	6.70	0.000116049	0.00116
63.6	64950	886.29	0.013645758	0.136458
75.2	77290	1497.26	0.019372027	0.19372
96.3	86720	2608.60	0.030080731	0.300807
108.9	100190	3272.24	0.032660375	0.326604
119.5	110740	3830.55	0.034590437	0.345904
125.4	121720	4141.30	0.034023151	0.340232
132.8	128290	4531.06	0.035318856	0.353189
133.3	137250	4557.39	0.033205035	0.33205
139.9	146970	4905.01	0.033374246	0.333742
146.4	157230	5247.37	0.033373835	0.333738

Table 4.6: Richmond Residual Results

YIELD (Y)	Water (m3/ha)	TR-TC(profits)	Profits/m3	Capi. @10%
3.4	41000	-2284.44	-0.0557181	-0.557181
9.5	51250	-1963.16	-0.03830546	-0.383055
18.6	61500	-1483.86	-0.02412777	-0.241278
29.3	71750	-920.29	-0.01282633	-0.128263
39.9	82000	-361.99	-0.00441448	-0.044145
50.5	92250	196.32	0.002128076	0.021281
61.9	102500	796.75	0.0077732	0.077732
72.2	112750	1339.25	0.011878084	0.118781
83.6	123000	1939.69	0.015769854	0.157699
93.5	133250	2461.13	0.018469981	0.1847
103.7	143500	2998.36	0.020894488	0.208945
113.6	153750	3519.79	0.022892956	0.22893
123.5	164000	4041.23	0.024641616	0.246416
132.6	174250	4520.52	0.025942737	0.259427
140.2	184500	4920.81	0.026671079	0.266711
147.1	194750	5284.24	0.027133438	0.271334
152.8	205000	5584.46	0.027241249	0.272412
158.5	215250	5884.68	0.027338792	0.273388
163.0	225500	6121.69	0.027147184	0.271472
166.1	235750	6284.97	0.026659457	0.266595
169.1	246000	6442.98	0.026190963	0.26191
170.6	256250	6521.98	0.025451637	0.254516

Source: Estimation

The results presented above show that the value of water is decreasing. For instance, in the case of Usutu the value starts from minus 1.22 cents then start to increase and reach 35 cents which is the maximum then, goes down to 33 cents. On the other hand, the value of water at the Richmond site starts from minus 56 cents then increases and reach plus 27 cents and then goes down to 25 cents. This is clear that in both sites, the law of diminishing marginal returns is present and that that there are economies of scale.

4.2.2.2. The Marginal Value Product (MVP)

Table 4.7: Usutu MVP Results

YIELD (Y)	Water (m3/ha)	Value=(b-cx)*p
-10.03643	19650	0.25769805
10.75819	32400	0.24923595
30.07945	46450	0.23991104
47.92736	57760	0.23240466
64.30193	64950	0.2276327
79.20313	77290	0.21944271
92.63099	86720	0.21318408
104.5855	100190	0.20424412
115.0667	110740	0.19724214
124.0744	121720	0.18995478
131.6089	128290	0.18559431
137.67	137250	0.17964761
142.2578	146970	0.1731965
145.3721	157230	0.166387

Table 4.8: Richmond MVP Results

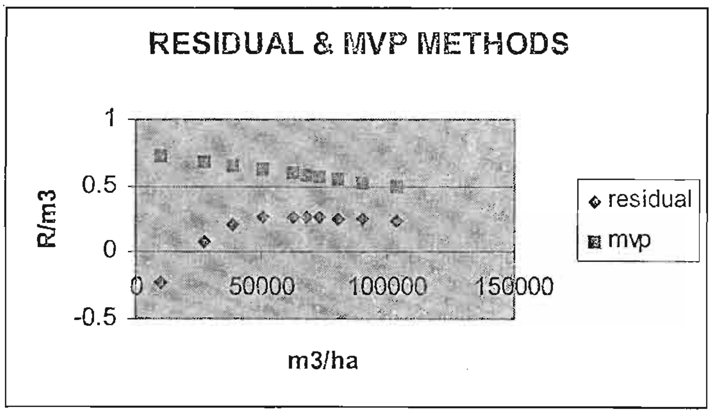
YIELD (Y)	Water (m3/ha)	Value=(b-cx)*price
-5.344564	41000	0.17928998
7.504193	51250	0.17657968
19.93264	61500	0.17386937
31.94077	71750	0.17115907
43.52858	82000	0.16844876
54.69609	92250	0.16573846
65.44328	102500	0.16302815
75.77016	112750	0.16031785
85.67672	123000	0.15760754
95.16297	133250	0.15489724
104.2289	143500	0.15218693
112.8745	153750	0.14947663
121.0998	164000	0.14676632
128.9048	174250	0.14405602
136.2895	184500	0.14134571
143.2539	194750	0.13863541
149.798	205000	0.1359251
155.9217	215250	0.1332148
161.6251	225500	0.13050449
166.9082	235750	0.12779419
171.7711	246000	0.12508388
176.2135	256250	0.12237358

Source: Estimation

The results above show the results of the value of water after the estimation of the function. The results are lower for pinus patula using the marginal value product (MVP) method. The results are decreasing to show that we are estimating the marginal value. They start from 26 cents and goes down to 17 cents in the Usutu site. The values for the Richmond site start from 18 cents and goes down to 12 cents. This shows that the value of water is lower for the pinus patula that for the eucalyptus.

