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WATER FOOTPRINT OF GHANA WITH RESPECT TO SOME SELECTED COMMODITIES AND SERVICES

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CERTIFICATION

I hereby declare that this submission is my own work towards the MSc. and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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Dedication

This work is dedicated to Mr. Daniel Akornor and the entire Akornor and Debrah family. God richly bless you all.

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Abstract

The water footprint concept was developed in order to have an indicator of water use in relation to the consumption pattern of people. The water footprint of a country is defined as the volume of water needed for the production of the goods and services consumed by the inhabitants of the country. Due to the bulky nature of water, it is not in its raw state a tradable commodity though it could be traded through the exchange of goods and services from one point to the other. Closely linked to the water footprint concept is the virtual water concept. Virtual water can be defined as the volume of water required to produce a commodity or service. The international trade of these commodities entails flow of virtual water over large distances. The water footprint of a nation can therefore be assessed by quantifying the use of domestic water resources, taking out the virtual water flow that leaves the country and adding the virtual water flow that enters the country.

This research focuses on the assessment and analysis of the water footprints of Ghana with respect to some selected commodities and services considering only the consumptive component of the water footprint. In addition to livestock, 13 crops were considered, 4 of which were cash crops. Data was analysed for the year 2001 to 2005. The estimated water footprint of Ghana was 24.84 billion m^3/yr. The use of domestic water resources accounts for 22.65 billion m^3/yr (91.2 %) of the estimated water footprint. And 2.19 billion m^3/yr was from foreign water resources. The majority of the water that is consumed is embedded in food. Based on this the average water footprint of a Ghanaian was obtained as 1145 m^3/cap/yr in respect of commodities and services considered.

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List of Abbreviations and Acronyms

AVRL:	Aqua Vitens Rand Limited
AWU:	Agricultural Water Use
CWR:	Crop Water Requirement
CWSA:	Community Water and Sanitation Agency
CY:	Crop Yield
DWW:	Domestic Water Withdrawal
ETc :	Crop Evapotranspiration
ETo:	Reference Crop Evapotranspiration
EWFP:	External Water Footprint
FAO:	Food and Agricultural Organization
FP*:	Consumptive Component of the Water Footprint
FP**:	Contaminative Component of the Water Footprint
GIDA:	Ghana Irrigation Development Authority
GLSS:	Ghana Living Standards Survey
GoG:	Government of Ghana
GWCL:	Ghana Water Company Limited
IW FP:	Internal Water Footprint
IWW:	Industrial Water Withdrawal
Kc:	Crop Coefficient
Lp:	Growing Period
MoFA:	Ministry of Food and Agriculture
MOM:	Monitoring Operation and Maintenance
MWH:	Ministry of Works and Housing
MWRWH:	Ministry of Water Resources, Works and Housing

SRID:	Statistics, Research and Information Directorate
SWD:	Specific Water Demand
VWC_{drink}:	Water Consume by the Animal
VWC_{feed}:	Virtual Water Content of Feed
VWC_{ser}:	Water Use to Service the Animal
VWC_{total}:	Total Virtual Water of Animal
VWEre:	Virtual Water Re-export
VWEx:	Virtual Water Export
VWI:	Virtual Water Import
WFP:	Water Footprint
WRC:	Water Resources Commission
WRM:	Water Resources Management

CHAPTER ONE

1. INTRODUCTION

1.1. Study background

Water is probably the most important natural resource in the world since without it life cannot exist. Water plays a vital role in the development of communities hence a reliable supply of water is an essential prerequisite for the establishment of a stable community. As far as human existence and development is concerned, water plays a very vital role in agriculture, domestic, industrial, recreational and religious activities (Debrah, 2006).

