THE ROLE OF VIRTUAL WATER IN FOOD SECURITY IN SOUTHERN AFRICA

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Abstract

The goal of this study is to analyse the interaction between water, food and trade. Botswana, Namibia, South Africa and Zimbabwe all have arid climates and are increasingly water stressed. Therefore, water and trade form an integral part of the food security of the region. The theory of Social Adaptive Capacity will be used to explain how countries respond to natural physical resource scarcity. The hypothesis is that a country with well-developed social resources can overcome physical resource scarcity and continue developing in a sustainable manner. In terms of the international grain trade this means that countries with higher levels of social resources will be able to import grain, which provides the bulk of the per capita calorie intake in the region. Each tonne of grain imported represents over a tonne of water saved locally. This water, used in the manufacture of grain, is called virtual water. The water saved can assist a country to achieve the goals of water demand management. The level of reliance of each of the four countries on virtual water is assessed and compared to the state of food security in the country. On an international level, the factors which have a large effect on the viability of a virtual water import policy are the level of agricultural assistance and trade barriers in developed countries. The possible implications of a change in world terms of trade are investigated. The theoretical background to virtual water in the international context is its application in the Heckscher-Ohlin model of international trade based on relative factor endowments. The model is applied to sixty-three countries' grain trade, in relation to their relative level of water resources. The model is found not to predict the reality well, yet the four countries studied do show a positive correlation between virtual water and food security. This leads to the conclusion that for such a study to be successful it has to use the relative endowments of soil water between the countries as a factor of production.

Key terms:

Virtual water, water demand management, Social Adaptive Capacity, international factor trade, Heckscher-Ohlin model, food security, allocative efficiency, productive efficiency, trade barriers, levels of agricultural assistance, soil water.

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Abbreviations used in the study

ABARE	Australian Bureau of Agricultural Resource Economics
ACP	African Caribbean and Pacific (countries)
AGRIC	Department of Agriculture (South Africa)
AoA	Agreement on Agriculture
DWAF	Department of Water Affairs and Forestry (South Africa)
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
GDP	Gross Domestic Product
GIEWS	Global Information and Early Warning System
GTEM	General Trade and Environment Model
HDI	Human Development Index
H-O	Heckscher Ohlin (model)
OECD	Organisation for Economic Cooperation and Development
SAC	Social Adaptive Capacity
SADC	Southern African Development Community
UNDP	United Nations Development Programme
WDM	Water Demand management
WTO	World Trade Organisation

INTRODUCTION

Virtual water, or real drought?

i. Goal of the Study

The goal of this study is to analyse the interaction between water, food and trade at a theoretical, as well as a practical level. This will be done by gauging the level of reliance on virtual water imports and the effect on food security in southern Africa and testing the concept of virtual water in terms of international trade theory.

Section **ii** will give an introduction to the debates surrounding food security. Section **iii**, on page three provides some background to the concept of virtual water. The specific objectives of this study are presented on page 6, in Section **iv**. These objectives will contribute toward achieving the overall goal of this study. This introductory chapter will end with Section **v**, which gives the regional context and associated policy issues of the countries in the study.

ii. Food Security

"Food security exists when all people, at all times,
have physical and economic access to sufficient,
safe and nutritious food to meet their dietary needs
and food preferences for an active and healthy life."

- 1996 World Food Summit

The individual is at the centre of the food security debate. As Amartya Sen (1981) pointed out, the emphasis should not be on the production or supply of food, but on the individual's access or entitlement to it. A country does not achieve food security, households and individuals do. Definitions of food security have moved from objective to subjective, reflecting a shift away from concerns about the number of calories consumed by a person.

Issues such as cultural acceptability and food quality, as defined by individuals, have gained prominence.

For the past century world food production has been outstripping population growth, resulting in a long-term trend of declining food prices in real terms (ABARE, 2000). Yet, despite this increase in food production there are still 800 million people in the world considered food insecure. Many of these people live in Sub-Saharan Africa, with over 46 per cent living below the international poverty line of US$1 per day (Devereux & Maxwell, 2001). The greatest single cause of famine in Africa is not drought, nor plagues, but war. Correspondingly the focus in development assistance has moved away from an emphasis on food self sufficiency to promoting sustainable livelihood strategies for the rural, as well as the urban poor. In effect, creating an enabling environment for household food security.

Agriculture is central to any food security policy, accounting for the production of all food grown on land. Self evident as this may be, it is important to remember that there is a finite amount of land and, more importantly, water available which is suitable for the production of food. The issue is deciding where to produce this food.

Food self-sufficiency, achieved by meeting all food needs through domestic supplies, used to be a national agricultural objective in many countries. It had the effect of keeping foreign exchange in the country, where it could then be used to import products, which could not be locally produced. A measure of control over producer prices, resulting from less exposure to the vagaries of international market prices, was kept. In the South African case there were the political factors of the 1970's and 1980's, which saw food self-sufficiency becoming part of a goal of national self-sufficiency.

Yet, in the 1990's nearly 80 percent of all malnourished children lived in developing countries, which produced food surpluses (FAO, 2000). Increasingly the trend is away from food self-sufficiency and towards partial reliance on food imports. This provides a measure of protection against droughts, an important factor in southern African agriculture. There is also the potential of releasing for other uses substantial amounts of water, used in the production of food crops.

Aside from the water savings from a reduction in agriculture, the other factor, which has an effect on food self-sufficiency policies, is international terms of trade. Trade barriers, in the form of import taxes and quotas, and agricultural subsidies have a direct effect on the world prices of agricultural commodities. These world market prices must form an integral part of any food security policy.

iii. The concept of virtual water

In the arid regions of the world water is the limiting factor in agriculture, with a direct bearing on what can and what cannot survive in a particular region. During the growth cycle of a plant water is applied to the field, whether by rainfall or by irrigation. Some of this is absorbed by the root system of the plant, while the remainder finds its way into rivers, percolates into the soil or evaporates. At harvest most of the water consumed by the plant has been lost to the atmosphere through the process of evapo-transpiration. A small portion of the water is locked inside the structure of the plant. Once the plant has been processed into an agricultural commodity, such as wheat, it contains very little moisture. Yet, the quantity of water involved in its production is large. In arid regions a tonne of wheat requires 1300 tonnes of water (Krieth, 1991). The concept of virtual water serves as a metaphor for the complex interaction between water, food and trade.

It has been calculated that the flow of virtual water into the Middle East region, in the form of grain imports is equivalent to the annual flow of the Nile (Allan, 1996). This has been a major factor in averting conflict over water in the region, as local water resources have, since the early 1970's been insufficient for the production of local food needs.

Importing food into arid regions not only mitigates physical water scarcity, but also provides economic benefits. Since the Second World War there has been a strong downward trend in food prices (Merret, 1997). World grain prices in 1999 were no more than half of their real value in 1961 (Figure 1), with no indication of a long-term reversal to this trend (Berkoff, 2001).

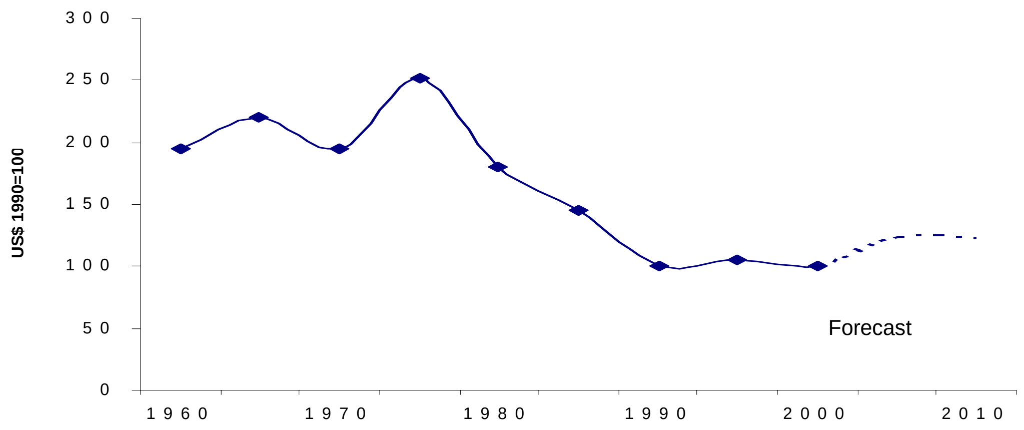


Figure 1: World grain prices (World Bank, 2000)

There are two main reasons for these low grain prices. First, crop productivity has increased. New and hybrid species have been created which respond well to large amounts of fertilisers commonly used in commercial farming. So effective have these productivity increases been that world food output has risen by more than 25 percent per capita from 1961 to 1998 (FAO, 2000).

Secondly, agricultural sectors of the large food exporting countries receive subsidies. These are in the form of restrictions or taxes on imports, direct payments or subsidised inputs to farmers and export subsidies. The 1995 Agreement on Agriculture of the World Trade

Organisation (WTO) was supposed to lead to a decrease in the level of support given to farmers in the North. This has not been the case (Figure 2) as the nominal rate of assistance has increased in the OECD countries and is fast approaching the high levels of the mid 1980's (ABARE, 2000).

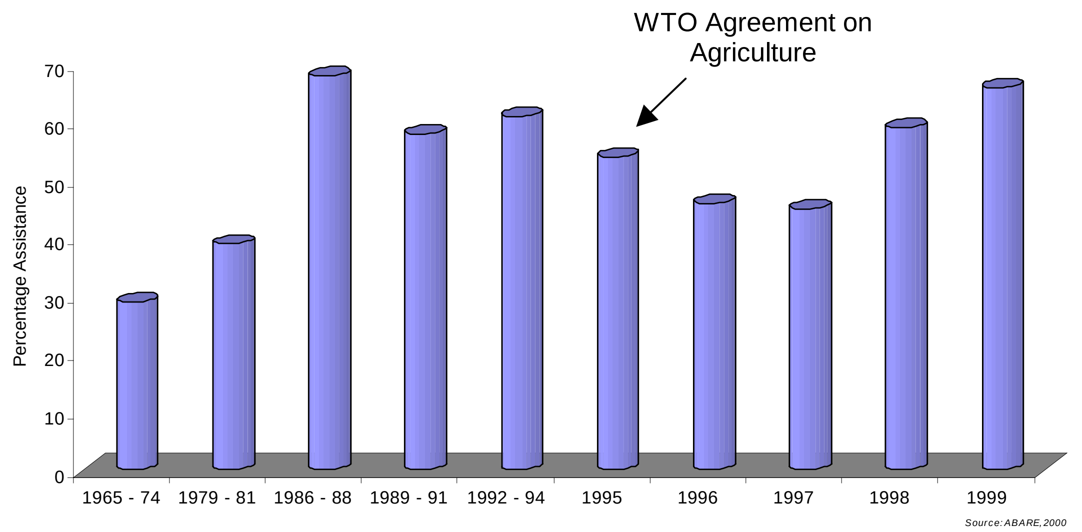


Figure 2: Rates of agricultural assistance – OECD countries (ABARE, 2000)

The potential consequence of a future change in these levels of support will be discussed in a later chapter. The point remains though that with world food prices at such a low level, imports form an important part of any food security policy in southern Africa.

Two thirds of annual grain exported on international markets comes from the countries of North America and the European Union (World Bank, 2000). These areas have temperate climates, well suited to large-scale rainfed agriculture. The water used in growing this grain was not diverted from another source. Assuming that the natural vegetation of these areas would have consumed a similar amount of rainwater as the grains grown there, the opportunity cost of this water is, in effect, zero. Rainfed agriculture accounts for sixty percent of the world food supply (FAO, 1998).

Arid developing countries are at a double disadvantage when attempting to compete in the international grain market. First, they do not have the resources to compete against the agricultural subsidies provided to farmers in the North. This means that their cost of production will always be greater than the international market prices.

Second, their climatic conditions are not conducive to the large-scale production of temperate-zone crops, such as wheat. They will have to mobilise large volumes of water for irrigation, often at great economic, social and environmental cost. Large parts of South Africa are well suited to rainfed farming; a third of South Africa's wheat is grown in the western Cape without irrigation and the majority of maize is grown on rainfed land (AGRIC, 2001) These areas can potentially produce grains efficiently, if they can keep costs below world market prices. In many circumstances irrigation schemes are efficient, using relatively little water and adding value to it, such as viticulture and various other horticultural products. Zimbabwe is in a similar situation, with large parts of the country also suitable for rainfed farming. Whereas, most of Botswana & Namibia's crop farming potential would involve irrigation, as less than half a percent of both countries areas receive more than 500 mm per year (FAO, 1995).

iv. Objective of the study

The goal of this study is to analyse the interaction between water, food and trade at a theoretical, as well as a practical level. To achieve this goal the study is divided into a number of objectives. Part One deals with the theory of Social Adaptive Capacity in the context of virtual water as an aid to food security in southern Africa. Part Two aims to provide an understanding of water, food and trade at the international level by applying it to international trade theory.

Part One: Regional Trends

- *First Objective: is virtual water a policy decision, or is it a reaction to drought?*

The study will investigate whether the four countries are adopting a long-term trend of relying increasingly on virtual water. In times of drought the need to import food is forced upon countries, but this does not imply a consistent reliance on virtual water. Data on agricultural trade and production over the past forty years will be used to identify trends in food provision. Changes in the composition of food trade and production, such as from cereals to cash crops, will also give an indication of the reliance on virtual water

- *Second Objective: what trends in food security are observable?*

Once it is determined how the food is supplied the study will investigate the effect on food security within the country. Data on calories per capita will be looked at to give an indication of long-term trends. The depth, as well as the extent, of hunger will be determined. The level of food security will be viewed in context of the result of the first objective. Any correlation between the adoption of a virtual water policy and the level of food security within the country should become visible. According to the theory of Social Adaptive Capacity, a country can overcome a shortage of first order resources if its second order resources are sufficiently evolved. Therefore, countries with the highest level of second order resources are expected to be able to adopt the concept of virtual water.

Part Two: International Context

First Objective: What are the likely implications of trade liberalisation?

The 1995 Agreement on Agriculture was meant to reduce the level of agricultural support. Clearly this has not happened (see Figure 2). However, if there were to be a reduction in the levels of support, the viability of a food import strategy may be negatively affected. Food prices would rise and developing countries may find it hard to raise the foreign currency to cover the cost of imports. Preferential trade agreements, such as Lome and its successors, would fall away. A rise in world commodity prices could, however, have a positive impact on developing countries' terms of trade. This part of the study will give a, very, brief description of the current trade conditions and attempt to determine the position of the four countries of the study after changes to world trade regimes.

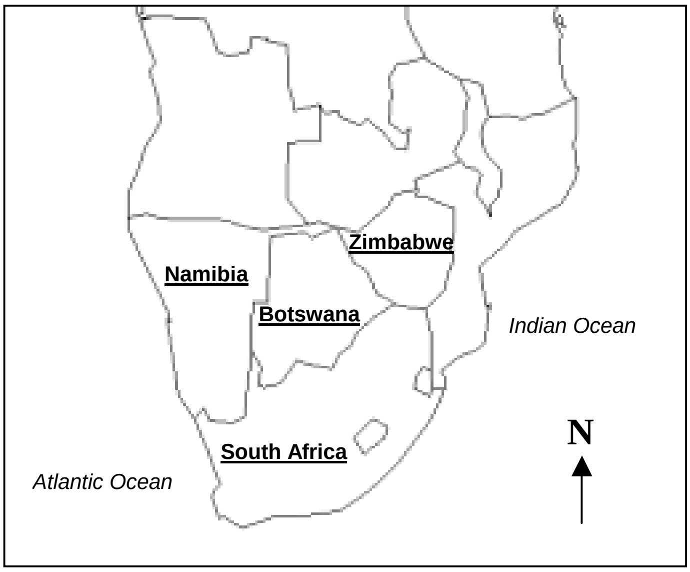
Second Objective: Does virtual water flow the way the Heckscher-Ohlin model predicts?

The Heckscher-Ohlin model predicts trade flows between countries, based on their relative factor endowments. Several studies have been performed applying the model to factors such as land and capital. In this study the model will be applied to the international grain trade in relation to water resources. A sample of 63 countries will be analysed to assess the validity of the model in predicting which way trade between countries will flow. A study by Bowen, Leamer & Sveikauskas, which appeared in *The American Economic Review (1987)*, will be used as a base for applying the H-O model.

The model predicts that once trade is established between countries the price of the relatively scarce factor in each country will decrease (Maneschi, 1998: 171). The result is that "*in an indirect way the two countries are, in effect, trading factors of production*" (Krugman & Obstfield, 1995).

v. Background to the study-region

This study will focus on Botswana, Namibia, South Africa and Zimbabwe. In a study by Turton (1998) these four states were grouped together as a "central belt of scarcity" (Map 1).