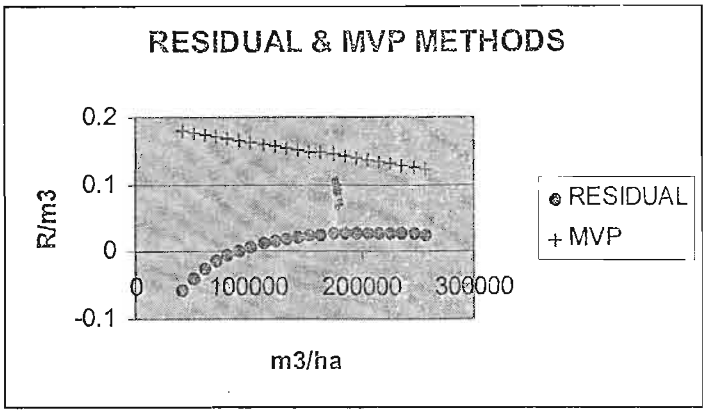
Since the quantity of water is the same for ET (Residual) and ET (MVP), it is possible to compare the results. Two graphs below show whether the residual method has higher values or lower values when compared with the MVP method. From the results it is clear that the residual method has lower values than MVP method. This does not mean that foresters have to use the residual method only. There must be reasons for the use of a particular method: In this case, using the residual method to estimate the value of water using the SFR water would not be satisfactory method. MVP is appropriate for the estimation of the value of water in SFR.

Figure 4.3 Kwambonambi Residual and MVP Values



Source: Estimation

Figure 4.4. Richmond Residual and MVP Values



Source: Estimation

Capitalisation of Water Values

All the costs of inputs have been included in the cost data (appendix A1) except the cost of land. Chapter two highlighted that the value is only attached to the property if that property would have future flows of returns, that property has scarcity in supply and it can also be appropriable. In the case of land, value can be attached to it because of the characteristics enlisted above (Barlowe, 1978). In our case, we have used the income capitalisation rate. The rate we used is 10 percent. This is the future income of land we incur from the plantation of timber. All the tables above have this capitalised rate and the formula used is the value divided by the rate of interest, which is 10%.

This capitalization of water values is presented here because we do not capitalize values from those derived from the use of MVP method. This means that we capitalize water values for the residual method only. As a result, only residual results contain the capitalized water values.

4.3. Stream Flow Reduction (SFR)

This is the second type of water that has been used to estimate the value of water in the commercial forestry. What is unique about SFR water is that it does not estimate the value of water using the residual method but it uses the MVP.

4.3.1. The Eucalyptus grandis

Table 4.9: Kwambonambi MVP Results

YIELD (Y)	Water (m3/ha)	Value=(b-cx)*price
4.757271	1750	5.0985484
47.3073	3500	4.8396926
85.04137	5250	4.5808369
117.9732	7000	4.3219812
146.0982	8750	4.0631255
169.4164	10500	3.8042698
187.9277	12250	3.5454141
201.6323	14000	3.2865584
210.53	15750	3.0277027
214.6209	17500	2.7688469

Source: Estimation

Table 4.10: Kia-Ora MVP Results

YIELD (Y)	Water (m3/ha)	Value=(b-cx)*price
12.7809	1020	4.8931262
25.77788	1530	4.7929808
38.20591	2040	4.6928354
50.065	2550	4.5926901
61.35515	3060	4.4925447
72.07636	3570	4.3923993
82.22864	4080	4.2922539
91.81197	4590	4.1921085
100.8264	5100	4.0919631
109.2718	5610	3.9918177

Source: Estimation

SFR results from the eucalyptus sites show that the value of water is higher. In the case of Kwambonambi the values are higher than those in the Kia-Ora. That is, the results for Kwambonambi site start from 5.10 cents and go down to 2.77 cents. However, with the Kia-Ora site, the values start from 4.89 cents and go down to 3.99. From the values stated above, it is clear that as we add more water in the Kwambonambi site, the value of water decreases substantially. With the Kia-Ora site the value of water does not go down dramatically. This can be attributed to the fact Kwambonambi site is found in Zululand, yet, Kia-Ora is in Natal Midlands. These areas do not receive equal rainfall. In the case of Zululand area, there is plenty of rainfall (Peter Dye, *et al,* 2001).

4.3.2 Pinus patula

Table 4.11: Usutu MVP Results

YIELD (Y)	Water (m3/ha)	Value=(b-cx)*price
-10.03643	2540	2.3947488
10.75819	3810	2.3180155
30.07945	5080	2.2412821
47.92736	6350	2.1645487
64.30193	7620	2.0878154
79.20313	8890	2.011082
92.68099	10160	1.9343486
104.5855	11430	1.8576153
115.0667	12700	1.7808819
124.0744	13970	1.7041486
131.6089	15240	1.6274152
137.67	16510	1.5506818
142.2578	17780	1.4739485
145.3721	19050	1.3972151

Source: Estimation

Table 4.12: Richmond MVP Results

YIELD (Y)	Water (m3/ha)	Value=(b-cx)*price
-5.344564	4840	1.5184371
7.504193	6050	1.4954009
19.93264	7260	1.4723646
31.94077	8470	1.4493283
43.52858	9680	1.4262921
54.69609	10890	1.4032558
65.44328	12100	1.3802195
75.77016	13310	1.3571832
85.67672	14520	1.334147
95.16297	15730	1.3111107
104.2289	16940	1.2880744
112.8745	18150	1.2650382
121.0998	19360	1.2420019
128.9048	20570	1.2189656
136.2895	21780	1.1959294
143.2539	22990	1.1728931
149.798	24200	1.1498568
155.9217	25410	1.1268205
161.6251	26620	1.1037843
166.9082	27830	1.080748
171.7711	29040	1.0577117
176.2135	30250	1.0346755

Source: Estimation

Pinus patula results are more or less the same in the sense that they start from 2.39 cents and goes down to 1.39 for Usutu site. Richmond site has values from 1.51 cents then goes down to 1.03 cents. This shows clearly that Usutu and Richmond are found in the same area and they use the same selling price.