A commodity can be manufactured locally or can be imported. Local production of the commodity requires the usage of the domestic water, and in the case of the imported product the water used is a resource from the country of origin. The water footprint of a country is defined as the volume of freshwater needed for the production of the goods and services consumed by the inhabitants of the country (Chapagain and Hoekstra, 2004; Chapagain, 2006). And the water footprint of a product (good or service) is the entire volume of fresh water required to produce the product, summed over the various steps of the production process. Notwithstanding water is not the only resources used in the production of a commodity.

Consumption of goods in a particular country may not exclusively be a product from that country; this is because the production of a commodity may be in one particular country but it consumption may be in various countries. The consumption of a commodity requires the_use of water from two sources: use of domestic water resources and the use of water from outside the borders of the country concerned. Hence the water footprint of a country consists of two parts, internal water footprint (use of domestic water resources) and external water footprint (use of water resources from external sources) (Chapagain and Hoekstra, 2004).

Water footprint can be estimated for any commodity or activity as well as for any definite group of consumers (e.g. an individual or family, or the inhabitants of a village, city, state or nation) or producers (e.g. a public organization, private enterprise or a whole economic sector) based on their consumption pattern.

The water footprint concept is closely linked to the virtual water concept, which is defined as the volume of water required to produce a commodity or to render a service. Due to the bulky nature of water, it is not in its raw state a tradable commodity though it could be traded through the exchange of goods and services from one point to the other. As a result, international trading of commodities involves flow of virtual water over large distances.

The concept of virtual water was introduced by Allan in the early 1990s (Allan 1993, Allan 1994) when studying the option of importing virtual water (as opposed to real water) as a partial solution to problems of water scarcity in the Middle East. Allan elaborated on the idea of using virtual water import (coming along with food imports) as a tool to release the pressure on the scarcely available domestic water resources. Virtual water import thus becomes an alternative water source, next to endogenous water sources. Imported virtual water has therefore also been called 'exogenous water' (Haddadin, 2003).

Water footprint is more than a figure of the total volume of water used; it refers explicitly to the type of water used, the location and the time the water was used. Looking at water usage along production and supply processes, water footprint aims to unearth the concealed link between human consumption and water use, that is, water footprint shows the extent of water use in relation to consumption of people. The concept is base on the assumption that water is the key resources in the production of a commodity; however, production of a commodity depends on other factors such as climatic condition, population size and the availability of other natural resources. Hence a country may be endowed with water resources but may not have the labour forces or the available land area for the production of a commodity and for that matter will be unable to go into intensive production of that commodity.

The research focuses on the assessment and analysis of the water footprints of Ghana with respect to the consumption of some selected commodities and services. The study is limited to agricultural commodities, which are responsible for the major part of global water use (Postel et al., 1996). The period 2001 - 2005 has been taken as the period of analysis, because this was the most recent five-year period for which all necessary data could be obtained.

1.2. Objectives

The main objective of this study is to determine the water footprints of Ghana with respect to some selected commodities and services.

Specific objectives

- To estimate the agricultural water use of the selected crops and livestock
- To estimate the domestic and industrial water use
- To quantify the virtual water balance of Ghana (with respect to agricultural goods)

1.3. Research justification

A commodity (goods) is something that is sold for money. The sale of a commodity has the sole purpose to meet a demand and to make profit. While services is something that the public needs such transport, energy or water supply, which is provided in a planned and organized way by the government or an official body (Cobuild, 2004). Water, essentially freshwater is a key component in the production procedure of most commodities most essentially for agricultural product.

Ghana's economy is basically agrarian, and agriculture is undoubtedly the largest sector (50.6%[1]) and the rate of the country's economic growth seems to be linked to the performance of the agricultural sector (FAO, 2003). In most countries the

[1] Percentages of employed Ghanaian population employed in the agricultural sector.

increase in water use was largely related to increased production of agricultural products and so it is the case of Ghana.

Fresh water is not evenly distributed across the world. The demands for water in some regions or countries are low as compared to other regions. It is therefore desirable for a water scarce region or country to import a water-intensive product and export product or services that require less water. Thus import of 'virtual water' (instead of importing real water, which is generally very difficult and expensive) as a means of alleviating the demands on the domestic water resources.