Map 1: Southern Africa

This region has relatively limited water resources. In relation to other countries in southern Africa, these four countries have the most developed economies, making current and future competition for water great. They also have the largest number of technological and economic options available.

The Governments of the countries in the study region have all committed themselves to implementing policies of water demand management. In South Africa the only right to water granted is to the reserve, comprised of a minimum amount of free water for each person and for the environment. Apart from this no other group or individual receives an automatic right to water, even if the water is on their property. There has been a move toward charging a market-related price for water, as water has been recognised as a scarce and strategic resource, which has to be used sustainably. Zimbabwe has also moved away from automatic rights to water. There, an order of priority of use has been developed. Primary water, for domestic purposes & non-commercial farming are at the top of the list, with the environment, urban sectors, industry & finally agriculture following.

The rural populations of both Namibia and Botswana are net consumers of food (SADC, 2000). The provision of water for domestic purposes has received priority. Although there is not a formal policy of water demand management in either country, Namibia has recognised the need to maximise returns to water and Botswana has focussed on the provision of domestic water and sanitation.

There is potential for a number of interbasin transfer schemes within and between countries. Botswana could, potentially, tap water from the Zambezi or the Okovango rivers, but this has environmental and political problems. Both Namibia and Zimbabwe have made tentative plans towards the large-scale use of the Zambezi, but the main hurdle to overcome is the distance this water will have to be transported to bring it to where it is needed.

Most of the available water resources within South Africa's borders have been used (Turton, 1998). The Lesotho Highlands Water Project is predicted to be able to supply the needs of Gauteng until about 2020, with current water use growth increases. The next available source of water will be from the Zambezi, 1200 km away. Such a project would prove to be expensive, both from an economic as well as from an environmental point of view. It would also leave South Africa vulnerable to interruptions in the supply of this water. This is an important factor as other riparians also have plans to use the water from the Zambezi. It is preferable for a country to be water self sufficient rather than food self sufficient, as food is much easier to transport internationally than water.

Water Demand Management (WDM) has as its focus the efficient use of existing water supplies, in preference to the development of new ones. For any WDM policy to be successful there must exist the economic capacity and the political will within the society. If water is to be allocated to more efficient uses the capacity must exist in the economy to add greater value to a unit of water than what agriculture can. The ability of a society to adapt to natural resource scarcity has been called *social adaptive capacity* by Turton & Ohlsson (1999). A scarcity of first order (or natural) resources leads to absolute scarcity only if there is also a scarcity of second order (or social) resources (Turton, 2000). Scarce water resources in a country, in combination with socio-economic resource abundance leads to *structurally induced relative water abundance* such as in Israel (Turton & Ohlsson, 1999). In such a situation virtual water acts as a bridge in achieving the goals of WDM.

Chapter 1: Societal Responses to Natural Resource Scarcity

"Wherever they perceived scarcity they would drive themselves to create abundance – when and where there was abundance they would make scarcity anew"

(Worster, 1985 – on water and the American West)

1.1 What water problem?

The pre-modern attitude to water was that of a free good, to be used by all. As societies started developing more of their water resources this view lead to the large-scale depletion, destruction and contamination of many water resources in the world (Worster, 1985). Gradually many of these societies have started viewing water as a limited natural resource, to be protected and conserved. There has been a gradual shift towards valuing water as an economic resource; based on the premise that humans will only conserve something if it is of economic value to them. Another trend has been to view access to domestic water as fundamental human right; one which 800 million people in the world do not yet have.

Water makes life possible on earth, yet 97 percent is seawater. Of the remaining three percent roughly two thirds is locked in the polar ice caps. Much of the groundwater on land is too deep to ever be exploitable, leaving only about 0.3 percent of the global total for life on land to use (Robinson & Ward, 1990). This 0.3 percent is highly unevenly distributed, with some countries receiving excess amounts of water and others not receiving enough. Attempts to quantify the levels of water scarcity faced by various countries have been made in a variety of studies. Falkenmark (1989) developed the concept of the "*water barrier*". This was set at a level of 2000 people per flow unit (one million cubic metres). If a country has more people per flow unit than this, further economic development will not be possible. Each country is placed in one of five possible ranges (Table 1).

Table 1: Water Barrier Scale (Falkenmark, 1989)

Conditions	*Persons / flow unit*
Well watered conditions	*<100*
Mid-European	*100 – 600*
Water stressed	*600 – 1000*
Chronic scarcity	*1000 – 2000*
Beyond the water barrier	*>2000*

In this way, the competition for water within as well as between each country is gauged. Estimations can also be made of future water availability, based on population projections. The four countries of the study can be classified according to the scale (Table 2).

Table 2: Water Barrier Scale classification for countries studied

Country	*Recoverable water resources (km^3/y)*	*Persons / flow unit (2000)*	*Conditions*
Botswana	*9*	*210*	*Mid-European*
Namibia	*9*	*260*	*Mid-European*
South Africa	*50*	*812*	*Water Stressed*
Zimbabwe	*23*	*660*	*Water Stressed*

As expected, South Africa and Zimbabwe are both classified as *Water Stressed*. This is largely due to their large populations increasing the demands placed on the water resources. It is also reflected in their rainfall levels of 451 mm and 652 mm per year (FAO, 1995). With 500 mm being the minimum for rainfed agriculture to be successful in the region, both countries can be termed semi-arid. The other problem with the rainfall is that it is both temporally and spatially highly variable. That means that some years can be very dry while other years receive floods. The spatial variation is extreme in South Africa, with areas in the west of the country receiving less than 10 mm per year and up to 1200 mm falling in the east of the country.

The classification of Botswana and Namibia as experiencing *Mid-European* conditions is surprising. While most of these two countries consist of deserts, they do have large rivers in the north (Zambezi, Okovango & Kunene). Combined, the countries are roughly three times the size of France. This large size makes the transport of water to people or people to water very difficult and expensive. They both receive less than 300 mm per year rainfall, placing them in the arid category. On a per person basis they have a similar amount of water to temperate countries in western Europe. However, unlike France or Germany they are not major agricultural exporters. The farmers of these and other temperate countries can grow water intensive crops, such as wheat, without relying on irrigation. The soil moisture provides the water needs of the plants. Comprised of tiny water molecules clinging to grains of soil, it is more or less static in the soil horizons. Unlike groundwater it cannot be pumped or quantified. Yet, it provides the moisture for the crops that feed the world.

Soil moisture (sometimes called *green water*) is negatively affected by the very high rates of evapotranspiration in the area. Values as high as 3700 mm per year are experienced in parts of Namibia and Botswana, with most of the region experiencing rates of evapotranspiration higher than average rainfall (FAO, 1995). This is much higher than the global average of 1200 mm per year and has an impact on moisture availability in the soil (FAO, 1998). A good example of the difference this can create between areas is that while London and Johannesburg receive roughly the same amount of rainfall annually (just over 600 mm), the former is experienced as being much wetter than the latter. Due to the higher rate of evapotranspiration in Johannesburg most of the rain that falls is rapidly converted to water vapour. Only small areas in Zimbabwe and South Africa are considered moderately suited to the production of wheat (Figure 3).

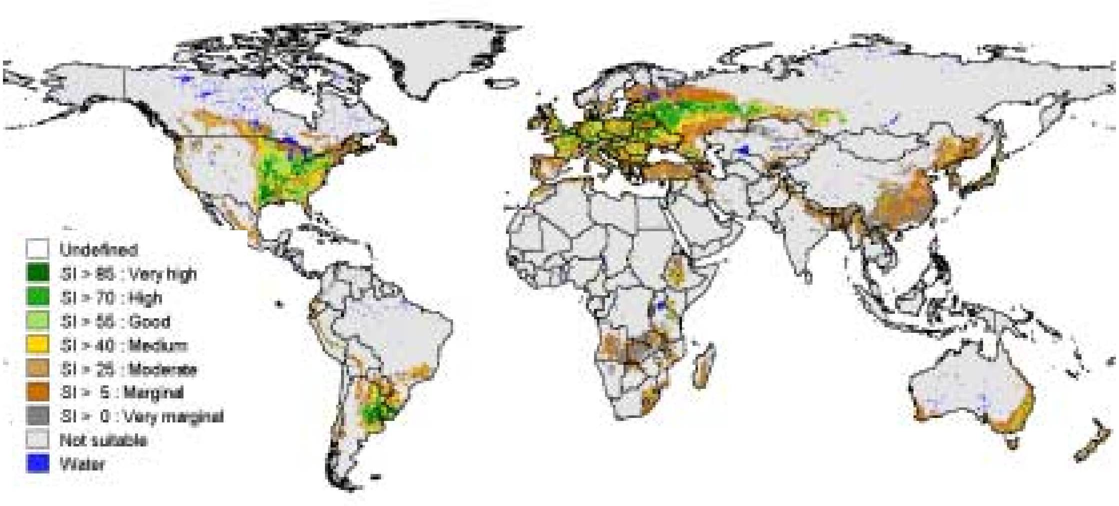


Figure 3: World suitability for rainfed wheat - intermediate inputs (FAO, 1998)

If the farmers of the region do not have the benefit of large soil water resources, what options do they have for the production of food crops?

Irrigation can make the desert bloom, creating abundance, where once there was scarcity. The problem is the same one limiting the quantity of soil moisture available. High rates of evapotranspiration prevent applied water from draining away through the soil. Instead, water converts directly to vapour and leaves behind tiny solid particles referred to by the generic term salt. This ranges from the sodium chloride we sprinkle on our food to calcium carbonate, zinc sulphate, barium chloride, sodium bicarbonate and various phosphates, nitrates and hydrates (Worster, 1995). Rainwater contains very little of these salts, whereas water that has been exposed to rocks and minerals can contain a variety of them. Over time salts cluster around the roots of plants and prevent effective moisture uptake, leading to lower productivity. Whole fields can be turned sterile in this way. Civilisations have disintegrated because of this problem, the Sumerian decline 4500 years ago being well documented (Postel, 1999). There are ways of avoiding salt build-up. These include ensuring effective drainage and the flushing out of salts by applying large quantities of water to the field. In the long run, salinisation is a persistent problem in arid climates, requiring ever-greater resources to combat it.

Frequently irrigation is not economically viable. Depending on the type of system used costs can be between US$ 1250 and US$ 2900 per hectare in southern Africa (FAO, 1995). This includes only the costs of the 'in-field' works and does not include large storage and transfer works or roads. When these indirect costs are factored in the average cost of irrigation in Africa is US$ 18 300 per hectare (FAO, 1998). Assuming a yield of five tonnes per hectare on an irrigated wheat field, an income of US$ 610 per hectare can be expected. Once other costs have been deducted, this will leave very little over to repay the capital costs of the irrigation scheme, let alone the operation and maintenance costs. In a study by IFPRI using their International Model for Policy Analysis of Agricultural Commodities and Trade the effect of doubling the amount of the irrigated area in Sub-Saharan Africa on grain production was compared to a baseline scenario of 35 percent increase. It predicted only a 12 percent increase in production over the baseline scenario (FAO, 1998). This makes it very difficult for irrigation projects to be economically viable, especially when used to produce low value staples. As a development tool it can also have negative consequences as it has been found that “the impact of irrigation in much of Africa may simply be to transfer production from rainfed farmers to (heavily subsidised) irrigated farmers, without adding significantly to domestic output” (Berkoff, 2001: p9). The money could be used more effectively in promoting local business and manufacturing opportunities or in assisting rainfed farmers to implement rainwater-harvesting schemes. This is not to say that irrigation is never efficient, just that all the costs and potential benefits must be taken into account when considering a scheme.

Frequently large water transfers for irrigation schemes have environmental consequences for the areas from which the water was taken. A prime example of this is the Aral Sea. In 1961, this was the world’s fourth largest inland waterbody, with a large quantity and variety of water life. By 1990 its volume had shrunk by 69 percent, largely due to withdrawals for cotton and rice fields. The water had also become badly contaminated with salts, pesticides and fertilisers from agricultural return flows (Barrow, 1999).

Although the application of fertiliser can improve yield and returns to water, this is not always economically viable. According to the FAO, “there is no evidence that the application of fertilisers pays off in the drier climatic zones. This is especially true for nitrogen, whose application has been found to be economic only in areas with at least 900 mm annual rainfall. Low initial yield levels imply that a small relative increase in yield does not produce enough grain to pay for the fertiliser” (FAO, 1998)

The above all paints a gloomy picture for agriculture in the region. Low levels of rainfall distributed unevenly and erratically. Coupled with high rates of evapotranspiration, this leads to low levels of soil moisture availability. Irrigation, if water sources are available, poses serious environmental risks and high costs. It is against this background that the region has had to develop its food security policy. Therefore when figures on water scarcity are used it must be remembered that they only provide part of the overall picture.

1.2 Social Adaptive Capacity

In order to understand how a country responds to resource scarcity it is necessary to look at the relationship between environmental capital and economic development. Countries pass through a series of phases in the management of their environmental resources (Karshenas & Allan, 1996). As an economy develops it starts to deplete its base of natural resources (Figure 4). These natural resources are used as inputs to generate further economic development (trajectory **A**). Over time, the stock of natural resources, such as water, becomes degraded. By this stage an economy should be strong and diversified enough to limit environmentally damaging activities and pursue income from more sustainable sources referred to as 'precautionary' development (trajectory **B**). The aim is for the country to follow a development strategy, which will keep it in the sustainable development box on the top right of Figure 4. To do this it will need to enter a phase of natural resource reconstruction (trajectory **C**). Failure to keep the development trajectory in a sustainable direction will lead to either ecological or Malthusian catastrophe. This would indicate irreversible damage to the environment or to the economy respectively, as has happened in some of the poorest of the world's countries.

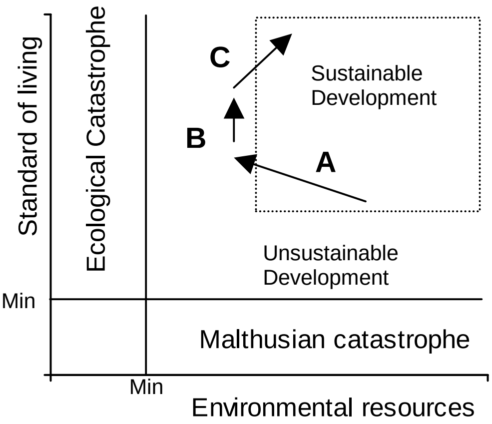


Figure 4: Environmental capital and economic development

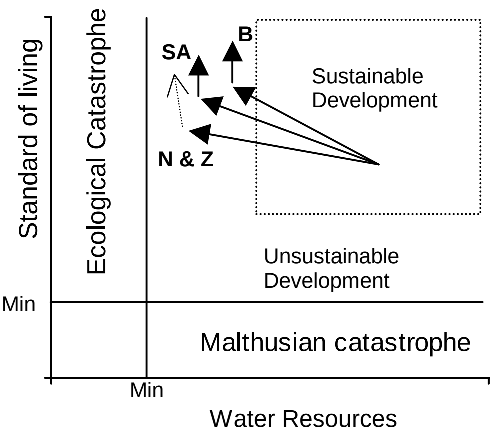


Figure 4a: Karshenas model applied to water resources in the study region (Turton, 1998)

According to Turton (1998), the four countries of this study can be depicted as in Figure 4a. Namibia and Zimbabwe (N & Z) are on an unsustainable development trajectory. A policy change could avert an ecological catastrophe. Since Turton's study, Zimbabwe has passed a new Water Act (1998). This has shifted the emphasis towards a more demand sided approach to water management. Most of the provisions in the act have yet to be enforced, thus it will be some time before it can be judged if this has placed Zimbabwe on a more sustainable development trajectory. Namibia would appear to be following a supply side approach to water management.

Botswana (B) has taken a policy decision to limit the amount of water used for agriculture. This has placed it on a sustainable development trajectory. Since South Africa passed the National Water Act (1998) the overall waterpolicy has become demand sided (DWAF, 2000). Priority is being given to domestic and industrial water supplies. As yet, it is too soon to tell what the effects are on the water supplies of the country.

The Karshenas model gives an indication of how countries should or do act. To find out why some countries manage to guide their development policies in a sustainable direction one needs to look at the level of societies' *adaptive capacity*. Natural resource (or first order) scarcity forces a society to adapt to a new level or method of resource use. For example, as Britain's' minerals were being depleted by the 17th century it had to start diversifying its economy. Britain switched from exporting raw materials to importing them and producing manufactured products for export, moving it onto a sustainable development trajectory (in terms of their mineral base).