It is clear that the value of water is higher for SFR water than for ET in both species. However, the results obtained from the estimation of different sites are diverse. This diversity is attributed to many factors. Firstly, with eucalyptus sites it is clear that Kwambonambi site yields the largest. This is due to the fact that it hardly experiences drought (Peter Dye, *et al,* 2001). This means that this site has plenty of rainfall. In other words, precipitation is the greatest in this area because of rain. One advantage of a moist area is that aquifers charge quickly. Furthermore, run-offs are not reduced greatly because there is always water available. The catchments cannot be dry because of the rainfall. Kia-Ora, on the other hand, has rainfall that varies greatly (Peter Dye, *et al,* 2001). There are times when this site experiences droughts and times when it experiences floods. This makes it difficult for timber yields or eucalyptus grandis to be higher. Lower rainfall in the Kia-Ora means that the value of water has to be higher than Kwambonambi site. Again, Bosch, *et al,* (2000) suggest that most of the time eucalyptus grandis uses more water than other species. This allows stream flows to be reduced greatly. As a result, water values for eucalyptus are higher than pinus patula values when estimating SFR water.

Secondly, pinus patula is being compared with the natural vegetation, which is the grassland. It has been discovered that pinus patula uses more water during the initial period. As the time goes on, however, the intake of water is reduced greatly. Pinus patula is grown the whole year unlike the natural vegetation, which grows mostly in winter. This allows this species to intercept more rainfall than natural vegetation (Armstrong, *et al,* 1996:36). This tells us that more water is lost through evapo-transpiration than with the natural vegetation. However, it is clear that pinus patula does not use more water because in this study it is compared to the natural vegetation unlike eucalyptus grandis. As a result, all water values are lower for pinus patula when compared to eucalyptus values.

4.4. Summary

This chapter has managed to estimate the value of water using two methods in the commercial forestry in South Africa. Kwambonambi appears to be the place where the value of water is higher because the yield produced is also higher and the quantity of water used is the lowest. Kia-Ora has some problems because when using the residual method, the value of water ends up increasing. It is difficult to adjust this increase because we use the actual yield. However, all other sites confirm that when one uses more water the value of water charged falls and this witnessed the presence of economies of scale. Diminishing marginal returns operates in the case of ET water using the residual method. This is due to the fact that the values start by increasing then reach a maximum point and finally, decreases. In the case of Kwambonambi, the value of water starts from 08 cents then goes up to 27 cents and then falls to 24 cents. On the other hand, the value of water for Usutu starts from 01 cents and reach a maximum value of 04 cents and eventually falls down to 03 cents. The Richmond residual value pinus patula starts from 01 cents then goes up to 27 cents and then falls down to 25 cents.

However, the value of water using the SFR water is ever decreasing because we are using the MVP method. Even in the case of ET water, the value of water using the MVP method has decreased.

CHAPTER 5

SUMMARY, CONCLUSIONS, POLICY RECOMMENDATIONS AND LIMITATIONS OF THE STUDY

5.1. Summary

The existence of commercial forestry means that more jobs are created in this country. This is due to the fact that there is an increase in the demand for timber and other forestry products. The plantation of more trees in the country must meet this increase. As a result, South Africa uses 1.4 million hectares (ha) for the plantation of commercial forestry. This land is expected to increase to meet a high demand for timber products. However, the effects of the plantation of above mentioned ha is that about 3.5 of surface water or 7.6 of current demand for water would be reduced as the plantation of trees take place. The problem is that water is a scarce resource in South Africa.

The scarcity of water has been shown when an estimation of the quantity of water takes place. Only three percent of water is available for consumption. This shows clearly that water is a scarce resource. Secondly, The climate that we receive is characterised by floods and droughts. This means that there is a problem of water when we have floods because it is difficult to store water. In the case of droughts, this also witnesses the problem of water in the country. Thirdly, the aquifers are depleted quickly because the rate of pumping them is higher. This rate is also due to the fact that the country has a problem of weather. Fourthly, it has been discovered that evaporation is greater than precipitation. This makes it difficult for the country to have enough water.

Another problem is that the government is concerned recently with the protection of an environment and indigenous trees. This means that even if these trees absorb more water, they need not be removed. Nanni (1970) states that indigenous forests are mainly found in areas that are moist. Automatically, they reduce runoffs greatly. This reduces catchments. The problem is that their existence in this country is very important because they are used for research purposes and they are also used for recreational purposes but the cost of them to water sector is enormous. The government is now in a dilemma because indigenous forests are needed and they cannot be removed. However, they contribute problems to South African resources and also to the lives of people. Most of the people in rural areas are still faced with the problem of clean and safe water and also proper sanitation. If trees were absorbing more water, it would take more years to provide them with these facilities.

In fact, it is not easy to regulate afforestation because South Africa is faced with an increase in the demand for timber products. Furthermore, there has been an increase in the demand for timber products in the foreign countries. This demand can be met by an increase in the plantation of timber and other forest products. The advantage of increasing the plantation of timber products is that more jobs would be implemented, as the rate of unemployment is high in South Africa. Again, an increase in the plantation of trees in this country means that small growers would be involved in the forestry business intensively, so equity would be achieved. As a result, Versfeld says:

> *But the returns from forestry are often good in terms of income generated, foreign exchange earned, and jobs created and supported, when weighted against cubic metres of water consumed* (1996:56).