The idea of actively promoting the importation of virtual water in water-scarce countries is based on the idea that a nation can save its domestic water resources by importing a water intensive product rather than domestic production of that product. Importation of virtual water thus leads to a 'national water saving'. In addition to this, Oki and Kanae (2004) introduced the idea of a 'global water saving'. International trade can save water globally when a water-intensive commodity is traded from an area where it is produced with high water productivity (low water input per unit of output) to an area with lower water productivity (high water input per unit of output). On the other hand, naturally, there can be a 'global water loss' if a water intensive commodity is traded from an area with low water productivity to an area with high water productivity. However, water use for producing export commodities has become important in different countries (Hoekstra and Hung, 2007).

The concept of water footprint can be used to map out the impact of the consumption (of goods and services) pattern of the people of a country on their water resources.

According to Hoekstra and Hung (2002) the water footprint, net virtual water import and water self-sufficiency of Ghana was estimated as follows 554 million m^3, 229 million m^3 and 58.7% respectively.

Earlier indicators and documentation of water use has been the estimation of the total water withdrawal for the various sectors of the nation's economy. The water footprint concept shows water use in relation to product consumption within a nation, while the traditional indicator of water use (i.e. total water withdrawal for the various sectors of the economy) shows water use in relation to production within a nation. The water footprint does not only show water use within the country considered, but also the water use outside the country's borders. It refers to all forms of water use that contribute to the production of goods and services consumed by the inhabitants of a certain country.

In summary the water footprint of a nation can be assessed by taking the use of domestic water resources, subtract the virtual water flow that leaves the country and add the virtual water flow that enters the country. The virtual-water balance of a country over a certain time period is defined as the net import of virtual water over this period, which is equal to the gross import of virtual water minus the gross export (Hoekstra and Chapagain, 2004). A positive virtual-water balance implies net inflow of virtual water to the country from other countries. A negative balance means net outflow of virtual water. In this way, the water footprint offers a link to impact assessment and policy formulation.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Introduction

To assess the consumption rate of a country in relation to a commodity and its effect on the country's natural resources and economy, consideration is usually given to how much is produced and the amount consumed in that country. This does not give the real picture about the situation on the ground, since some of the goods consumed by the people of the country are produced in other countries using resources from that country (Hoekstra and Chapagain, 2007). In the production processes of most goods water is a prerequisite. Freshwater of ample quality is a requirement for human societies and natural ecosystems. There are various competitive uses of freshwater such that water scarcity is severe in most regions. For many companies, freshwater is a basic ingredient for their operations, while effluents may lead to pollution of the water body and subsequently the local hydrological ecosystem.

Increase in population over the years call for increase in economic activities which directly or indirectly call for increase in most agricultural and industrial activities which adversely result in the decline of the available freshwater for human consumptive use (Postel et al., 1996; Shiklomanov, 2000; Vörösmarty et al., 2000; Vörösmarty and Sahagian, 2000). The water footprint concept was introduced by Hoekstra and Hung (2002) when looking for an indicator that could map the impact of consumption of people on the global water resources. The concept was subsequently elaborated by Chapagain and Hoekstra (2004). The water footprint of a nation is defined as the total volume of freshwater that is used to produce the goods and services consumed by the people of the nation. Since not all goods consumed in one particular country are produced in that country, the water footprint consists of two parts, as stated by Chapagain and Hoekstra (2004)

- Use of domestic water resources (internal water footprint).
- Use of water from outside the borders of the country (external water footprint).

2.2. Water resources

Ghana is well endowed with water resources. According to Ministry of Water Resource, Works and Housing (MWRWH, 2007), the total annual runoff is 56.4 billion m^3 with the Volta river basin accounting for 41.6 billion m^3. The mean annual runoff flowing out of Ghana to the sea is about 40 billion m^3 and the total water available from surface water sources that can be readily used is about 39.4 billion m^3 per annum.