For a society to be able to make this change, it needs a high level of, what Ohlsson calls, *second order resources*. These are the social, economic and political factors necessary for a society to adapt to change (Turton, 2000). All four of the countries in this study experience water scarcity, in terms of the agricultural possibilities possible. They only suffer from water poverty if the water scarcity is in conjunction with a lack of second order resources. The level of second order resources, or *social adaptive capacity* is much more important in determining future development levels of a country than what the levels of first order resources are.

As was pointed out earlier, a water scarcity index does not give an accurate indication of the water availability situation in Botswana and Namibia. Yet, it is difficult to quantify factors such as soil moisture and costs of water transport. Various attempts to improve upon the index have met with limited success. These included considering the area of the country, as well as trying to factor in effective rainfall. All proved to produce distortions of some sort, with few improvements on the original. It is with these reservations that the index is used as an indication of water availability. A country's Human Development Index (HDI) indicates second order or social resource availability. This is a composite ranking system used by the United Nations Development Programme (UNDP) and strives to give an indication of the overall level of development in a country. It looks at factors such as education levels, nutrition and income per person (see Appendix C for a full explanation). Figure 5 shows that levels of socio-economic development are not correlated to availability of water resources.

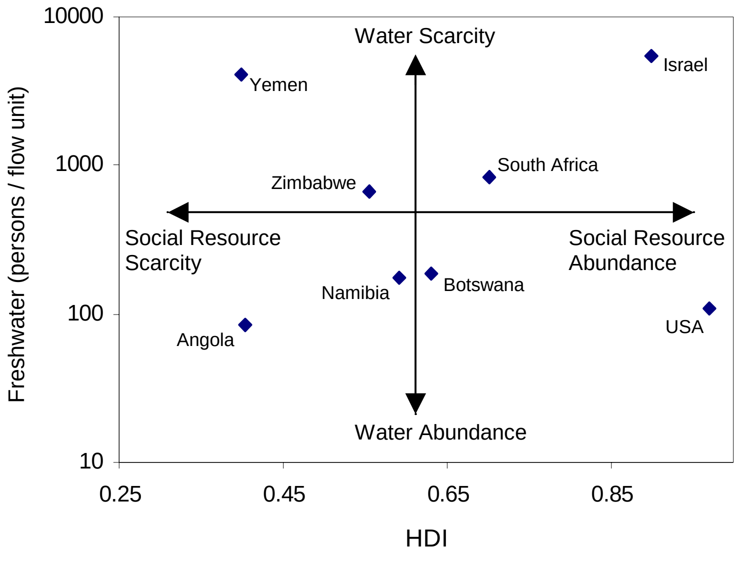


Figure 5: Water Resources in relation to social adaptive capacity

Large engineering schemes to transfer water over great distances can increase a country's availability of water resources. An increase in water resources will not, necessarily, lead to an increase in economic development. An increase in social adaptive capacity will allow a country to find solutions to its water scarcity. For these solutions to be sustainable, they will have to break the dependency of the country on a scarce resource. In terms of water, this will involve switching from productive efficiency to allocative efficiency. The former implies that current users use their water more efficiently, such as the introduction of drip irrigation to replace flood irrigation. Allocative efficiency means using water in the situation where it will generate the most income (Figure 6). Industries and services generate anywhere between one and ten thousand times more income from a unit of water than what agriculture can (Allan, 2000).

For example, wheat yields between one and two and a half tonnes per hectare in the study area (World Bank, 2000). Most of this is rainfed. Under irrigated conditions yields increase by an average of 2.2 times (FAO, 1996). Five tonnes per hectare is a typical irrigated yield, accompanied by increased fertiliser use. This production will take 6 500 cubic metres assuming the water use for wheat is 1300 cubic metres per tonne (Krieth, 1991). At the average 2000 grain price of US$ 122, the value added to each cubic metre of water would be US$ 0.09 (World Bank, 2001). In contrast, about 400 cubic metres of water are needed to produce a tonne of oranges. In 2000 this tonne was worth US$ 360, adding US$ 0.9 to each cubic metre of water consumed, ten times that which is added by wheat (World Bank, 2001). In a sense, this is still a form of productive efficiency, as it still keeps the water within the agricultural sector. Allocative efficiency would cause the water to be diverted to a use such as aluminium production. Five cubic metres of water are used to make a tonne of aluminium, although much of this is not consumed and can be used again. As there are costs involved in recycling the water it will be counted as a consumptive use. At the 2000 price of US$ 1535 per tonne, aluminium adds US$ 307 to every cubic metre of water, or 3411 times more than wheat.

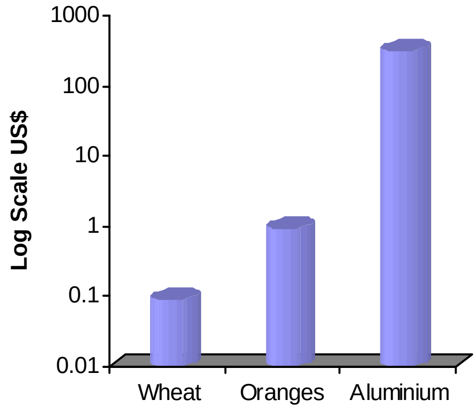


Figure 6: Water use per tonne production

One of the least efficient options would be to devote all the land and water resources in the area to wheat production. Two effects of the market can prevent this from happening. First, low rates of protection for local farmers make them dependent on the international market price for wheat. The low prices would not make it cost effective to farm with wheat and would cause a shift to producing higher value crops. If soil and climatic conditions are good for wheat production and input costs are low, the continued production of wheat may well be the most efficient option.

Second, pricing water at a rate related to its scarcity in the region encourages productive efficiency. Farmers switch to the production of less water intensive crops, with a higher market price. This is also the first step along the road to allocative efficiency as farms suited to the production of low value; water intensive crops are not necessarily suitable for growing oranges, grapes or vegetables. The most efficient option in some cases might prove to be to take such a piece of land out of farming if it cannot operate with the reduced water supplies available. However, this would be politically stressful.

The success of such a shift in economic focus depends upon the level of social adaptive capacity in the country. The economy needs to be diversified enough to be able to compensate for any loss of income from the agricultural sector. This is why gauging the level of a country’s dependence on virtual water gives a good indication of its social adaptive capacity. Imports of food may save local water supplies, but only if there is the capital to pay for them.

Chapter 2: Regional trends in food trade and production

2.1 Method of Analysis and Data Used

The chapter will identify trends in water use and allocation by analysis of figures on agricultural trade and production. These figures are gathered by the FAO from the member countries and are updated annually. Production is measured in metric tonnes and trade in tonnes and thousand US dollars at constant 1990 prices. This cancels out the effects of inflation on the prices, making the data comparable between years.

The data on water resources and consumption are from the World Bank as well as the individual countries. Most of the comparisons will be between the early 1970's and 2000, but there is some variation in the time periods for which data are available.

First, allocative efficiency within the agricultural sector of each country will be gauged. As agriculture is still a large employer of labourers in the region it is to be expected that there would be strong opposition to directing water out of the sector on a large scale. South Africa and Zimbabwe are net exporters of agricultural products, although its share of their relative GDPs is decreasing.

If farmers start exporting crops that have a higher return to the water used, cereals will have to be imported. The level of this shift is indicated by the composition of a country's trade. A variety of crops will be selected, the sample representing the majority of all crops traded and produced by each country (see Appendix D for a list of all crops looked at). These are the crops that will be referred to when the levels of agricultural trade for each country are discussed. Seventy percent of the region's average per capita calorie supply comes from cereals, starchy roots and sugar (FAO, 2001). Cereals alone supply 54 percent of the region's calories. These crops are also the lowest priced, with none of them receiving more than US$ 210 per tonne on the world market in 2000 (World Bank, 2001). They are referred to as *mass* *intensive*, as opposed to *value intensive* crops, which receive higher prices on world markets. Therefore it can be assumed that if a country's exports (imports) are mass intensive, rather than value intensive, then it is exporting (importing) a larger proportion of the above crops. If the exports (imports) are value intensive, the trade is mainly in agricultural products that do not contribute a great deal to the calorific intake in the region. Many of the higher value crops have an absolute water efficiency advantage, such as oranges. They consume less water to produce a given quantity of mass. Others have a relative water efficiency advantage over cereals, as they consume roughly the same amount of water to produce a given mass, but add more value to this water. Coffee is such a crop.

The percentage change in the composition of each country's trade will be calculated. In order to compensate for seasonal fluctuations four-year averages will be used. The first set, *period 1*, will be from 1996 to 1999 and the next set, *period 2*, from 1976 to 1979. The current situation is compared with that of twenty years ago, as this was the period when most of the countries in the region were attempting to achieve food self sufficiency. The percentage change in a county's level of **value intensive imports** (*VI*) is given by:

$$VI = \left(\frac{IT_1}{I\$_1} - \frac{IT_2}{I\$_1} \right) \times \frac{I\$_1}{IT_1} \times 100$$

IT_1 and IT_2 represent the country's imports, in tonnes, for period 1 and period 2 respectively. $I\$_1$ and $I\$_2$ represent the imports in thousand US dollars for period 1 and period 2 respectively. The same equation will be used to determine the change in the level of **value intensive exports** (*VE*), with mass of exports (ET) being substituted for imports (IT).
A country that has started implementing allocative efficiency within its agricultural sector can be expected to display positive values for *VE* and negative values for *VI*. If this is the case it would indicate a shift towards a reliance on virtual water by the country. Higher value, non-staple diet foods would be exported and lower value staples imported. Overall agricultural production could thus be maintained, or increased, while generating foreign currency from

exports and allowing a water demand management programme to be implemented with a minimum of social disruption.

The second part of the analysis will look at inter-sectoral water efficiency. For a country to effectively bring its water use down over the long run and move into the phase of natural resource reconstruction, it has to use the water in the most efficient way possible. A high level of second order resources would be needed in the country for this to happen. Such a large-scale shift of water away from the agricultural sector will prove to be economically and politically stressful for any government and would require rapid development in the other sectors of the economy for it to be viable. This would necessitate a heavy reliance on virtual water imports and would be accompanied by a decrease in the size of the agricultural sector. Whereas, the adoption of allocative efficiency *within* the agricultural sector can have two possible outcomes. The most likely is that agricultural water use will drop and that the sector will contribute the same amount to the GDP of the country. The extra water would then either aid in resource reconstruction or be used by other sectors of the economy. The other possible outcome is that agricultural water use remains the same, but that the sector contributes a larger amount to the GDP. Such an outcome would indicate that the country is still on the path towards ecological catastrophe.

Therefore the outcome of the first analysis must be compared with the inter-sectoral shifts in water allocation. Current water use of the various sectors of the economy in relation to their contribution to the GDP will be compared with past levels. This *sectoral water efficiency* is the ratio of water consumed in a sector (as a percentage of national consumption) in relation to its contribution to the GDP (Turton, 1998). If the agricultural sector shows an absolute decrease in size, this would imply a shift towards using virtual water. This shift can be shown graphically by plotting the production and trade figures on a chart. A country relying heavily on virtual water imports to achieve food security will be a net importer of staple foods, particularly grains. If successful, there will also be a drop in production, accompanied by an

increase in per capita food availability. Calories per capita will be used as a measure of food availability. This can only act as a rough guide to food security. Food security, as defined earlier, is to be measured at the household level. There is often massive variation within countries, especially in southern Africa as income inequality is large. The UNDP compile figures on nutrition levels as part of their HDI. These include the percentage of undernourished people and the percentage of children who are underweight. These figures will be incorporated for the years for which they are available. The prevalence of malnutrition is classed as *low* if less than five percent of the population are malnourished. It is considered *moderate* between 5 and 19 percent, and *high* when it is over 20 percent (FAO, 2000b).
The FAO use a system of calculating the depth of hunger or food deficit of the undernourished people in a population. This looks only at the people who are not receiving enough calories to maintain body weight at intermediate activity levels. The amount of calories needed per person varies, depending on height, gender and activity level (FAO, 2000b). The minimum required is typically between about 2200 and 2600 calories per person per day. The average energy deficit is calculated for the undernourished people in the population. People who lack between 100 and 400 calories per day are considered chronically hungry. A deficit of less than 200 is considered *low*, 200 to 300 is *moderate* and over 300 is *high*. These people will not necessarily appear emaciated, but they will suffer from tiredness, weakened immune systems and, in the case of children, slower growth, depending on the severity (FAO, 2000b). Therefore the HDI figures give an indication of the prevalence of malnutrition and the FAO figures tell one about the severity of that malnutrition.

Each country will be assessed separately, using the methods outlined above. At the end of the chapter there will be a discussion of the results and their likely implications.

2.2 Botswana

Botswana relies heavily on imports of agricultural products. Since 1981 a greater volume of agricultural products is imported than what is produced locally (Figure 7). This reflects the fact that the country has a formal policy of not pursuing national food self- sufficiency (Arnestrand et al, 1993). According to the trade data (Table 3) the VE has had a positive increase of about 59 percent. This conforms to the agricultural sector pursuing more value intensive agricultural imports. The VI, which should show a drop if a country is pursuing a policy of importing food crops, shows an increase of 52 percent.

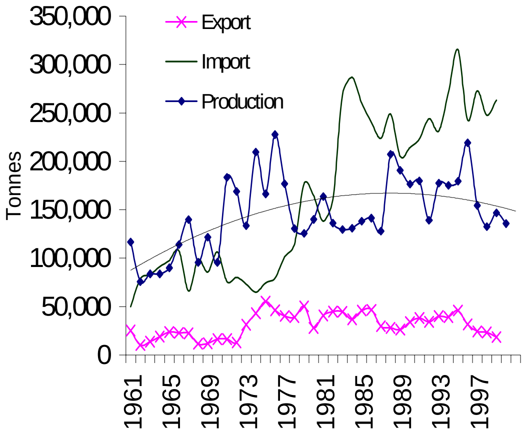


Figure 7: Botswana Agricultural Trade & Production (FAO)

Table 3: Changes in composition of agricultural trade - Botswana

Year	Tonnes Export	Tonnes Import	1000 US$ Export	1000 US$ Import	Exp: T/$	Imp: T/$	% Change VE	% Change VI
1996 - 1999	24,581	256,646	75,236	157,761	0.33	1.63	**58.57**	**51.84**
1976 - 1979	44,114	118,021	55,937	34,941	0.79	3.38		

The above would imply that exports as well as imports are becoming more value intensive. The leading export is meat, accounting for 89 percent and 98 percent by volume and value respectively of the top ten exports (Appendix D). This is a very high value agricultural product, with 2000 world prices being close to US$ 2000 per tonne. Admittedly, beef takes about 16 times more water than wheat to produce, but this is only an issue if the bulk of the animal's diet is prepared feed. It is not an issue if the cattle survive on natural rangeland, eating shrubs, which can survive in the arid conditions.

By far the largest imports, by value, are fruit and vegetables at 27 percent of the top ten imports (Figure 8). The next largest import is maize, at 14 percent. When looking at quantities though, they are both at 18 percent.

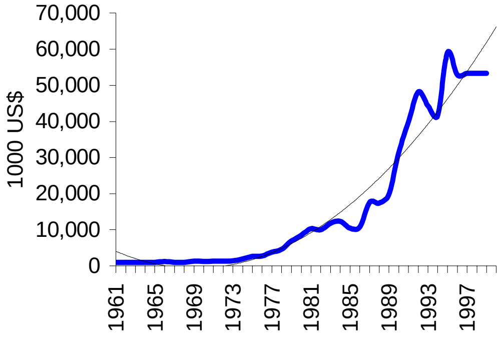


Figure 8: Botswana Fruit & Vegetable Imports (FAO)

This obviously makes the fruit and vegetables more value intensive than the maize. The average 1999 price for fruit and vegetables is about US$ 640 per tonne, whereas maize was about US$ 90 per tonne (World Bank, 2001).