The suggestion that more water would be released to other sectors if the government deforest some of the forests has negative impacts on the lives of people more especially those who make living through forestry.

To solve the problem of water, there has to be a shift from treating water as a free good. Water has to be treated as a scarce resource. Every good that is scarce has a price attached to it. The price signals that it is a scarce resource. Furthermore, a price signals that there is an opportunity cost foregone in the use of a resource. In the case of the commercial forestry, water used could have been used in other sectors or to grow other agricultural crops. Moreover, if water were treated as a scarce resource, marginal benefits (MB) would be equal to marginal cost (MC) of using a commodity. All these issues would be achieved if an estimation of the value of water takes place. This estimation allows water to have an economic price and also to show that there is an opportunity cost foregone.

There are several factors that reveal that the commercial forestry uses more water. Firstly, it has been shown more water is lost due to evapo-transpiration and stream flows are reduced greatly due to afforestation. Secondly, there are regulations and acts passed so that the use of water by the commercial forestry can be restricted. However, it is clear that unless water is treated as a scarce resource, this problem will persist. The recent acts and regulations stress that water has to be treated as an economic good therefore, uses the forces of demand and supply. For a resource to be treated as a scarce resource, there must be an estimation of its value. The essay eventually, came with different valuation methods that can be used in the environmental sector as well as in the commercial forestry. In the case of environmental resources, there are four methods that can be used. They are, changes in productivity, the contingent valuation method, opportunity cost as well as averting expenditure. All these methods have problems in their use but there are able to estimate the value of different environmental resources.

There are two methods developed to estimate the value of water in the commercial forestry and they are the residual method and the marginal value product (MVP) method. The residual method uses the actual yield to estimate the value of water. This method has first estimate the value of water using the ET water. The results obtained are as follows: in the case of the eucalyptus grandis, the values ranges from 05 cents to 23 cents. On the other hand, in the case of pinus patula, the values ranges from 01 cents to 03 cents. When estimating the ET water using the MVP method, all the values are decreasing. In the case of eucalyptus they range from 72 cents and goes down to 28 cents. And in the case of pinus patula they range from 26 cents and goes down to 12 cents. The second type of water that has been used to estimate the value of water is stream flow reduction (SFR). This water only uses the MVP method to estimate the value of water in the commercial forestry. The values range from R5,10 and falls down to R2,77 in the case of eucalyptus. Whereas, the values for pinus patula ranges from R2,39 and goes down to R1,03. This is clear that eucalyptus values are higher than pinus patula values. Furthermore, SFR water values are higher than ET water values. Moreover, when comparing MVP with the residual method, we discovered that MVP method has higher values than the residual method. This can be due to the fact MVP measures the change in the value of water when adding one extra cubic metre of water. If more water is added, it means that the change in the last unit would be higher. However, both methods are expected to decrease to witness the presence of diminishing marginal returns. The three sites dealt with agreed with the theory but the values of water in the Kia-Ora site using the residual method are increasing. They do not reach a point of inflection then start to decrease. When one looks at the graph of this site, one can see that they have a potential of decreasing. This tells us that this site is not totally different from other sites. Another thing is that the values obtained from this site are very high when compared to the water they use. It means that it is not wise to grow this type of tree when faced with an increasing value of water.

Finally, it should be noted that the major objective of the study is to estimate the value of water in the commercial forestry. This objective of the study has been tackled in the sense that water used in the commercial forestry can be estimated using the forces of demand and supply. Previously, these forces were not used because water is not categorised as an environmental resource, where the forces of demand and supply are not applied. In fact, the aims of this study were as follows:

1. to review the literature on different acts to regulate the use of water in the commercial forestry.
2. To review the literature on different methods that can be used to estimate the value of natural/ environmental resources.
3. To estimate the value of water in the commercial forestry using two sources of water, ie, evapo-transpiration (ET) and stream flow reduction (SFR) water.

The study managed to tackle all these objectives enlisted above as the estimation of the value allows all of them to take place. The relationship between water and the commercial forestry has been discussed how afforestation affects the water sector as there is a decrease in the stream flows and eventually, the catchments and run-offs. This shows that there must be the valuation of water in this sector. Furthermore, the study revealed policies and regulations to limit the use of water and the procedure to be followed when issuing permits. Finally, the estimation of the value of water using different methods was dealt with. All this took place so that our objectives are achieved.

5.2. Conclusions and Policy Recommendations

An estimation of the value of water means that water is treated as a scarce resource. This estimation allows the forces of demand and supply to operate in the allocation of a scarce resource. To allocate water in an efficient and equitable manner requires that the value of water be estimated. The value of water ensures that marginal benefits (MB) are equated to marginal cost (MC) of a scarce resource. If the MB is greater or less than MC, it means that there is misallocation of water and also that water is not treated as a scarce commodity. The estimation of the value of water ensures that every environmental good is not treated as a public good where it is difficult to exclude other members of the society and where the environmental goods are exploited because there are no laws governing them.

The advantage of estimating the value of water is that the demand for water would be elastic as the foresters who use more water are expected to pay more. Furthermore, they are charged an opportunity cost value. This means that a price charged to them reveals that there is an opportunity cost of planting trees than to grow other agricultural crops. If the value of water is not based on the opportunity cost, it means that the resources would be misallocated because the demand for them would be inelastic. An opportunity cost value allows for the protection of biodiversity and other natural resources. For example, most of the time the plantation of trees most of the time takes place where there was natural vegetation. Again, the plantation of trees reduces stream flows and catchments. So, if the value of water is not based on the opportunity cost, it means that the country will have problems of water. This study has revealed that through the acts passed by the government as permits are no longer based on the quantity of water reduced due to the plantation of trees but on the opportunity cost value (www.dwaf.pwv.gov.za.whitpap.htlm).