The Volta, South-Western and Coastal systems contribute 65%, 29% and 6%, respectively, of the total runoff (56.4 billion m^3). The Volta river basin system (consisting of the Oti, Daka, Pru, Sene and Afram rivers as well as the White and Black Volta Rivers) covers about 70% of the land area of Ghana. Another 22% of the land area of Ghana is covered by the southwestern river system watershed comprising the Bia, Tano, Ankobra and Pra rivers. The coastal river system watershed, comprising the Ochi-Nawuka, Ochi Amissah, Ayensu, Densu and Tordzie rivers, covers the remaining 8% of the country. The Volta Lake, with a surface area of 8,500 km^2, is one of the world's largest artificial lakes (MWRWH, 2007).

2.3. Water supply

The two main institutions in charge of water supply for domestic, commercial and industrial purposes in Ghana are Ghana Water Company limited (GWCL) and Community Water and Sanitation Agency (CWSA). According to the standard of CWSA, the bases for production are that a rural or small community dweller consumes on the average 20 l/cap/day (CWSA, 2007). The range considered for urban dwellers water production 90-120 l/cap/day (GWCL, 2008). Ghana Water Company Limited is entirely owned by the Government of Ghana and has Aqua Vitens responsible for the management (i.e. operation management) of pipe-borne water in most urban areas and towns. The activities of Aqua Vitens are supervised by the GoG. Community Water and Sanitation Agency is mandated by the GoG to facilitate the provision of safe drinking water and related sanitation services to rural and small towns in the country. Groundwater is the primary source of potable water for small communities. Surface water sources are explored for small communities only if groundwater is unavailable or inadequate. Groundwater is generally of good quality and requires minimum treatment. GWCL usually uses surface water, however groundwater is used when the need arises. Groundwater based schemes are designed in accordance with the CWSA design guidelines and standard drawings for boreholes and hand dug wells. The cost of treatment and the infrastructure for surface water is very expensive. Despite the availability of water to meet water supply, there are deficits in coverage. While urban water supply coverage is estimated at 55% (2004), the rural and small town coverage is about 51.6% (2004) (MWRWH, 2007).

2.4. Water use

In 2000, total water withdrawal was 982 million m^3, of which two thirds (654.7 million m^3) were used for agricultural purposes. Another 98.3 million m^3 (10%) was withdrawn for industry, leaving 235 million m^3 (24%) for domestic use. Furthermore, 37.84 million m^3 are used for hydroelectricity generation at the Akosombo Dam each year (MWRWH, 2006). Water consumption is usually expressed in litres per capita per day. It is of extreme importance to have reliable drinking water in sufficient quantities available; also of importance is water for food preparation and that needed to improve hygiene and to prevent illness (washing, cleaning, flushing etc.). There are occasions when water is needed for convenience reasons (e.g. Swimming pool and recreational parks). Water consumption depends on numerous factors; these include living standards (housing, car and garden), income level, water price, type and number of connections (house, yard connection and public stand post), climatic condition and consumer habits. The uses of water can be grouped into two main components; thus the consumptive (results in the reduction of water quantity) and contaminative (results in the loss of original quality of the water resource) components.

2.5. Green, Blue and Grey water

According to Falkenmark (2003), the terms green water and blue water use are used to tell the difference between the sources of the water used. Green water is the infiltrated water or ground water in the root zone which is available for photosynthetic processes. The source of green water is rain; green water use is therefore the water loss through evapotranspiration (evapotranspiration through either transpiration by the plant or direct evaporation from the surface of soil or leaf). On the other hand blue water use refers to evaporated irrigation water. The source of blue water is ground water or surface water. Grey water is the water that has lost its original quality as a result of contamination due to various uses of the water. The gray virtual-water content of a product is the volume of water that becomes polluted during production of the product concerned (Hoekstra and Chapagain, 2008). The water footprint is a quantitative measure of the amount of water consumed. It is made of three components: the blue, green and grey water footprint. The blue water footprint is the volume of freshwater that evaporated from the national or regional blue water resources (surface water and ground water) to produce the goods and services consumed by the people in a nation. The green water footprint is the volume of water evaporated from the global green water resources (rainwater stored in the soil as soil moisture). The grey water footprint is the volume of polluted water associated with the production of all goods consumed and services rendered in the nation. The grey water footprint is calculated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water corresponds with the agreed water quality standards (Hoekstra and Chapagain, 2007b; 2008)