The above result indicates that Botswana operates on an inter-sectoral water allocation efficiency system. There is very little water allocation within the agricultural sector, with not even higher value crops such as fruit and vegetables being grown locally. This fits in with the water use figures for the various sectors of the economy. Less than two percent of the available freshwater resources were exploited in 1995. Of this water 48 percent was used by agriculture, the lowest in the region (Appendix B). Twenty percent was used by industry and a further 32 percent was for domestic use. In 1999 industry and manufacturing added 50 percent to the GDP, whereas the figure for agriculture was four percent (World Bank, 2001). The country has had continued high levels of economic growth, mainly driven by the mining sector and, increasingly, the services sector, which includes tourism. The domestic water use is high, with 100 percent of the urban population and 94 percent of the rural population having access to an improved water resource (World Bank, 2001). Food production per

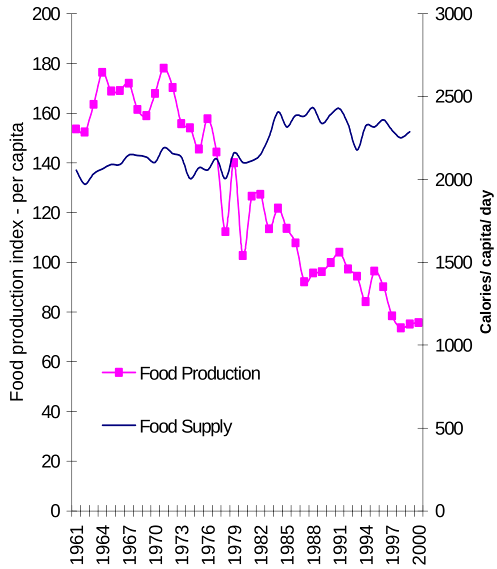


Figure 9: Botswana Food Production & Supply (FAO)

person has been declining since 1972 (Figure 9). The average amount of calories consumed per person has been increasing steadily over the same period. The prevalence of malnutrition is high at 27 percent of the population. The food deficit, amongst the malnourished is moderate at 240 calories per person per day.

2.3 Namibia

Agricultural imports have increased threefold in the past thirty years (Figure 10). Exports have remained small, the majority from meat. Local production has also increased, with 57 percent being accounted for by root and tuber production (mainly yams and cassava). Very little of this is exported, as most of it is produced by subsistence farmers. The main imports are fruits and vegetables, accounting for 27 percent and 56 percent by mass and by value respectively. Table 4 shows a change in VE of 61 percent, reflecting the relative strength of meat exports. Namibia benefits from reduced duties on its meat exports to the EU (Page & Hewitt, 2001).

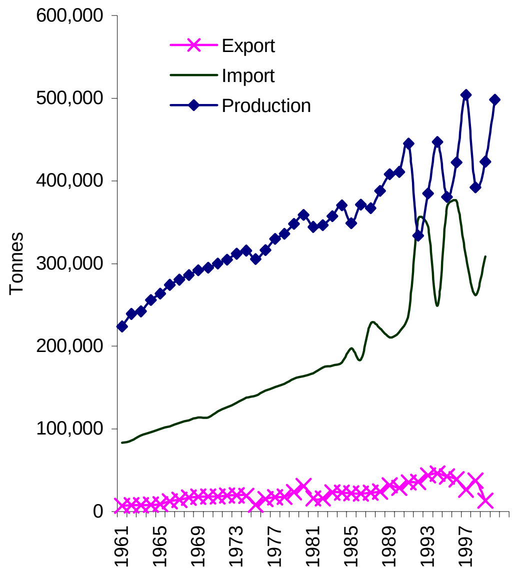


Figure 10: Namibia Agricultural Trade & Production (FAO)

Table 4: Changes in composition of agricultural trade – Namibia

Year	Tonnes		1000 US$				% Change	
	Export	Import	Export	Import	Exp: T/$	Imp: T/$	VE	VI
1996 - 1999	28,979	313,279	77,920	101,479	0.37	3.09	**61.18**	**-11.57**
1976 - 1979	18,443	153,063	19,250	55,319	0.96	2.77		

The VI decreased by 11.5 percent, due to a large increase in the quantity of maize imported in the past five years (Figure 11).

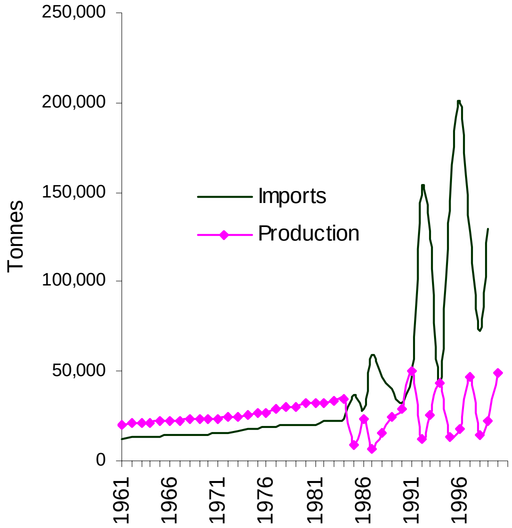


Figure 11: Namibia Maize Imports & Production (FAO)

The agricultural sector is still the main user of water in the country, withdrawing 68 percent of the total. Agriculture accounts for 14 percent of the economy and industry 33 percent, using three percent of the water (Appendix B). This would indicate that Namibia still relies heavily on the agricultural sector and that it is a large water consumer. Within the sector there is some evidence of allocative water efficiency, such as the drop in maize production, but roughly a quarter of the cereal production, mainly millet and maize, is used as animal feed. This makes the meat industry less efficient and accounts for the relatively low returns to water of the agricultural sector.

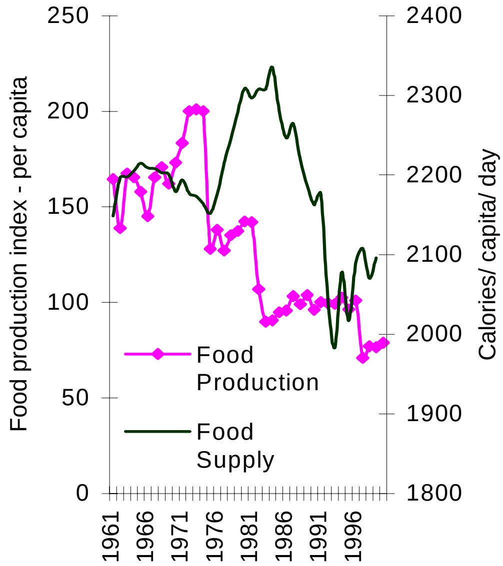


Figure 12: Namibia Food Supply & Production (FAO)

The amount of food produced per person has halved in the past 25 years (Figure 12), showing the heavy reliance on imports.

The calories available per person per day dropped from the highs of the early 1980's. The past eight years have shown a small increase. The prevalence of malnutrition is high at 21 percent of the population, yet the food deficit is moderate at 260 calories per capita per day.

2.4 South Africa

The level of agricultural production in South Africa has remained high (Figure 13a), although the level of imports has been increasing (Figure 13b). The composition of the trade has changed markedly. VE has increased by 41 percent, while VI has dropped by 126 percent (Table 5). Therefore, exports have become more value intensive over time, while imports have become increasingly mass intensive. For example, in 1979 slightly over two million tonnes of maize was exported; by 1999 the figure had dropped to 420 thousand tonnes (see Appendix D). In contrast, orange exports increased from about 300 thousand to almost 600 thousand tonnes in the same period. This trend is the same for most other high value crops grown in the country, with rapid growth in exports evident after the lifting of economic sanctions in 1994. South Africa has shifted from being a net exporter of cereals twenty years ago to being a net importer as the production of its major cereal crops has reduced (Figure 14).

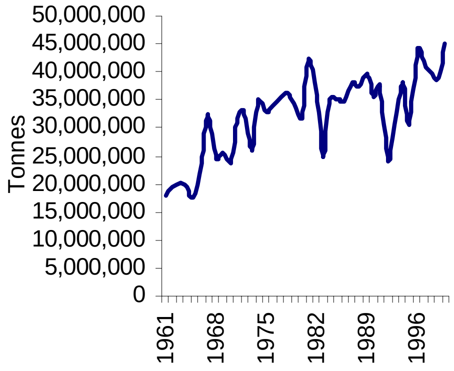


Figure 13a: South African Agricultural Production (FAO)

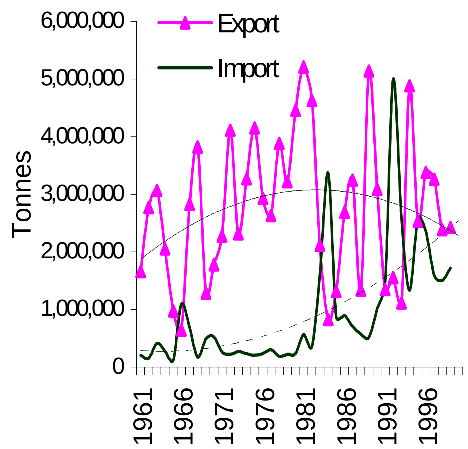


Figure 13b: South African Agricultural Trade (FAO)

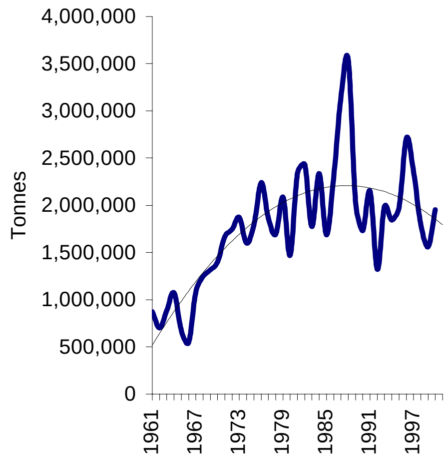


Figure 14: South African Wheat Production (FAO)

Table 5: Changes in the composition of agricultural trade – South Africa

Year	Tonnes		1000 US$				% Change	
	Export	Import	Export	Import	Exp: T/$	Imp: T/$		
SA							VE	VI
1996 - 1999	2,858,612	1,791,063	1,315,092	574,684	2.17	3.12	**41.11**	**-126.22**
1976 - 1979	3,163,549	237,483	857,044	172,379	3.69	1.38		

There is a difference between the figures given by the South African Department of Water Affairs and the World Bank for agricultural water use. The former claims it is 52 percent of the total, while the latter, 72 percent (Appendix B). The World Bank Atlas technical notes state that water use figures are provided by individual member governments, therefore there should be no reason for a difference. The DWAF figures do include water set aside for the ecological reserve (15%), which may contribute to the difference. Either of the two figures would make the agricultural sector an inefficient user of water, as it contributes less than four percent to the GDP. Industry uses 11 percent and contributes 32 percent to the GDP.

There is very little recent data on the level of irrigation of the various crops in South Africa. According to the FAO, nine percent of the country's grain production in 1988 was grown under irrigation. A current figure for maize is five percent grown under irrigation (AGRIC, 2001). One third of the irrigated area is animal pasture, and about the same percentage of the total grain crop is used as animal feed. This amounts to a large quantity of wasted water, considering the low water use efficiency of rearing cattle on feed.

The per capita level of food production has dropped steadily since the early 1980's (Figure 15). The available food per person

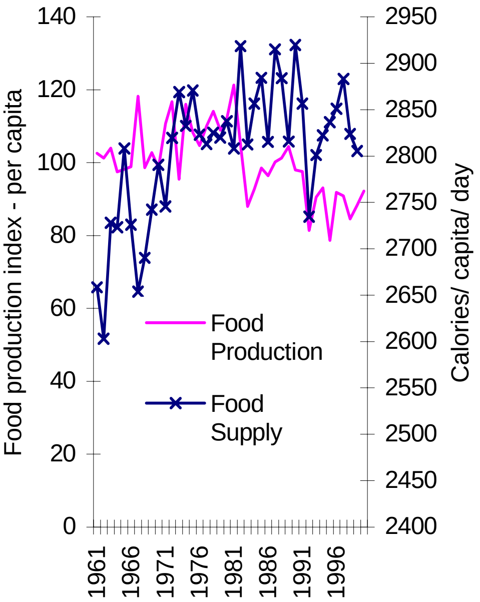


Figure 15: South African Food Production & Supply (FAO)

has continued to rise, as imports have increased. Malnourishment has a low prevalence of about 5 percent. The food deficit of 160 calories per person is low.

2.5 Zimbabwe

Agriculture is an important sector of the economy, earning twenty percent of the GDP in 1999 (World Bank, 2001). It is the only one, of the four countries in the study, to show growth in the sector. In 1990 it contributed 16 percent to the GDP, but there is a large degree of variability between seasons, with the sectors contribution dropping to ten percent during the drought year of 1992 (Turton, 1998).

Generally, agricultural production has shown high levels of growth (Figure 16a). There is a large reliance on rainfed farming, causing the high fluctuations in output depending on rainfall. For most years the country in a net exporter of agricultural products (Figure 16). As can be seen from Table 6 the value of VE has increased by 58 percent, while the value of VI has increased by 11 percent.

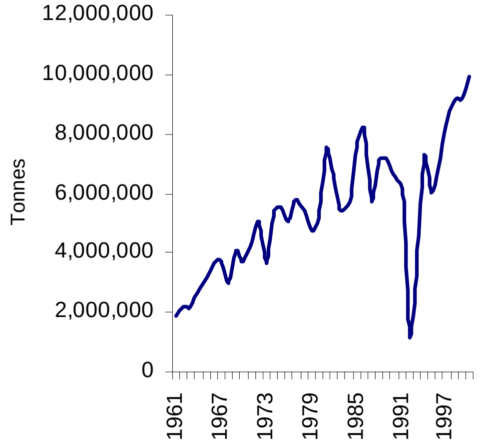


Figure 16a: Zimbabwe Agricultural Production (FAO)

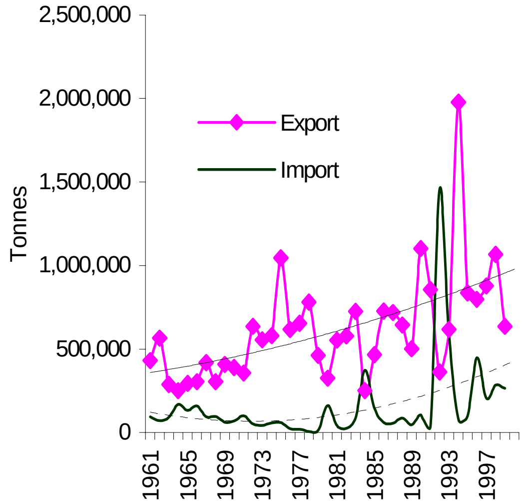


Figure 16b: Zimbabwe Agricultural Trade (FAO)

Table 6: Changes in the composition of agricultural trade – Zimbabwe

Year	Tonnes		1000 US$				% Change	
	Export	Import	Export	Import	Exp: T/$	Imp: T/$		
Zim							**VE**	**VI**
1996 - 1999	844,835	299,633	1,241,621	120,525	0.68	2.49	58.46	11.14
1976 - 1979	628,312	14,388	383,609	5,143	1.64	2.80		

The increase of the value component of exports has been due to the increase in tobacco production. Tobacco and tobacco leaves together account for about 34 percent of exports by volume, but contributed about 87 percent to the value of agricultural exports from 1961 to 1999. Tobacco exports accounted for a third of all foreign currency earnings in 1999 (SADC, 2000). There has also been an increase in the production and export of horticultural products such as fresh flowers and citrus fruit. This indicates a shift toward allocative efficiency within the sector.

However, the increase in the value component of imports would indicate that the country is not increasing its reliance on virtual water by much. Low value goods are still produced and exported, while many higher value products are imported. The gains made by tobacco exports are partly offset by the continued reliance on cereal production. Zimbabwe is still a net exporter of cereals, with little sign of a decrease in the production of major cereal crops (Figure 17). This fits with its stated policy of achieving food self-sufficiency combined with the export of high value crops (Derman, 1999).

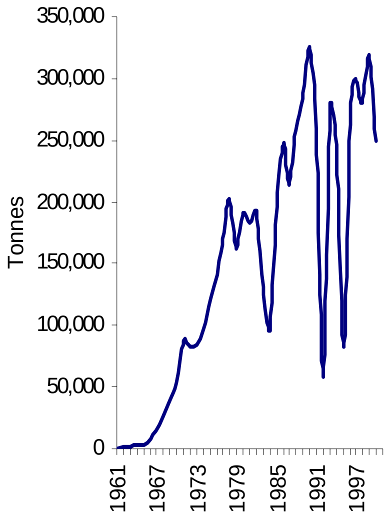


Figure 17: Zimbabwe Wheat Production (FAO)

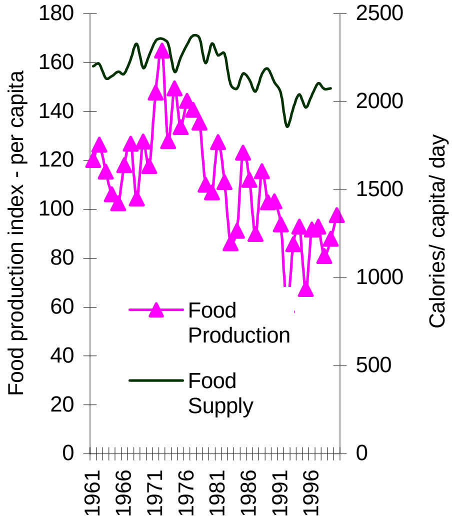


Figure 18: Zimbabwe Food Production & Supply (FAO)

Although agriculture contributes 20 percent to the GDP its water use efficiency is not very good as it consumes 79 percent of the water withdrawn (Appendix B). Industry contributes 25 percent to the GDP while using seven percent of the water.