Winpenny, (1994) states that if the focus is on demand management rather than supply augmentation or the working together of these policies, there must be an enabling environment. As a result, the government and the policy makers noticed that the plantation of trees reduce more water than other species, they passed acts to regulate the use of water in the commercial forestry. The regulations enable the foresters to limit the use of water. If the regulations were not present, it would have been difficult for an estimation of the value of water to occur. The regulations are two-fold. There are those that took place long time ago and those that are recent. All these regulations favour the estimation of the value of water. The impact of them on the estimation of the value of water is that they involve legal actions when one disobeys them. This makes it easier for the value of water to be estimated. The acts also recommend that water be charged a price so that there would be the allocation of water in an efficient manner.

The price that is charged after the estimation of the value of water would be used to fund water resource management, to fund water developments and finally, to fund water works (www.dwaf.pwv.gov.za). This means that the budget from the government for the water sector would not be exhausted quickly as more funds would be gained from the foresters. Furthermore, the funds from the foresters would ensure that they grow trees of high value than those of low value because the value of water is derived from the output. If they are to change from growing low value crops to those with high value it means that the reallocation and conservation of water would take place as more is released.

In estimating the value of water in the commercial forestry, we use different methods. Firstly, all these methods reveal that there must be the valuation of environmental resources. However, they differ in the approach they use. Others use the costs of any method as the value of water. Others rely on direct questioning of consumers to reveal how much they are prepared to pay for environmental resources. Different methods can be used to value water. In the case of commercial forestry, two methods were developed to estimate the value of water. These methods are the residual method and the marginal value product method. What is important about these methods is that they are to estimate the value of water in the commercial forestry. In this study two types of forest products were used to estimate the value of water. They are eucalyptus and pinus patula. All these products are found in KwaZulu-Natal province. If one looks at the values obtained from using both methods, one can see that the value of water is higher when using marginal value method (MVP) than using the residual method. Furthermore, the results show that eucalyptus grandis charges higher prices than pinus patula. In the case of eucalyptus grandis, higher prices signal that this species reduce stream flows more than pinus patula as the theory suggested.

Afforestation on the other hand, creates more jobs in South Africa. Currently, South Africa employs more than one million people of which, most of them belong to rural areas (www.dwaf.pwv.gov.co.za). If this sector increases the plantation of trees because of the shortage of them and because of an increase in the demand for them, it means that more jobs would be created. South Africa faces a problem of unemployment this century, so the creation of jobs for South Africans means that this problem is alleviated. Furthermore, people employed in this sector would be able to increase the Gross Domestic Product (GDP) of this country and also their lives are made better of. Automatically, there would be economic growth in this country.

If the plantation of trees increased it means that there would be more revenues derived. This is witnessed by the contribution of this sector to the economy of this country. The forestry sector has contributed on output. They also earned R1.28 billion on net foreign exchange in the year 1994/95 (www.dwaf.pwv.gov.za). An increase in the demand for forestry products tells us that the contribution of this sector would be enormous. This also tells us that there must be other means of solving the problem of water in this country when it comes to afforestation. Fortunately, this study is able to regulate the use of water as the value of water is estimated and eventually, a price of water is attached to water for commercial forestry.

5.3 Limitations and Areas of Further Study

There are few problems that one encountered when undertaking this study. Firstly, a detailed data is needed for the estimation of the value of water. The data is limited in the sense that it is difficult to obtain it. This can be due to the fact this is the first time a kind of study undertaken. May be in the future it will be much better. Another problem with the data is that when reviewing the literature it is difficult to trace any background of the regulation of water in the KwaZulu-Natal province. One is forced to look at the Cape Town and generalise that what happened there also happened in this province. Generalisation sometimes creates problems.

The price of water must be elastic not inelastic so that water can be allocated in an efficient manner. This is used also so that it can be easier to conserve and reallocate water. The agricultural sector consumes more water than any sector at the same time they are heavily subsidised by the government. The allocation of water thus becomes inefficient because of subsidies. Subsidies can be a problem because it is difficult to charge an economic price that reflects all the costs of production. For example, if the price of water increases substantially, the effects of this increase is not felt because not all the costs of production are included or because of the subsidy. This makes the demand for water to be price inelastic and the policy makers would fail to conserve and reallocate water because no water is released from this sector.

Thirdly, two methods are not sufficient in the estimation of the value of water because there are problems with using them. It would be better if linear programming is used because it shows how profits can be maximised or costs be minimised subject to constraints. If this method is not used it is difficult to see whether the foresters are able to maximise profits even if they are expected to pay for water which they previously not expected to pay.

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APPENDICES

APPENDIX A: THE COST DATA

The table below shows the costs used to estimate the value of water in the commercial forestry.