There is little evidence of a planned decrease in the water used for agriculture, with farmers encouraged to build their own dams, although water licensing is being implemented. There are also plans for the increase of the area under irrigation. In 1995 it was estimated that 40 percent of the value of the nine principle crops was produced under irrigation (FAO, 1995). These crops include tobacco, wheat, cotton and sugar cane.

Figure 18 shows the drop in food production levels. During the period when economic sanctions were applied to the country there was a policy of national food self sufficiency (Turton, 1998). Since then, production has dropped by close to 50 percent. The drop in the level of calories per capita per day has been slower, with the lowest levels indicated in drought years. The prevalence of malnutrition is high at 37 percent, so is the food deficit at 340 calories per person per day.

2.6 Analysis

Botswana shows the highest level of reliance on virtual water imports in the region. Its agricultural sector uses the lowest proportion of the total water withdrawn. The quantity of imports is higher than local production, with most staple foods coming from outside the country. The irrigated area comprises a small percentage of the total arable area and is getting less (see Table 7). The area devoted to cereal production has decreased by over 40 percent in the past two decades.

Namibia has a high level of imports. Its production is also high, mainly devoted to the roots & tubers grown on a subsistence basis. The majority of its staple foods, mainly cereals, are imported. The only agricultural product with sizeable exports is meat, also accounting for much of the water consumed in the country. Although virtual water is relied upon in the provision of staple foods, there is still a relatively high level of water used to produce other low value crops. In some areas irrigation is provided as a form of development assistance by the state, increasing the water use. Although the portion of land under irrigation is still small, it has increased by fifty percent since 1980, as has the area devoted to cereal production

(Table 7). There is little evidence of demand management, with several new water storage and construction schemes either being built or planned (Turton, 1998).

Table 7: Agricultural Land Use (World Bank)

	Irrigated Land as % of Cropland		*Land Under Cereal Production Thousand hectares*	
	1980	**1997**	**1980**	**1999**
Botswana	0.5	0.3	153	87
Namibia	0.6	0.9	195	298
South Africa	8.4	8.5	6760	4742
Zimbabwe	3.1	3.5	1633	1784

South Africa is still a net exporter of agricultural products, but the gap between imports and exports is decreasing. It is a net importer of staple cereal crops. There is evidence of a shift within the agricultural sector toward favouring more water efficient crops. The area devoted to the production of cereals has dropped by about thirty percent since 1980 (Table 7). However, the agricultural sector is still a very large water user, with the size of the irrigated area remaining constant. This is likely to change over time, as the state has committed itself to implementing demand management (DWAF, 1998). If these goals are to be achieved there will be an increase in the import of staple foods. It is likely that the agricultural sector will continue to be a large employer of workers as farmers focus on the production of higher value crops for the export market. This is possible as there are parts of the country well suited to agriculture.

Zimbabwe shows relatively little sign of adopting a virtual water policy. Although it does produce high value crops such as tobacco, it also produces much of its staple foods. The area used for the production of cereals has increased moderately since 1980, as has the irrigated area (Table 7). It would also appear that there is not a long-term policy of decreasing demand for water. Of the four countries in the study, it is most in the position to carry on with a strong agricultural policy, due to its higher level of rainfall. Yet, if the population continues growing at a high rate it could find itself having to implement a demand management strategy.

In terms of food security, both Botswana and South Africa have experienced an increase in the per person calorie availability over the past twenty years. Namibia and Zimbabwe have shown decreases.

Yet, both Botswana and Namibia have high levels of malnutrition and intermediate food deficits (Figure 19a). Zimbabwe is in a worse situation having high levels of malnutrition as well as high levels of food deficits. South Africa is the most food secure, as it has low levels of malnutrition and a low food deficit. This is reflected in the levels of foreign food aid to each of the countries since 1970 (Figure 19b).

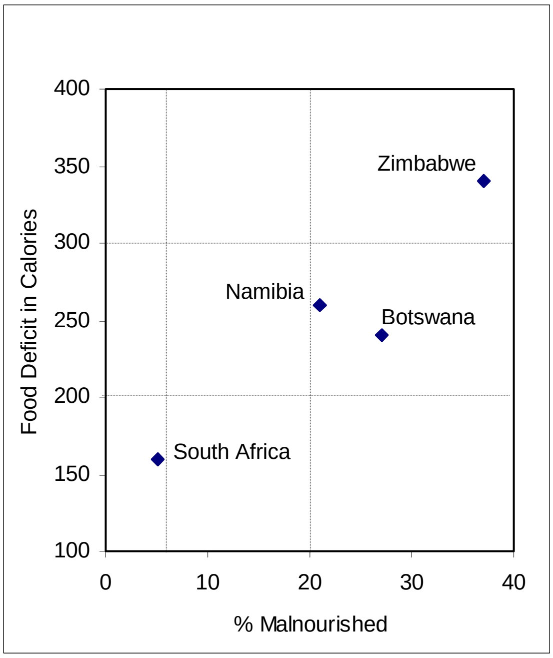


Figure 19a: Extent of malnutrition and depth of hunger (FAO)

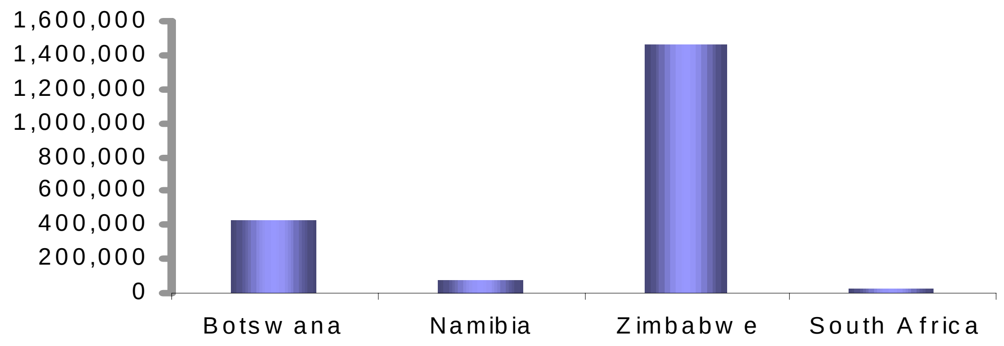


Figure 19b: Total Levels of Foreign Aid Received (FAO)

Botswana has been a consistent recipient of small quantities over the past thirty years. It has not received any in the past five years (See Appendix E). Zimbabwe has received most of its aid in the past decade, with much of it given during the drought of 1992 (FAO, 2001). The FAO's Global Information and Early Warning System (GIEWS) on food and agriculture predicts a serious food deficit in Zimbabwe for 2001 and 2002 (FAO, 2001b). The total agricultural production of the country is low, due to drought and disruption caused by land acquisition activities (FAO, 2001b). As the amount of tobacco exported has dropped, it is predicted that there will be a shortfall in the level of commercial grain imports, due to a lack of foreign exchange. The FAO predicts that as much as half a million tonnes of maize will be required as aid. The other three countries are predicted to have reduced production levels, though none will require food aid.

Generally, Botswana and South Africa appear to be in the most favourable positions, with relatively low levels of malnutrition and a steady increase in calories available per person. This is in a large pert due to their higher levels of social adaptive capacity, allowing them to find alternatives in the face of adversity. They also appear to be relying increasingly on virtual water imports. Namibia is also moving toward greater reliance on imports. The lower levels of food availability are due to lower levels of social adaptive capacity. This may be a result of not having had the same level of political cohesiveness as Botswana in the past three decades. Zimbabwe, the country the least reliant on virtual water supplies for food security, would appear to be in the most negative situation. In theory, the levels of social adaptive capacity should be at least as high as in Botswana and Namibia. Due to political and economic disruption, it has not been able to respond to changes and fluctuations in climatic and environmental conditions.

Chapter 3: Trade Barriers – The Winners and the Losers

> *"It is notable that no developing country has 'developed' – has become rapidly growing and increased its share of world trade – through commodity exports"*
>
> *(ODI Special Report on World Commodity Prices, 2001)*

3.1 The Present Situation

Rates of agricultural assistance in the developed countries are still high (see Figure 2 in Introduction), with the aggregate level of support amongst the OECD countries in 2000 at 66 percent (ABARE, 2000). For every dollar a farmer in Europe spends on producing wheat, the EU provides another dollar and a half (Appendix A). The increase since 1997 is due to the low world prices of agricultural commodities, largely linked to the period after the Asian financial crises. The three main ways of providing agricultural assistance are:

- Restricting imports, either by taxation or by limiting quotas.
- The provision of subsidised goods and services by the government to the farmers.
- The payments of export subsidies.

As world market prices decline, levels of assistance to farmers in developed countries are increased. This has the effect of lowering imports in these countries, resulting in a further decrease in world prices. In this way, the farmers and consumers in the developed countries are insulated from the market. Few developing countries can provide such long-term insulation from the market, with the four countries in this study all providing rates of assistance to farmers less than ten percent of agricultural production (ABARE, 2000). The result is that developing countries experience reduced access to developed countries' markets, as well as increased competition on international markets, due to competing against subsidised products.

Net importers of agricultural products, such as Botswana and Namibia, derive some benefit from the situation. Consumers in these countries pay less for their food due to the indirect subsidies from the developed countries. The main disadvantage is that local production is not stimulated, keeping the country dependent on food imports, whilst not able to generate revenue from other agricultural exports.

The Uruguay round Agreement on Agriculture sought to reduce the level of protection extended to most agricultural products. A, very, brief description of the alterations to tariffs will be given, as the documents covering the agreement run into “hundreds of thousands of pages” (Devereux & Maxwell, 2001). Countries have to reduce the level of subsidies and tariffs over a set period. Developed countries must reduce tariffs by an average of 36 percent over six years from 1995. Middle-income developing countries have to cut theirs by 24 percent over ten years, whilst least developed countries do not need to make any cuts. The average reductions are not trade weighted. Therefore, a country can cut the tariff on a marginally imported item by 57 percent and the tariff on a more important product by 15 percent to achieve an average of 36 percent. The baseline period against which tariffs are calculated is 1986 to 1988, a time when world commodity prices were very low, and tariffs correspondingly high (see Figure 2). Additionally there is a ‘special safeguard clause’, an amount added to the tariff whenever import prices fall more than ten percent than what they were for the base period. There are also provisions for providing minimum access to markets and reducing the level of domestic subsidies to the agricultural sector. Due to a variety of clauses and special conditions, these are of very limited real effect.

For socio-political reasons, the EU has a strong commitment to supporting its agricultural sector. It is also the largest trading partner of all four of the countries in the study, thus exerting a large effect on their terms of trade. “Future negotiations *may* agree more substantial cuts, but it is reasonable to expect Europe’s heartland agricultural products to remain heavily protected well into the twenty-first century” (Devereux & Maxwell, 2001).

3.2 Implications for Food Security

All four countries already have favourable trading agreements with the EU, such as the Lome convention and other bilateral trade agreements. These agreements ensure improved market access and a reduction in tariffs on a variety of agricultural products. Most of these would fall away if full-scale trade liberalisation were to be implemented. The effects of agreements such as Lome have been mixed. Although originally intended to stimulate the economies of member countries into greater diversification, this has rarely been the case. Most of the countries are still very dependent on just a few primary commodities for their export earnings, making them highly vulnerable to price shocks. In a study by the ODI, on the effects of commodity prices on developing countries, it was found that diversification occurred faster in the relatively labour abundant countries than in the commodity abundant ones. The conclusion was drawn that the higher the initial endowment in natural resources/commodities, the more difficult it is to move away from them, with small countries diversifying faster than larger ones (Hewitt & Page, 2001). Lome also failed to increase the ACP countries' share in imports to the EU, seeing a drop from six to three percent over 25 years.

A general liberalisation of trade barriers on all products should have more success in stimulating the economies of developing nations to diversify. No longer will, potentially, inefficient industries be given preferences. Efficiently manufactured goods will enjoy greater access to the markets of the developed countries as well as higher international prices. This will enable countries to earn more from a variety of exported products and to import the products it needs.

In a study by the Australian agricultural research group – ABARE – a General Trade and Environment Model (GTEM) was used to gauge the effects of a 50 percent reduction of agricultural support levels. It includes effects such as changes in productive efficiency and inter-sectoral capital shifts resulting from a drop in tariffs. If implemented by 2010 the model predicts a 0.14 percent increase in real world GDP relative to the reference case of no tariff reductions. This translates to benefits of US$ 40 billion for developed countries and US$ 14 billion to developing countries (ABARE, 2000). Gains in developed countries would stem mainly from cost savings from cutting down on agricultural subsidies. In developing countries, the largest gains would be by countries currently producing and exporting products that receive high levels of protection in developed countries. Africa stands to gain a 0.08 percent increase in GDP. Unfortunately, the data are not dis-agregated to a country level within Africa. Presumably, South Africa and Zimbabwe would benefit considerably due to their current production of export products.

This increase would go together with an increase in the price of many staple foods. The GTEM predicts a five percent increase in the value of wheat imports to Africa.

It is impossible to know with any accuracy the exact implications of future changes in trade liberalisation, but it would seem that no major increase in the price of cereals is predicted. The increases that do take place can be compensated for by the increases in revenue from exported products. Even a very high increase of 50 percent, in real terms, would have a minimal effect on the returns to water of wheat production. It would increase from the current nine cents per cubic metre to fourteen cents per cubic metre. Assuming no increase in prices of other products, such as oranges or aluminium, wheat would still give the lowest returns to water. This would still give the temperate zones a comparative advantage in the production of wheat, due to their favourable climatic conditions.

It would appear that the most likely scenario for the next decade would be very little change in the effective levels of agricultural protection in developed countries. The farming lobbies of the United States and the EU have the political power to maintain their position. If trade liberalisation takes place on a large scale, it is unlikely that the countries in the study will be worse off. The improvement in the level of exports to developed countries will more than offset any potential increases in cereal prices.

The two major potential importers of grain are India and china, together accounting for some 40 percent of the world's population. It is conceivable that if they started importing food on a large scale, international prices would be increase. India has been a consistent net exporter of food for the past decade and China produces

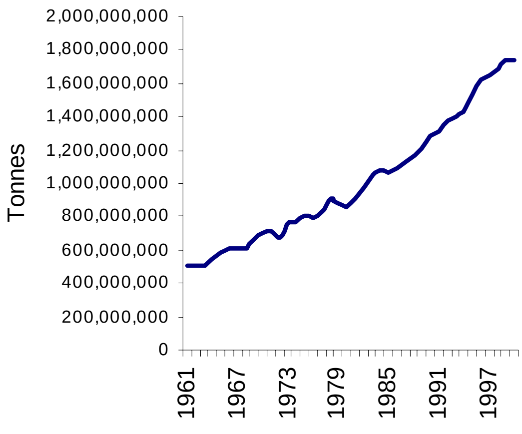


Figure 20: China & India combined food production (FAO)

enough locally to satisfy demand. There is no indication of them cutting back on production (see Figure 20). It is likely that, for the near future, the international terms of trade will remain little changed.

Chapter 4: The Heckscher-Ohlin Model Applied to Virtual Water

4.1 Factor endowments and trade

The concept of virtual water is, intuitively, easily understandable. It allows countries to act in an economically rational manner while keeping local social tumult to a minimum. It is a practical concept, rather than a theoretical model. In an attempt to test its theoretical economic validity, the empirical evidence for virtual water will be tested in the context of the factor-proportions model. This is also commonly referred to as the Heckscher-Ohlin (H-O) model, after the two Swedish economists who developed it. There have been various variations and additions to it over the years, by a number of economists, but the basic hypothesis of the model has remained the same. It proposes that international trade is driven largely by differences in countries' resources (Krugman & Obstfield, 1995).