		Eucalyptus grandis		Pine
Particulars	Unit	Natal	Zululand	Natal
FIXED COSTS				
1. Establishment	R/ha	1356.59	1519.23	1452.24
2. Tending	R/ha	115.38	158.34	85.75
Total		**1471.97**	**1677.57**	**1537.99**
3. Mgmt & Admn.	R/ha	457.25	462.64	457.25
4. Depreciation	R/ha	9.95	17.28	9.95
5. Other Overheads	R/ha	73.53	54.44	73.53
Total		**540.73**	**534.36**	**540.73**
6. Land Rental	R/ha	99.75	99.75	99.75
7. Interest on Capital @14%	R/ha	98.3	98.3	98.3
Total		**198.05**	**198.05**	**198.05**
Protection and Conservation	R/ha	186.75	165.24	186.75
Total		**186.75**	**165.24**	**186.75**
Sub Total (1)	**R/ha**	**2397.5**	**2575.22**	**2463.52**
VARIABLE COSTS				
1.Harvesting	R/ton	29.13	19.72	22.19
2.Loading and Transport	R/ton	52.59	47.40	57.35
Sub Total (2)	**R/ton**	**81.72**	**67.12**	**79.54**
Total FixedCosts	R/ha	2397.5	2575.22	2463.52
Total Vaariable Costs	R/ton	81.72	67.12	79.54

Avg.Price Received	R/ton	180.15	188.43	132.21

APPENDIX B: THE REGRESSION RESULTS

The results below are taken from the regression output. We have estimated two sources of water, ie, evapo-transpiration (ET) and stream flow reduction (SFR). Both of them are statistically significant at five percent level.

Table B.1 : Evapo-transpiration

SITE	Constant	b	C	R^{-2}	F	RMSE	Observa.
Kwambo nambi	-53.305	0.00396	-1.30E-08	0.99	405.94	7.708	10
Kia-Ora	-28.7345	0.002329	-8.49E-09	0.98	165.32	5.405	10
Usutu	-50.1289	0.00204	-5.02E-09	0.98	373.77	6.7365	14
Richmond	-60.9427	0.00143	-2.00E-09	0.9958	2468.82	3.6957	22

Source: Estimation (stata program)

Table B.2 : Stream Flow Reduction

SITE	Constant	B	C	R^{-2}	F	RMSE	Observa.
Kwambo nambi	-42.595	0.028432	-7.85E-07	0.98	225.58	10.305	10
Kia-Ora	-14.9199	0.028273	-1.09E-06	0.96	98.54	6.95231	10
Usutu	-56.0457	0.019274	-4.57E-07	0.99	567.84	5.479	14
Richmond	-60.9427	0.012182	-1.44E-07	0.9958	2468.82	3.6957	22

Source : Estimation (stata program)

APPENDIX C : THE FORMULAS

This appendix shows different formulas and models that were used in the essay.

Appendix C.1:The conversion of millimeters to cubic meters

The quantity of water that we are using was in milli-meters, so we had to change it cubic meters.

Firstly, 1mm=1000000m^3

1/1000 * mm

1/100 * 1000000 *mm

=m^3

or mm*10=m^3

Appendix C.2: The formula used to integrate

MVP method uses integration to find the area under the demand curve.

This is the formula we used to integrate:

$a + bX - cX^2$

Differentiate with respect to x and get:

b-2cx

(b-2cx)dx

$bx-2cx^2/2$

$bx-cx^2/x$

(b-cx)*price

Appendix C.3: The formula used to capitalize land

The third formula is the capitalization of land.

We say value/interest.

Appendix C.4: The model function

The model of timber yield is as follows:

Y=f (X)

Where Y= Yield

f= function of

X= quantity of water in m^3

Expected sign of coefficient (-). To gain an expected sign we are forced to use a double linear function.

Model: $Y=a + bX - cX^2$

APPENDIX D: ET- APP and MPP RESULTS USING ACTUAL YIELD

This appendix looks at the derivation of average physical product (APP) and marginal physical product of evapo-transpiration (ET) water. The estimation of the value of water allows us to first estimate them. Both of them are traced from the stages of production. The first stage occurs when MPP is greater than APP. The second stage occurs when MPP is decreasing and is also less than APP. However, MPP must be greater than zero. The last stage, which is stage three occurs when MPP is negative. What signify this stage is the addition of variable inputs and the total output generated is decreasing. In the case of the estimation of the value of any good, that product has to be produced at stage two where MPP is less than APP but greater than zero. The tables below show APP and MPP for four sites using ET water. We start with eucalyptus then pinus patula in showing APP and MPP.

Appendix D.1 : Kwambonambi APP and MPP Results

YIELD (Y)	X (m3/ha)	X2 (m3/ha)	APP (Y/X)	MPP (dY/dX)
3	9930	98604900	0.000302	0
39.6	27390	7.5E+08	0.001446	0.0020962
86.9	38240	1.46E+09	0.002272	0.0043594
130.4	50850	2.59E+09	0.002564	0.0034496
154.3	62590	3.92E+09	0.002465	0.0020358
172.1	68110	4.64E+09	0.002527	0.0032246
177.7	73440	5.39E+09	0.00242	0.0010507
187.7	80820	6.53E+09	0.002322	0.001355
207.2	90700	8.23E+09	0.002284	0.0019737
226.4	104310	1.09E+10	0.00217	0.0014107

Appendix D.2: Kia-Ora APP and MPP Results

YIELD (Y)	X (m3/ha)	X2 (m3/ha)	APP (Y/X)	MPP (dY/dX)
8.8	18510	3.43E+08	0.000475	0
22.9	26090	6.81E+08	0.000878	0.0018602
41.4	32940	1.09E+09	0.001257	0.0027007
61.7	41350	1.71E+09	0.001492	0.0024138
64.3	45750	2.09E+09	0.001405	0.0005909
68.9	53100	2.82E+09	0.001298	0.0006259
75.6	59260	3.51E+09	0.001276	0.0010877
83.6	68150	4.64E+09	0.001227	0.0008999
101.8	79310	6.29E+09	0.001284	0.0016308
115.4	88820	7.89E+09	0.001299	0.0014301

Source : Estimation

Kwambonambi site complies with the theory above. However, with the Kia-Ora site, in the case of APP the values are increasing. This is clear that this site has a problem.