The Ricardian theory of comparative advantage states that a country will export (import) that commodity in which its comparative factor productivity is higher (lower) (Bhagwati, 1998). This is useful in predicting why trade begins. The H-O model attempts to predict the composition of that trade and states that a country will export (import) that commodity which uses its abundant (scarce) factor intensively. Thus, a country with much labour and little capital will find that labour is comparatively cheap and capital comparatively expensive. It will then export goods that are labour-intensive and import capital-intensive goods. In terms of virtual water, this can be applied to the international grain trade. As grains are water intensive, countries with large (small) water supplies will export (import) grain.

The basic model makes the following assumptions:

- Factors of production are mobile within countries, but are immobile between countries.
- Consumer tastes in the various countries are the same.

- Technology used in the production of the product is the same for the different countries.
- Countries do not specialise completely; they produce a range of products. They may be net exporters or net importers of the products.
- International trade is assumed to be ‘frictionless’, in other words there are no transportation costs, import duties or other restrictions.

It is obvious that many of the above assumptions due not hold true in the context of the international grain trade. International trade is far from ‘frictionless’, with barriers and transportation costs playing a large role. There are also some technological differences between grain producers in various countries. However, one of the assumptions more applicable to the trade in grains, than to other products and factors, is that the factors of production are not traded between countries. The intensively used factor is water, probably one of the least traded goods at an international level. The mobility of factors such as labour and capital is relatively higher.

The textbook on international trade theory by Krugman & Obstfield (1995) gives a good summary of the way the model works. Two countries, Home and foreign have different resource endowments. Home is labour abundant, relative to its land supplies, and Foreign is land abundant, relative to its labour supplies. This implies that the price of labour is lower than the price of land in Home, and the corollary in Foreign. The production of cloth is considered labour abundant and therefore Home’s production possibility frontier is shifted more in the direction of cloth production than is Foreign's (see Figure 21). Essentially, for any price of cloth, Home (line RSH) will produce a larger quantity than what Foreign (RSF) will. The relative demand line, RD, is assumed the same for both countries. In the absence of trade

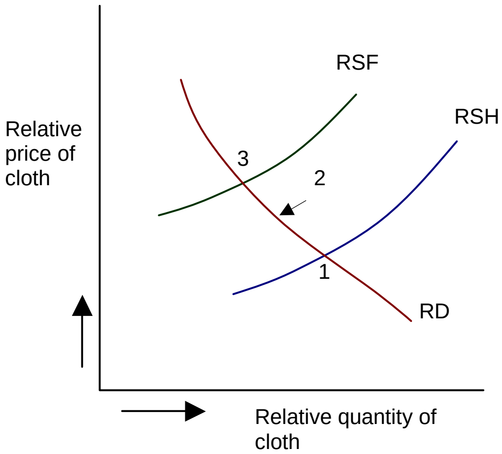


Figure 21: Trade leads to a convergence of relative prices (Krugman & Obstfield 1995)

the equilibrium point for Home would be **1** and the equilibrium point for foreign would be **3**. This means that the relative price of cloth would be lower in Home than in Foreign.

As trade proceeds the relative prices of cloth in the two countries converge, Home's increasing and Foreign's decreasing. A world price can be established at point **2**. This increase in the relative price of cloth for Home causes it to increase exports. The decrease in the relative price of cloth in Foreign causes it to increase imports.

The effect of this relative convergence in the prices of goods implies a convergence in the relative prices of the factors of production. This is known as the equalisation of factor prices and comes about because of the trade in goods. Indirectly they are trading in the factors of production by trading goods. Home lets foreign use some of its abundant labour, not by selling labour directly but by trading goods produced with a high ratio of labour to land for goods produced with a low ratio of labour to land. In other words, there is more labour embodied in Home's exports than its imports.

In terms of virtual water, this is equivalent to Egypt importing wheat from, water abundant, Canada. Canada imports clothing from Egypt, which is labour-abundant. The result is that Canada receives a higher price for its wheat, relative to the local price. Egypt can receive a higher price for its clothing, while paying a lower price for its wheat. The value of the scarce resource in each country is reduced as trade progresses. As value is an indication of scarcity, this implies a drop in the scarcity of water in Egypt, avoiding water shortages.

4.2 Method of Analysis

There have been a variety of empirical tests of the H-O theorem, producing mixed results. As early as 1953, the Leontief paradox was observed. The study found that US exports were less capital intensive than US imports in the post Second World War years, which was not the reality (Grossman & Rogoff, 1995). Other studies have shown better results, with trade between developing and developed countries fitting the model the best. The problem is summed up in the study by Bowen, Leamer & Sviekauskas, 1987:

The data suggest errors in measurement in both trade and national factor supplies, and favour the hypothesis of neutral technological differences across countries. However, the form of the technological differences favoured by the data involves a number of implausible estimates, including some in which factors yield strictly negative outputs. Thus, … The H-O model does poorly, but we do not have anything that does better.

The model is not intended to provide a true or false type of result, but rather to assist in understanding the complexity of a real life situation. The strength or weakness of a model therefore does not lie in its hypothesis, but rather in the assumptions that have to be made to validate it. In these terms a model can, at best, verify whether these assumptions can be made or not.

The Bowen, Leamer & Sviekauskas study of 1987 was based on the premise that trading goods is an indirect way of trading in factors. If the factors of production embodied in a country's imports and exports were to be calculated, it should be found that the country is a net exporter of the factors in which it is abundantly endowed. Their study looked at 27 countries and 12 factors of production. For each factor, the portion of countries behaving in the way the model predicted was calculated. Some of the factors produced high predictive success rates, such as 70 percent for 'Production workers', 'Arable land' and 'Forest' (Krugman & Obstfield, 1995). Others, such as 'Managerial workers', at 22 percent, were less successful.

Applying this to water and grain in 63 countries, the first step is to determine the ratio of each country's endowment of water compared to the world supply. Then these ratios are compared to each country's share of world production. According to the theory, a country will export factors for which its factor share exceeds its production share and import factors for which it is less (Krugman & Obstfield, 1995).

For this study, each country's total annual freshwater runoff will be compared to world annual freshwater runoff. To ensure parity all figures are from the World Bank Atlas (2001). Figures on grain production and trade are from the FAO (2001) and represent a four-year average, from 1996 to 1999. This is to compensate for seasonal fluctuations. The 63 countries chosen represent about

89 percent of the world's available freshwater resources and 92 percent of the world's grain production. The countries chosen include the major grain exporting, importing and producing countries as well as the countries with the largest and smallest portion of world water supplies. The countries represent most of the different agro-climatic zones on the earth. The world's total freshwater resources is taken as 42 000 cubic kilometres (World Bank, 2001).

The theory predicts those countries whose share of world water resources is greater than their share of world grain production to be net exporters of grain. The number of countries out of the sample that conform to the theory will be calculated.

4.3 Results

The result of the analysis is shown in Table 8. The complete dataset is in Appendix F. Twenty-seven countries perform as the model would predict and form 43 percent of the sample. Of these 27, four are net grain exporters with a higher proportion of world water resources than world grain production. The other 23 are net grain importers, with low proportions of the world's water. The other 36 countries are either net grain importers or exporters, but not in accordance with the prediction of the model.

Of the four countries exporting grain as the model predicts, three have very high proportions of the world's water. The production levels are moderately high, enough to feed the local population and to export the remainder. The fourth, Sweden, has less water and relatively low levels of production. Due to its small population, it is relatively easy for it to export any excess.

The countries that import grain, in accordance with the model, are mainly large, dry countries, such as Mexico, Syria, Saudi Arabia and South Africa. The only two exceptions to this are Italy and Poland, who both have more water available.

Of the world's largest grain exporters, the USA, Australia, Argentina, Canada, France and Germany, only Canada responds as the model predicts. All the others have production shares larger than their water resource shares. Overall, the theory does not explain the reality well at all.

Table 8: Results of the H-O theorem applied to trade in grain between 63 countries

Country	Result	Country	Result
Afghanistan	1	Jordan	0
Algeria	0	Kazakhstan	1
Argentina	1	Kenya	0
Australia	1	Korea, Dem People's Rep	1
Austria	1	Korea, Republic of	0
Bangladesh	1	Lebanon	1
Belarus	0	Lesotho	1
Belgium-Luxembourg	1	Mexico	0
Botswana	1	Morocco	0
Brazil	1	Myanmar	2
Bulgaria	1	Namibia	1
Canada	2	Pakistan	0
Chile	1	Philippines	1
China	0	Poland	0
Colombia	1	Portugal	1
Czech Republic	1	Romania	1
Denmark	1	Russian Federation	1
Egypt	0	Saudi Arabia	0
Ethiopia	0	South Africa	0
France	1	Sudan	0
Germany	1	Sweden	2
Ghana	1	Syrian Arab Republic	0
Greece	0	Thailand	1
Hungary	1	Turkey	0
India	1	Ukraine	1
Indonesia	1	United Kingdom	1
Iran, Islamic Rep of	0	United States of America	1
Iraq	0	Venezuela, Boliv Rep of	1
Ireland	1	Viet Nam	2
Israel	0	Yemen	0
Italy	0	Zimbabwe	1
Japan	1		

0 : Importer as predicted
1 : Not behaving as predicted
2 : Exporter as predicted

4.4 Conclusion

The hypothesis of the H-O model is very similar to the concept of virtual water. Both speak of the embodied factors within traded goods. Both would view the world trade in grains as a trade in water, by proxy. Empirical evidence of countries responding to water shortages in a virtual water rational fashion abounds. In the Middle East region more virtual water is imported annually than the annual flow of the Nile (Allan, 1996). There is also much evidence of it in other parts of the world, such as Sub-Saharan Africa. The H-O theorem has, in several studies, performed reasonably satisfactorily. Why then the bad performance in unison with virtual water?

The answer has much to do with the assumptions that the model makes. Issues such as production technologies and consumer tastes being the same between countries are obviously problematic. Yet, it is unlikely that these would cause such skewing of the results. An assumption previously presumed to be valid is probably responsible for the poor performance of this application of the model. That is the assumption that ‘the factors of production are mobile within countries, but can not be moved between them'. The last part of this is valid, but the first part brings one back to the difficulty in assessing water scarcity in a country. Water availability per person in Botswana works out to be roughly the same as in France, yet the agricultural possibilities are very different. The higher rates of evapotranspiration and consequent lower volumes of soil water in Botswana make it unsuited to the production of cereals. In temperate regions, this water is treated as an ‘invisible’ input, as it is free. Yet, over sixty percent of the world’s staple food is grown from it (FAO, 1998). Soil water is not readily quantifiable or transportable and is not included in water availability data for countries. For an H-O analysis to have validity the factors must be directly comparable between countries. That is why, in the study by Bowen, Leamer & Sviekauskas, factors are split into specific categories. Instead of looking just at land, they look at ‘Pasture land’, ‘arable land’ and ‘forest’. Labour splits into a range of categories, including ‘Professional’, ‘Managerial’, ‘Clerical’ and ‘Sales’. Annual runoff, used in the World Bank figures, comprises surface flows and groundwater, all quantifiable. As this water is not responsible for most of the world’s food, it is wrong to use it as a factor in grain production.

A suggestion for a future study would be to define a factor of grain production called ‘moist soil’, soil that is suitable to the production of rainfed cereals. Each country’s relative area of this type of soil can then be used in the H-O model. There are no readily available worldwide data, to derive these figures; therefore, much research will need to be done in the field.

Conclusion

The goal of this study is to provide a greater understanding of the complex interaction between water, food and trade. This was done by first looking at the level of reliance on virtual water by the countries in the region. The theory of Social Adaptive Capacity predicts a movement away from a reliance purely on first order resources. As development progresses the social resources become increasingly important, especially once there is a shortage of the physical resources. The next set of objectives of the study was to study the concept of virtual water in relation to international trade, theory and practise.

The first part of the study showed that Botswana and South Africa rely the most on virtual water imports. This is as predicted by the theory of Social Adaptive Capacity (SAC), as they have higher levels of social resources. Although Botswana has a slightly lower HDI value than Namibia, its GDP is higher, therefore it can import more. As their water resources have become increasingly limited they have started using water where it will receive maximum returns. The success of their policy is borne out by the fact that they are also the two countries which are most food secure.

As the SAC theory predicts, the country with the lowest levels of social resources, Zimbabwe, is least able to find alternatives as physical scarcity threatens. Reliance on virtual water remains low and it is the only country in the study that is a net exporter of grains. Despite this, it is also the least food secure. It would appear that for the four countries studied there is a positive correlation between levels of SAC, reliance on virtual water and the state of food security.

On an international level the import of grains by arid developing countries is likely to continue. It seems unlikely that agricultural assistance levels and trade barriers will be reduced in the near future. If they were reduced the results would also appear to be mixed for the four countries, with some even showing an improvement in terms of trade. Virtual water imports are likely to remain a rational choice for the countries in the study.

The Heckscher-Ohlin model did not respond well in the study applied to grain and water. Yet, the reasons for this have more to do with the assumptions made in the model than with the hypothesis itself. The outcome illustrates just how important the ‘hidden’ soil water is in the production of the world’s grain. All the major world grain exporters and producers have large parts of land with good soil water availability. Freshwater reserves are a misleading guide to the agricultural production possibilities in a country. What crops are produced where is a factor of soil water and international grain prices. Any future study would have to attempt to quantify the levels of soil water for it to produce a useable outcome.