Appendix D.3:Usutu APP and MPP Results

YIELD (Y)	X (m3/ha)	X2 (m3/ha)	APP (Y/X)	MPP (dY/dX)
1.1	19650	3.86E+08	5.6E-05	0
4.1	32400	1.05E+09	0.000127	0.0002353
22.1	46450	2.16E+09	0.000476	0.0012811
46.9	57760	3.34E+09	0.000812	0.0021927
63.6	64950	4.22E+09	0.000979	0.0023227
75.2	77290	5.97E+09	0.000973	0.00094
96.3	86720	7.52E+09	0.00111	0.0022375
108.9	100190	1E+10	0.001087	0.0009354
119.5	110740	1.23E+10	0.001079	0.0010047
125.4	121720	1.48E+10	0.00103	0.0005373
132.8	128290	1.65E+10	0.001035	0.0011263
133.3	137250	1.88E+10	0.000971	5.58E-05
139.9	146970	2.16E+10	0.000952	0.000679
146.4	157230	2.47E+10	0.000931	0.0006335

Source : Estimation

Appendix D.4: Richmond APP and MPP Results

YIELD (Y)	X (m3/ha)	X2 (m3/ha)	APP (Y/X)	MPP (dY/dX)
3.4	41000	1.68E+09	8.29E-05	0
9.5	51250	2.63E+09	0.000185	0.0005951
18.6	61500	3.78E+09	0.000302	0.0008878
29.3	71750	5.15E+09	0.000408	0.0010439
39.9	82000	6.72E+09	0.000487	0.0010341
50.5	92250	8.51E+09	0.000547	0.0010341
61.9	102500	1.05E+10	0.000604	0.0011122
72.2	112750	1.27E+10	0.00064	0.0010049
83.6	123000	1.51E+10	0.00068	0.0011122
93.5	133250	1.78E+10	0.000702	0.0009659
103.7	143500	2.06E+10	0.000723	0.0009951
113.6	153750	2.36E+10	0.000739	0.0009659
123.5	164000	2.69E+10	0.000753	0.0009659
132.5	174250	3.04E+10	0.000761	0.0008878
140.2	184500	3.4E+10	0.00076	0.0007415
147.1	194750	3.79E+10	0.000755	0.0006732
152.8	205000	4.2E+10	0.000745	0.0005561
158.5	215250	4.63E+10	0.000736	0.0005561
163.0	225500	5.09E+10	0.000723	0.000439
166.1	235750	5.56E+10	0.000705	0.0003024
169.1	246000	6.05E+10	0.000687	0.0002927
170.6	256250	6.57E+10	0.000666	0.0001463

Source : Estimation

The two sites show what we are expecting because both APP and MPP start by rising then reach a maximum point then start to decrease.

APPENDIX E : ET-APP and MPP RESULTS USING PREDICTED YIELD

The essay stated that we have two methods that can be used to estimate the value of water in the commercial forestry and they are: residual method and the marginal value product (MVP) methods. It should be clear that when using the residual method we also use the actual yield. However, in the case of the MVP method, we use the predicted yield. Below we are going to show the derivation of average physical product (APP) and marginal physical product (MPP) using the predicted yield. The theory is the same except that the yield is different.

We start with eucalyptus grandis then the pinus patula in showing the APP and MPP.

Appendix E.1: Kwambonambi APP and MPP Results

YIELD (Y)	X (m3/ha)	APP (Y/X)	MPP (dY/dX)
-5.314435	9930	-0.000535	0
55.24902	27390	0.0020171	0.0034687
88.87897	38240	0.0023242	0.0030995
124.1065	50850	0.0024406	0.0027936
153.1759	62590	0.0024473	0.0024761
165.6015	68110	0.0024314	0.002251
176.8454	73440	0.002408	0.0021095
191.1906	80820	0.0023656	0.0019438
208.1717	90700	0.0022952	0.0017187
227.3948	104310	0.00218	0.0014124

Source: Estimation

Appendix E.2: Kia-Ora APP and MPP Results

YIELD (Y)	X (m3/ha)	APP (Y/X)	MPP (dY/dX)
11.47121	18510	0.00062	0
26.25618	26090	0.001006	0.0019505
38.77777	32940	0.001177	0.001828
53.06013	41350	0.001283	0.0016984
60.05514	45750	0.001313	0.0015896
71.00501	53100	0.001337	0.0014898
79.47525	59260	0.001341	0.001375
90.56303	68150	0.001329	0.0012472
102.5816	79310	0.001293	0.0010769
111.1538	88820	0.001251	0.0009014

Source: Estimation

APP values above start by increasing and reach a maximum point then start to decrease in both sites. However, in the case of MPP the values are decreasing. This means there is no maximum point. This does not confirm our theory.