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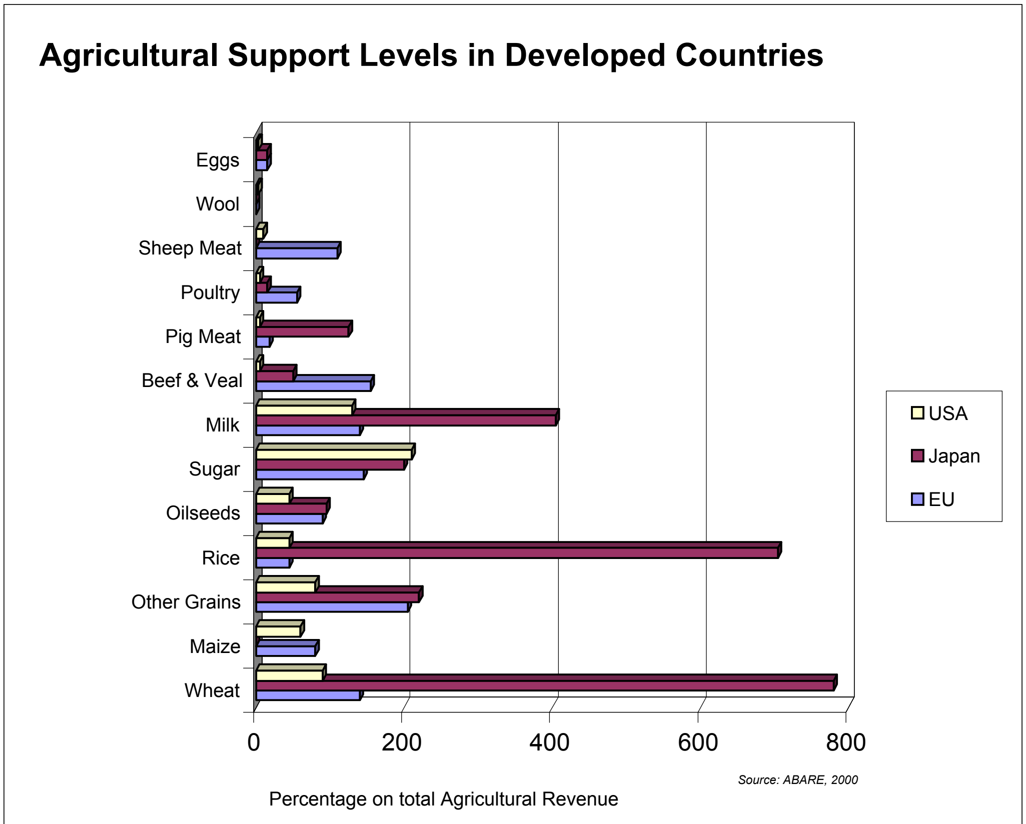
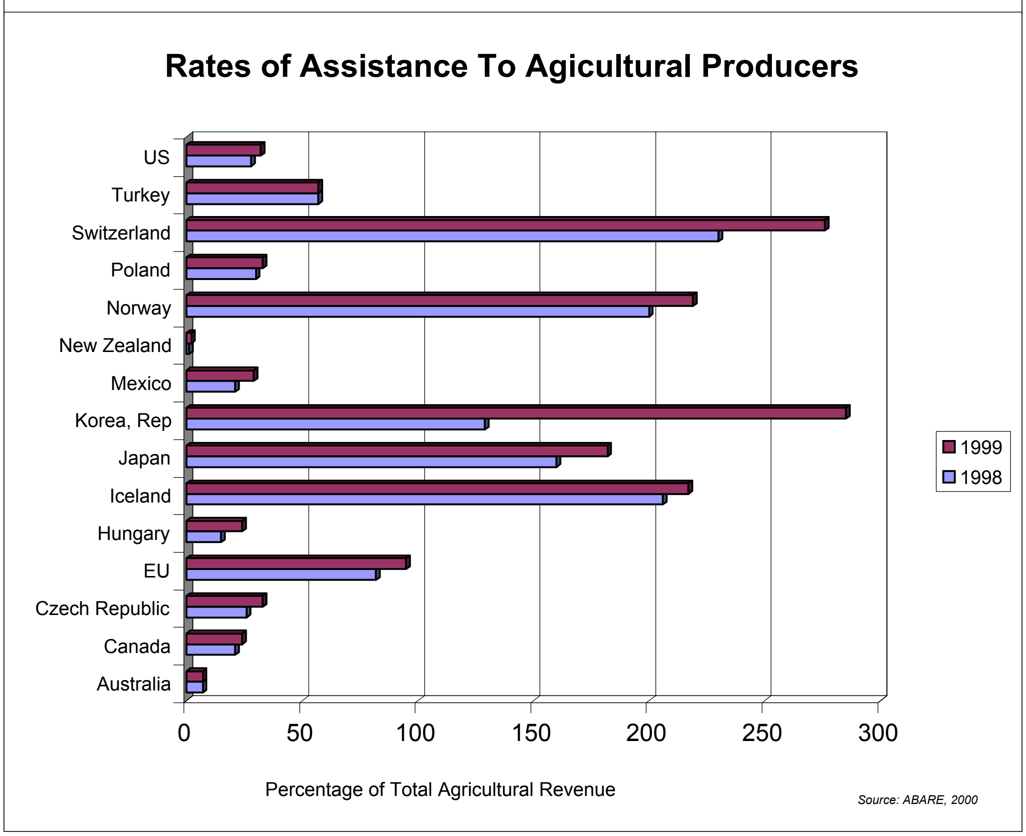
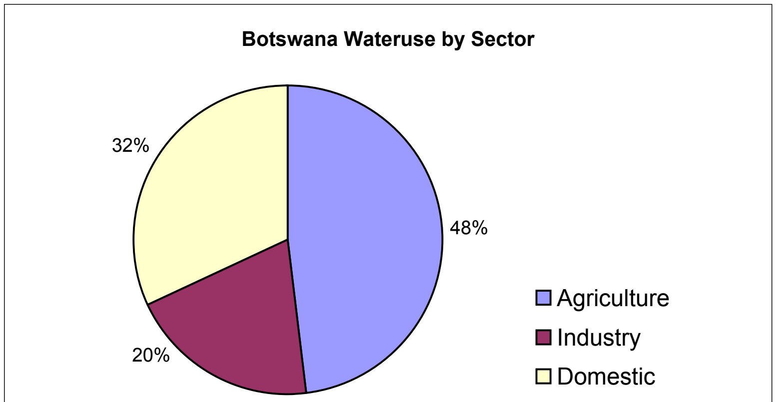
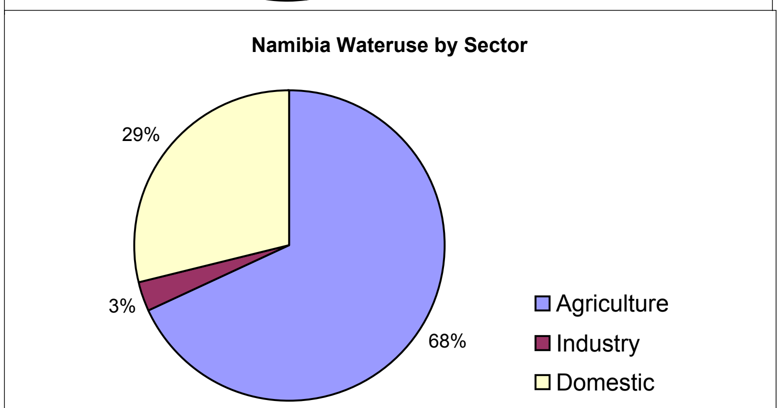
Appendix A: Levels of agricultural assistance

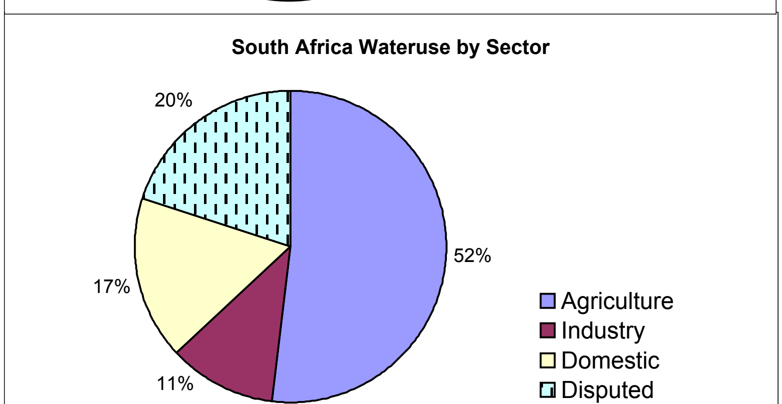


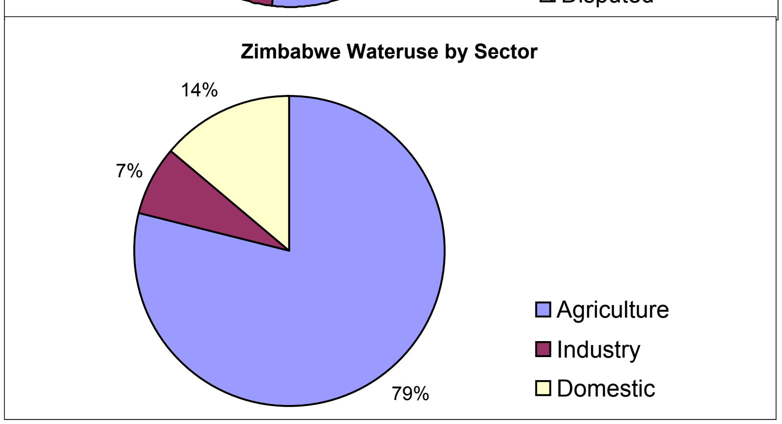


Appendix B: Sectoral wateruse









1 Human development index

HDI rank [a]	Life expectancy at birth (years) 1999	Adult literacy rate (% age 15 and above) 1999	Combined primary, secondary and tertiary gross enrolment ratio (%) [b] 1999	GDP per capita (PPP US$) 1999	Life expectancy index 1999	Education index 1999	GDP index 1999	Human development index (HDI) value 1999	GDP per capita (PPP US$) rank minus HDI rank [c]
High human development									
1 Norway	78.4	.. [d]	97	28,433	0.89	0.98	0.94	0.939	2
2 Australia	78.8	.. [d]	116 [e]	24,574	0.90	0.99	0.92	0.936	10
3 Canada	78.7	.. [d]	97	26,251	0.89	0.98	0.93	0.936	3
4 Sweden	79.6	.. [d]	101 [e]	22,636	0.91	0.99	0.90	0.936	13
5 Belgium	78.2	.. [d]	109 [e]	25,443	0.89	0.99	0.92	0.935	4
6 United States	76.8	.. [d]	95	31,872	0.86	0.98	0.96	0.934	-4
7 Iceland	79.1	.. [d]	89	27,835	0.90	0.96	0.94	0.932	-3
8 Netherlands	78.0	.. [d]	102 [e]	24,215	0.88	0.99	0.92	0.931	5
9 Japan	80.8	.. [d]	82	24,898	0.93	0.93	0.92	0.928	2
10 Finland	77.4	.. [d]	103 [e]	23,096	0.87	0.99	0.91	0.925	5
11 Switzerland	78.8	.. [d]	84	27,171	0.90	0.94	0.94	0.924	-6
12 Luxembourg	77.2	.. [d]	73 [f]	42,769 [g]	0.87	0.90	1.00	0.924	-11
13 France	78.4	.. [d]	94	22,897	0.89	0.97	0.91	0.924	3
14 United Kingdom	77.5	.. [d]	106 [e]	22,093	0.87	0.99	0.90	0.923	5
15 Denmark	76.1	.. [d]	97	25,869	0.85	0.98	0.93	0.921	-7
16 Austria	77.9	.. [d]	90	25,089	0.88	0.96	0.92	0.921	-6
17 Germany	77.6	.. [d]	94	23,742	0.88	0.97	0.91	0.921	-3
18 Ireland	76.4	.. [d]	91	25,918	0.86	0.96	0.93	0.916	-11
19 New Zealand	77.4	.. [d]	99	19,104	0.87	0.99	0.88	0.913	3
20 Italy	78.4	98.4	84	22,172	0.89	0.94	0.90	0.909	-2
21 Spain	78.3	97.6	95	18,079	0.89	0.97	0.87	0.908	6
22 Israel	78.6	95.8	83	18,440	0.89	0.91	0.87	0.893	3
23 Greece	78.1	97.1	81	15,414	0.89	0.92	0.84	0.881	10
24 Hong Kong, China (SAR)	79.4	93.3	63	22,090	0.91	0.83	0.90	0.880	-4
25 Cyprus	77.9	96.9	69 [h]	19,006	0.88	0.87	0.88	0.877	-2
26 Singapore	77.4	92.1	75	20,767	0.87	0.87	0.89	0.876	-5
27 Korea, Rep. of	74.7	97.6	90	15,712	0.83	0.95	0.84	0.875	5
28 Portugal	75.5	91.9	96	16,064	0.84	0.93	0.85	0.874	2
29 Slovenia	75.3	99.6 [d]	83	15,977	0.84	0.94	0.85	0.874	2
30 Malta	77.9	91.8	80	15,189 [i]	0.88	0.88	0.84	0.866	5
31 Barbados	76.6	97.0 [j, k]	77	14,353	0.86	0.90	0.83	0.864	5
32 Brunei Darussalam	75.7	91.0	76	17,868 [j, l]	0.85	0.86	0.87	0.857	-4
33 Czech Republic	74.7	.. [d]	70	13,018	0.83	0.89	0.81	0.844	6
34 Argentina	73.2	96.7	83	12,277	0.80	0.92	0.80	0.842	6
35 Slovakia	73.1	.. [d]	76	10,591	0.80	0.91	0.78	0.831	8
36 Hungary	71.1	99.3 [d]	81	11,430	0.77	0.93	0.79	0.829	5
37 Uruguay	74.2	97.7	79	8,879	0.82	0.92	0.75	0.828	9
38 Poland	73.1	99.7 [d]	84	8,450	0.80	0.94	0.74	0.828	11
39 Chile	75.2	95.6	78	8,652	0.84	0.90	0.74	0.825	9
40 Bahrain	73.1	87.1	80	13,688 [i]	0.80	0.85	0.82	0.824	-3
41 Costa Rica	76.2	95.5	67	8,860	0.85	0.86	0.75	0.821	6
42 Bahamas	69.2	95.7	74	15,258 [i]	0.74	0.89	0.84	0.820	-8
43 Kuwait	76.0	81.9	59	17,289 [i]	0.85	0.74	0.86	0.818	-14
44 Estonia	70.3	98.0 [j, k]	86	8,355	0.76	0.94	0.74	0.812	6
45 United Arab Emirates	74.8	75.1	68	18,162 [i]	0.83	0.73	0.87	0.809	-19
46 Croatia	73.6	98.2	68	7,387	0.81	0.88	0.72	0.803	10
47 Lithuania	71.8	99.5 [d]	80	6,656	0.78	0.93	0.70	0.803	13
48 Qatar	69.3	80.8	75	18,789 [j, l]	0.74	0.79	0.87	0.801	-24
Medium human development									
49 Trinidad and Tobago	74.1	93.5	65	8,176	0.82	0.84	0.74	0.798	4
50 Latvia	70.1	99.8 [d]	82	6,264	0.75	0.93	0.69	0.791	12

1 Human development index

HDI rank [a]		Life expectancy at birth (years) 1999	Adult literacy rate (% age 15 and above) 1999	Combined primary, secondary and tertiary gross enrolment ratio (%) [b] 1999	GDP per capita (PPP US$) 1999	Life expectancy index 1999	Education index 1999	GDP index 1999	Human development index (HDI) value 1999	GDP per capita (PPP US$) rank minus HDI rank [c]
51	Mexico	72.4	91.1	71	8,297	0.79	0.84	0.74	0.790	0
52	Panama	73.9	91.7	74	5,875	0.81	0.86	0.68	0.784	15
53	Belarus	68.5	99.5 [d]	77	6,876	0.73	0.92	0.71	0.782	5
54	Belize	73.8	93.1	73	4,959	0.81	0.86	0.65	0.776	21
55	Russian Federation	66.1	99.5 [d]	78	7,473	0.69	0.92	0.72	0.775	0
56	Malaysia	72.2	87.0	66	8,209	0.79	0.80	0.74	0.774	-4
57	Bulgaria	70.8	98.3	72	5,071	0.76	0.90	0.66	0.772	16
58	Romania	69.8	98.0	69	6,041	0.75	0.88	0.68	0.772	6
59	Libyan Arab Jamahiriya	70.3	79.1	92	7,570 [j, l]	0.75	0.83	0.72	0.770	-5
60	Macedonia, TFYR	73.0	94.0 [j, k]	70	4,651	0.80	0.86	0.64	0.766	20
61	Venezuela	72.7	92.3	65	5,495	0.79	0.83	0.67	0.765	10
62	Colombia	70.9	91.5	73	5,749	0.76	0.85	0.68	0.765	6
63	Mauritius	71.1	84.2	63	9,107	0.77	0.77	0.75	0.765	-19
64	Suriname	70.4	93.0 [j, k]	83	4,178 [i]	0.76	0.89	0.62	0.758	23
65	Lebanon	72.9	85.6	78	4,705 [i]	0.80	0.83	0.64	0.758	13
66	Thailand	69.9	95.3	60	6,132	0.75	0.84	0.69	0.757	-3
67	Fiji	68.8	92.6	84	4,799	0.73	0.90	0.65	0.757	10
68	Saudi Arabia	71.3	76.1	61	10,815	0.77	0.71	0.78	0.754	-26
69	Brazil	67.5	84.9	80	7,037	0.71	0.83	0.71	0.750	-12
70	Philippines	69.0	95.1	82	3,805	0.73	0.91	0.61	0.749	21
71	Oman	70.8	70.3	58	13,356 [j, l]	0.76	0.66	0.82	0.747	-33
72	Armenia	72.7	98.3	80	2,215 [i]	0.80	0.92	0.52	0.745	44
73	Peru	68.5	89.6	80	4,622	0.72	0.86	0.64	0.743	8
74	Ukraine	68.1	99.6 [d]	77	3,458	0.72	0.92	0.59	0.742	22
75	Kazakhstan	64.4	99.0 [j, k]	77	4,951	0.66	0.92	0.65	0.742	1
76	Georgia	73.0	99.6 [d, j, k]	70	2,431	0.80	0.89	0.53	0.742	32
77	Maldives	66.1	96.2	77	4,423 [i]	0.68	0.90	0.63	0.739	7
78	Jamaica	75.1	86.4	62	3,561	0.84	0.78	0.60	0.738	17
79	Azerbaijan	71.3	97.0 [j, k]	71	2,850	0.77	0.88	0.56	0.738	27
80	Paraguay	69.9	93.0	64	4,384	0.75	0.83	0.63	0.738	5
81	Sri Lanka	71.9	91.4	70	3,279	0.78	0.84	0.58	0.735	19
82	Turkey	69.5	84.6	62	6,380	0.74	0.77	0.69	0.735	-21
83	Turkmenistan	65.9	98.0 [j, k]	81	3,347	0.68	0.92	0.59	0.730	16
84	Ecuador	69.8	91.0	77	2,994	0.75	0.86	0.57	0.726	19
85	Albania	73.0	84.0	71	3,189	0.80	0.80	0.58	0.725	16
86	Dominican Republic	67.2	83.2	72	5,507	0.70	0.79	0.67	0.722	-16
87	China	70.2	83.5	73	3,617	0.75	0.80	0.60	0.718	7
88	Jordan	70.1	89.2	55	3,955	0.75	0.78	0.61	0.714	2
89	Tunisia	69.9	69.9	74	5,957	0.75	0.71	0.68	0.714	-23
90	Iran, Islamic Rep. of	68.5	75.7	73	5,531	0.73	0.75	0.67	0.714	-21
91	Cape Verde	69.4	73.6	77	4,490	0.74	0.75	0.63	0.708	-9
92	Kyrgyzstan	67.4	97.0 [j, k]	68	2,573	0.71	0.87	0.54	0.707	15
93	Guyana	63.3	98.4	66	3,640	0.64	0.87	0.60	0.704	0
94	South Africa	53.9	84.9	93	8,908	0.48	0.87	0.75	0.702	-49
95	El Salvador	69.5	78.3	63	4,344	0.74	0.73	0.63	0.701	-9
96	Samoa (Western)	68.9	80.2	65	4,047	0.73	0.75	0.62	0.701	-8
97	Syrian Arab Republic	70.9	73.6	63	4,454	0.76	0.70	0.63	0.700	-14
98	Moldova, Rep. of	66.6	98.7	72	2,037	0.69	0.90	0.50	0.699	19
99	Uzbekistan	68.7	88.5	76	2,251	0.73	0.84	0.52	0.698	15
100	Algeria	69.3	66.6	72	5,063	0.74	0.69	0.66	0.693	-26

1 Human development index

HDI rank [a]		Life expectancy at birth (years) 1999	Adult literacy rate (% age 15 and above) 1999	Combined primary, secondary and tertiary gross enrolment ratio (%) [b] 1999	GDP per capita (PPP US$) 1999	Life expectancy index 1999	Education index 1999	GDP index 1999	Human development index (HDI) value 1999	GDP per capita (PPP US$) rank minus HDI rank [c]
101	Viet Nam	67.8	93.1	67	1,860	0.71	0.84	0.49	0.682	19
102	Indonesia	65.8	86.3	65	2,857	0.68	0.79	0.56	0.677	3
103	Tajikistan	67.4	99.1 [d]	67	1,031 [j, l]	0.71	0.88	0.39	0.660	36
104	Bolivia	62.0	85.0	70	2,355	0.62	0.80	0.53	0.648	7
105	Egypt	66.9	54.6	76	3,420	0.70	0.62	0.59	0.635	-8
106	Nicaragua	68.1	68.2	63	2,279	0.72	0.66	0.52	0.635	7
107	Honduras	65.7	74.0	61	2,340	0.68	0.70	0.53	0.634	5
108	Guatemala	64.5	68.1	49	3,674	0.66	0.62	0.60	0.626	-16
109	Gabon	52.6	63.0 [j, k]	86	6,024	0.46	0.71	0.68	0.617	-44
110	Equatorial Guinea	50.6	82.2	64	4,676	0.43	0.76	0.64	0.610	-31
111	Namibia	44.9	81.4	78	5,468	0.33	0.80	0.67	0.601	-39
112	Morocco	67.2	48.0	52	3,419	0.70	0.49	0.59	0.596	-14
113	Swaziland	47.0	78.9	72	3,987	0.37	0.77	0.62	0.583	-24
114	Botswana	41.9	76.4	70	6,872	0.28	0.74	0.71	0.577	-55
115	India	62.9	56.5	56	2,248	0.63	0.56	0.52	0.571	0
116	Mongolia	62.5	62.3	58	1,711	0.62	0.61	0.47	0.569	7
117	Zimbabwe	42.9	88.0	65	2,876	0.30	0.80	0.56	0.554	-13
118	Myanmar	56.0	84.4	55	1,027 [j, l]	0.52	0.75	0.39	0.551	22
119	Ghana	56.6	70.3	42	1,881	0.53	0.61	0.49	0.542	0
120	Lesotho	47.9	82.9	61	1,854	0.38	0.75	0.49	0.541	1
121	Cambodia	56.4	68.2 [m]	62	1,361	0.52	0.66	0.44	0.541	13
122	Papua New Guinea	56.2	63.9	39	2,367	0.52	0.55	0.53	0.534	-12
123	Kenya	51.3	81.5	51	1,022	0.44	0.71	0.39	0.514	18
124	Comoros	59.4	59.2	36	1,429	0.57	0.51	0.44	0.510	7
125	Cameroon	50.0	74.8	43	1,573	0.42	0.64	0.46	0.506	2
126	Congo	51.1	79.5	63	727	0.44	0.74	0.33	0.502	29
Low human development										
127	Pakistan	59.6	45.0	40	1,834	0.58	0.43	0.49	0.498	-5
128	Togo	51.6	56.3	62	1,410	0.44	0.58	0.44	0.489	5
129	Nepal	58.1	40.4	60	1,237	0.55	0.47	0.42	0.480	7
130	Bhutan	61.5	42.0 [j, k]	33 [n]	1,341	0.61	0.39	0.43	0.477	5
131	Lao People's Dem. Rep.	53.1	47.3	58	1,471	0.47	0.51	0.45	0.476	-2
132	Bangladesh	58.9	40.8	37	1,483	0.57	0.39	0.45	0.470	-4
133	Yemen	60.1	45.2	51	806	0.59	0.47	0.35	0.468	16
134	Haiti	52.4	48.8	52	1,464	0.46	0.50	0.45	0.467	-4
135	Madagascar	52.2	65.7	44	799	0.45	0.59	0.35	0.462	16
136	Nigeria	51.5	62.6	45	853	0.44	0.57	0.36	0.455	11
137	Djibouti	44.0	63.4	22	2,377 [j, l]	0.32	0.50	0.53	0.447	-28
138	Sudan	55.6	56.9	34	664 [j, l]	0.51	0.49	0.32	0.439	19
139	Mauritania	51.1	41.6	41	1,609	0.43	0.41	0.46	0.437	-14
140	Tanzania, U. Rep. of	51.1	74.7	32	501	0.44	0.61	0.27	0.436	21
141	Uganda	43.2	66.1	45	1,167	0.30	0.59	0.41	0.435	-4
142	Congo, Dem. Rep. of the	51.0	60.3	32	801 [i]	0.43	0.51	0.35	0.429	8
143	Zambia	41.0	77.2	49	756	0.27	0.68	0.34	0.427	9
144	Côte d'Ivoire	47.8	45.7	38	1,654	0.38	0.43	0.47	0.426	-20
145	Senegal	52.9	36.4	36	1,419	0.47	0.36	0.44	0.423	-13
146	Angola	45.0	42.0 [j, k]	23	3,179	0.33	0.36	0.58	0.422	-44
147	Benin	53.6	39.0	45	933	0.48	0.41	0.37	0.420	-4
148	Eritrea	51.8	52.7	26	880	0.45	0.44	0.36	0.416	-3
149	Gambia	45.9	35.7	45	1,580	0.35	0.39	0.46	0.398	-23
150	Guinea	47.1	35.0 [j, k]	28	1,934	0.37	0.33	0.49	0.397	-32

1 Human development index

HDI rank [a]	Life expectancy at birth (years) 1999	Adult literacy rate (% age 15 and above) 1999	Combined primary, secondary and tertiary gross enrolment ratio (%) [b] 1999	GDP per capita (PPP US$) 1999	Life expectancy index 1999	Education index 1999	GDP index 1999	Human development index (HDI) value 1999	GDP per capita (PPP US$) rank minus HDI rank [c]
151 Malawi	40.3	59.2	73	586	0.26	0.64	0.30	0.397	8
152 Rwanda	39.9	65.8	40	885	0.25	0.57	0.36	0.395	-8
153 Mali	51.2	39.8	28	753	0.44	0.36	0.34	0.378	0
154 Central African Republic	44.3	45.4	24	1,166	0.32	0.38	0.41	0.372	-16
155 Chad	45.5	41.0	31	850	0.34	0.38	0.36	0.359	-7
156 Guinea-Bissau	44.5	37.7	37	678	0.33	0.37	0.32	0.339	0
157 Mozambique	39.8	43.2	23	861	0.25	0.36	0.36	0.323	-11
158 Ethiopia	44.1	37.4	27	628	0.32	0.34	0.31	0.321	0
159 Burkina Faso	46.1	23.0	23	965	0.35	0.23	0.38	0.320	-17
160 Burundi	40.6	46.9	19	578	0.26	0.37	0.29	0.309	0
161 Niger	44.8	15.3	16	753	0.33	0.15	0.34	0.274	-7
162 Sierra Leone	38.3	32.0 [j, k]	27	448	0.22	0.30	0.25	0.258	0
Developing countries	64.5	72.9	61	3,530	0.66	0.69	0.59	0.647	–
Least developed countries	51.7	51.6	38	1,170	0.45	0.47	0.41	0.442	–
Arab States	66.4	61.3	63	4,550	0.69	0.62	0.64	0.648	–
East Asia and the Pacific	69.2	85.3	71	3,950	0.74	0.81	0.61	0.719	–
Latin America and the Caribbean	69.6	87.8	74	6,880	0.74	0.83	0.71	0.760	–
South Asia	62.5	55.1	53	2,280	0.63	0.54	0.52	0.564	–
Sub-Saharan Africa	48.8	59.6	42	1,640	0.40	0.54	0.47	0.467	–
Eastern Europe and the CIS	68.5	98.6	77	6,290	0.73	0.91	0.69	0.777	–
OECD	76.6	.. [o]	87	22,020	0.86	0.94	0.90	0.900 [o]	–
High-income OECD	78.0	.. [o]	94	26,050	0.88	0.97	0.93	0.928 [o]	–
High human development	77.3	.. [o]	91	23,410	0.87	0.96	0.91	0.914 [o]	–
Medium human development	66.8	78.5	67	3,850	0.70	0.75	0.61	0.684	–
Low human development	52.6	48.9	38	1,200	0.46	0.45	0.41	0.442	–
High income	78.0	.. [o]	93	25,860	0.88	0.97	0.93	0.926 [o]	–
Middle income	69.5	85.7	74	5,310	0.74	0.82	0.66	0.740	–
Low income	59.4	61.8	51	1,910	0.57	0.58	0.49	0.549	–
World	66.7	.. [o]	65	6,980	0.70	0.74	0.71	0.716 [o]	–

Note: The human development index has been calculated for UN member countries with reliable data in each of its components, as well as for two non-members, Switzerland and Hong Kong, China (SAR). For data on the remaining 29 UN member countries see table 28.

a. The HDI rank is determined using HDI values to the fifth decimal point.
b. Preliminary UNESCO estimates, subject to further revision.
c. A positive figure indicates that the HDI rank is higher than the GDP per capita (PPP US$) rank, a negative the opposite.
d. For purposes of calculating the HDI a value of 99.0% was applied.
e. For purposes of calculating the HDI a value of 100% was applied.
f. The ratio is an underestimate, as many secondary and tertiary students pursue their studies in nearby countries.
g. For purposes of calculating the HDI a value of $40,000 (PPP US$) was applied.
h. Excludes Turkish students and population.
i. Data refer to a year other than that specified.
j. Data refer to a year or period other than that specified, differ from the standard definition or refer to only part of a country.
k. UNICEF 2000.
l. Aten, Heston and Summers 2001.
m. UNESCO 2001a.
n. Human Development Report Office estimate based on national sources.
o. For purposes of calculating the HDI a value of 99.0% was applied for OECD countries for which data on adult literacy are missing. The resulting aggregates (97.5% for OECD countries, 98.8% for high-income OECD countries, 98.5% for high human development countries, 98.6% for high-income countries and 79.2% for the world) were used in obtaining the HDI aggregates.

Source: Column 1: UN 2001d; *column 2:* unless otherwise noted, UNESCO 2000a; *column 3:* UNESCO 2001b; *column 4:* unless otherwise noted, World Bank 2001b; aggregates calculated for the Human Development Report Office by the World Bank; *column 5:* calculated on the basis of data in column 1; *column 6:* calculated on the basis of data in columns 2 and 3; *column 7:* calculated on the basis of data in column 4; *column 8:* calculated on the basis of data in columns 5-7; see technical note 1 for details; *column 9:* calculated on the basis of data in columns 4 and 8.

Appendix D: Agricultural products included in the study

Production	***Imports***	***Exports***
BOTSWANA	BOTSWANA	BOTSWANA EXPORTS (MT)
WHEAT	WHEAT	WHEAT
MAIZE	FLOUR OF WHEAT	FLOUR OF WHEAT
MILLET	MAIZE	MAIZE
SORGHUM	RICE	FLOUR OF MAIZE
Citrus Fruit,Total	FLOUR OF MAIZE	FLOUR OF CEREALS
Fruit excl Melons,Total	FLOUR OF CEREALS	RICE
Roots and Tubers,Total	SUGAR CANE	SUGAR REFINED
Vegetables&Melons, Total	SUGAR REFINED	WINE
Meat, Total	WINE	TOBACCO LEAVES
Fruit & Vegetable Tot	TOBACCO LEAVES	Sorghum
	Sorghum	Citrus Fruit nes
NAMIBIA	Citrus Fruit nes	Millet
WHEAT	Millet	Fruit + Vegetables -05
Maize	Fruit + Vegetables -05	Fruit Fresh nes
MILLET	Fruit Fresh nes	Potatoes
Sorghum	Potatoes	Total Meat
Fruit excl Melons,Total	Total Meat	
Roots and Tubers,Total		Namibia
Vegetables&Melons, Total	NAMIBIA	Total Meat
Meat, Total	Maize	
Fruit & Vegetables tot	Sugar Refined	SOUTH AFRICA
	Wheat	FLOUR OF WHEAT
SOUTH AFRICA	Fruit + Vegetables -05	FLOUR OF MAIZE
WHEAT	Fruit Fresh nes	SUGAR CANE
MAIZE	Total Meat	SUGAR REFINED
MILLET		GROUNDNUTS IN SHELL
SUGAR CANE	SOUTH AFRICA	GROUNDNUTS SHELLED
TOBACCO LEAVES	FLOUR OF WHEAT	WINE
RICE	FLOUR OF MAIZE	COFFEE, GREEN
Sorghum	SUGAR CANE	COFFEE ROASTED
Citrus Fruit,Total	SUGAR REFINED	TEA
Apples	GROUNDNUTS IN SHELL	TOBACCO LEAVES
Grapes	GROUNDNUTS SHELLED	TOBACCO PRODUCTS NES
Oranges	WINE	HONEY
Tea	COFFEE, GREEN	TOBACCO
Tobacco Leaves	COFFEE ROASTED	WHEAT
Barley	TEA	MAIZE
Potatoes	TOBACCO LEAVES	Rice
Groundnuts in Shell	TOBACCO PRODUCTS NES	ORANGES
Beef and Veal	HONEY	APPLES
Chicken Meat	TOBACCO	APRICOTS
Pigmeat	WHEAT	GRAPES
Sheep and Goat Meat	MAIZE	MANGOES
	RICE	AVOCADOS
	ORANGES	PAPAYAS
	APPLES	Sorghum
	APRICOTS	Citrus Fruit nes
	GRAPES	Millet
	AVOCADOS	Barley
	Sorghum	Potatoes
	Citrus Fruit nes	Beef and Veal
	Millet	Chicken Meat

Appendix D: Agricultural products included in the study

ZIMBABWE
WHEAT
TOBACCO LEAVES
SUGAR CANE
MILLET
MAIZE
CASSAVA
RICE
Sugar
Sorghum
Coffee, Green
Citrus Fruit,Total
Barley
Potatoes
Beef and Veal
Chicken Meat
Pigmeat
Sheep and Goat Meat

Barley
Potatoes
Beef and Veal
Chicken Meat
Mutton and Lamb
Pigmeat

ZIMBABWE
FLOUR OF WHEAT
FLOUR OF MAIZE
SUGAR REFINED
GROUNDNUTS IN SHELL
GROUNDNUTS SHELLED
WINE
COFFEE, GREEN
COFFEE ROASTED
TEA
TOBACCO LEAVES
TOBACCO PRODUCTS NES
HONEY
TOBACCO
WHEAT
MAIZE
RICE
Sorghum
Citrus Fruit nes
Millet
Barley
Potatoes
Beef and Veal
Chicken Meat
Mutton and Lamb
Pigmeat

Mutton and Lamb
Pigmeat

ZIMBABWE
FLOUR OF WHEAT
FLOUR OF MAIZE
SUGAR CANE
SUGAR REFINED
GROUNDNUTS IN SHELL
GROUNDNUTS SHELLED
WINE
COFFEE, GREEN
COFFEE ROASTED
TEA
TOBACCO LEAVES
TOBACCO PRODUCTS NES
HONEY
TOBACCO
WHEAT
MAIZE
RICE
Sorghum
Citrus Fruit nes
Millet
Barley
Potatoes
Beef and Veal
Chicken Meat
Mutton and Lamb
Pigmeat

Appendix E: Amounts of food aid received