Appendix E.3: Usutu APP and MPP Results

YIELD (Y)	X (m3/ha)	APP (Y/X)	MPP (dY/dX)
-11.82755	19650	1.11E-07	0
10.95161	32400	0.000338	0.0008588
34.16396	46450	0.000735	0.0016521
51.41027	57760	0.00089	0.0015249
61.70668	64950	0.00095	0.001432
78.16882	77290	0.001011	0.001334
89.71879	86720	0.001035	0.0012248
104.6692	100190	0.001045	0.0011099
115.1071	110740	0.001039	0.0009894
124.7843	121720	0.001025	0.0008813
129.9961	128290	0.001013	0.0007933
136.4057	137250	0.000994	0.0007154
142.4479	146970	0.000969	0.0006216
147.7971	157230	0.00094	0.0005214

Source: Estimation

Appendix E.4: Richmond APP and MPP Results

YIELD (Y)	X (m3/ha)	APP (Y/X)	MPP (dY/dX)
-5.344564	41000	-0.00013	0
7.504193	51250	0.000146	0.0012535
19.93264	61500	0.000324	0.0012125
31.94077	71750	0.000445	0.0011715
43.52858	82000	0.000531	0.0011305
54.69609	92250	0.000593	0.0010895
65.44328	102500	0.000638	0.0010485
75.77016	112750	0.000672	0.0010075
85.67672	123000	0.000697	0.0009665
95.16297	133250	0.000714	0.0009255
104.2289	143500	0.000726	0.0008845
112.8745	153750	0.000734	0.0008435
121.0998	164000	0.000738	0.0008025
128.9048	174250	0.00074	0.0007615
136.2895	184500	0.000739	0.0007205
143.2539	194750	0.000736	0.0006795
149.798	205000	0.000731	0.0006384
155.9217	215250	0.000724	0.0005974
161.6251	225500	0.000717	0.0005564
166.9082	235750	0.000708	0.0005154
171.7711	246000	0.000698	0.0004744
176.2135	256250	0.000688	0.000433

Source: Estimation

In the vase of the pinus patula, APP values start by increasing until a maximum point then start to decrease. MPP values for Usutu site are decreasing. This means that there is no maximum point. In the case of Richmond the values start by decreasing and towards the end they start to increase. It is then difficult to identify stage two, which is the stage of production if the values do not reach a maximum point.

APPENDIX F: SFR-APP and MPP USING PREDICTED YIELD

The tables below show the APP and MPP values using the SFR water.

Appendix F.1: Kwambonambi APP and MPP Results

YIELD (Y)	X (m3/ha)	APP (Y/X)	MPP (dY/dX)
4.757271	1750	0.002718	0
47.30273	3500	0.013515	0.024311691
85.04137	5250	0.016198	0.021564937
117.9732	7000	0.016853	0.018818189
146.0982	8750	0.016697	0.016071429
169.4164	10500	0.016135	0.013324686
187.9277	12250	0.015341	0.010577886
201.6323	14000	0.014402	0.0078312
210.53	15750	0.013367	0.0050844
214.6209	17500	0.012264	0.002337657

Source: Estimation

Appendix F.2: Kia-Ora APP and MPP Results

YIELD (Y)	X (m3/ha)	APP (Y/X)	MPP (dY/dX)
12.78091	1020	0.01253	0
25.77788	1530	0.016848	0.025484255
38.20591	2040	0.018728	0.024368686
50.065	2550	0.019633	0.023253118
61.35515	3060	0.020051	0.022137549
72.07636	3570	0.020189	0.02102198
82.22864	4080	0.020154	0.019906431
91.81197	4590	0.020003	0.018790843
100.8264	5100	0.01977	0.017675353
109.2718	5610	0.019478	0.016559608

Source: Estimation

Appendix F.3: Usutu APP and MPP Results

YIELD (Y)	X (m3/ha)	APP (Y/X)	MPP (dY/dX)
-10.03643	2540	-0.003951	0
10.75819	3810	0.002824	0.016373717
30.07945	5080	0.005921	0.015213591
47.92736	6350	0.007548	0.014053472
64.30193	7620	0.008439	0.012893362
79.20313	8890	0.008909	0.011733228
92.63099	10160	0.009117	0.010573118
104.5855	11430	0.00915	0.009413
115.0667	12700	0.00906	0.008252913
124.0744	13970	0.008881	0.007092677
131.6089	15240	0.008636	0.005932677
137.67	16510	0.008339	0.00477252
142.2578	17780	0.008001	0.003612441
145.3721	19050	0.007631	0.002452205

Source: Estimation

Appendix F.4: Richmond APP and MPP Results

YIELD (Y)	X (m3/ha)	APP (Y/X)	MPP (dY/dX)
-5.344564	41000	-0.00013	0
7.504193	51250	0.000146	0.0012535
19.93264	61500	0.000324	0.12125
31.94077	71750	0.000445	0.0011715
43.52858	82000	0.000531	0.0011305
54.69609	92250	0.000593	0.0010895
65.44328	102500	0.000638	0.0010485
75.77016	112750	0.000672	0.0010075
85.67672	123000	0.000697	0.0009665
95.16297	133250	0.000714	0.0009255
104.2289	143500	0.000726	0.0008845
112.8745	153750	0.000734	0.0008435
121.0998	164000	0.000738	0.0008025
128.9048	174250	0.000740	0.0007615
136.2895	184500	0.000739	0.0007205
143.2539	194750	0.000736	0.0006795
149.798	205000	0.000731	0.0006384
155.9217	215250	0.000724	0.0005974
161.6251	225500	0.000717	0.0005564
166.9082	235750	0.000708	0.0005154
171.7711	246000	0.000698	0.0004744
176.2135	256250	0.000433	0.0014381

Source: Estimation

The tables above show APP and MPP using SFR water. In the case of APP all value start by increasing then reach a maximum point then start to decrease. With MPP, the values are decreasing so there is no maximum point. In the case of Richmond however, the MPP values start by increasing then reach a maximum point. Instead of going down towards the end they start to increase. This shows that there is a problem with this site.