2.6. The Concept of Water Footprint

Increasing human demand for water coupled with the effects of climate change mean that the future of our water supply is not secured; but there is hope. Proper water management can lead to a secure future, hence the significance of the concept, water footprint.

The water footprint is an indicator of water use that looks at both direct and indirect water use of a consumer or producer. The water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business. The water footprint of an intermediate or final product (including energy) is defined as the total volume of freshwater that is used directly or indirectly to produce the product. Water use is measured in terms of water volumes consumed (evaporated) and/or polluted per unit of time. A water footprint can be calculated for any well defined group of consumers (e.g. an individual, family, village, city, province, state or nation) or producers (e.g. a public organization, private enterprise or economic sector). The water footprint is a geographically explicit indicator, not showing only volumes of water used and polluted, but also the locations. The water footprint aims to uncover this hidden link between human consumption and water use (Chapagain and Hoekstra, 2004; Chapagain, 2006).

There are four major factors that influence the water footprint of a nation:

1. Amount and type of consumption (often positively related to income)
2. Consumption patterns (for example, high versus low meat consumption)

3. Climatic conditions; and

4. Agronomic practice (for example, irrigation efficiency or availability of technologies).

Agricultural practices in the country are yet to adapt to the modern form of mechanized farming, considering the above factors it is only expected that the water footprint of Ghana which also a tropical country will be large. This because agriculture is predominantly on a smallholder basis in Ghana, and for matter more water is used in the cultivation of small quantity of crops. About 90% of farm holdings are less than 2 hectares in size, although there are some large farms and plantations, particularly for rubber, oil palm and coconut and to a lesser extent, rice, maize and pineapples. Main system of farming is traditional. The hoe and cutlass are the main farming tools. There is little mechanized farming, but bullock farming is practiced in some places, especially in the North. Agricultural production varies with the amount and distribution of rainfall (MOFA, 2006).

2.7. Definition of Virtual Water

Closely linked to the water footprint concept is the virtual water concept. The expression 'virtual water' was introduced by Tony Allan in the early 1990s (Allan, 1993; 1994). It is defined as the volume of water required to produce a commodity or service (Allan, 1998, 1999; Hoekstra, 1998). When there is a transfer of goods or services from one place to another, there is little or no direct physical transfer of water (apart from the water content of the product, which is quite insignificant in terms of volume). There is however a significant transfer of virtual water. From a country's perspective, Haddadin (2003) has defined this water also as 'exogenous' water. The water that is used in the production process of an agricultural or industrial product is called the 'virtual water' contained in the product. For instance, to produce a kilogram of grain, grown under rain-fed and favourable climatic conditions, about one to two cubic metres of water is needed (that is 1000 to 2000 kg of water). For the same amount of grain, but grown in an arid country, where the climatic conditions are unfavourable (high temperature, high evapotranspiration) about 3000 to 5000 kg of water is required (Hoekstra and Hung, 2002). Therefore the volume of water used to produce a commodity measured at the place where the commodity was actually produced is the virtual water content of the commodity. Water scarce countries mostly import water intensive commodities instead of importing the real water which is; if not complicated, quite expensive. Thus importing water in the virtual form (hidden or embedded water) thereby saving domestic water resource. Examples of such countries are South Africa, Mexico and Japan (Chapagain and Hoekstra, 2004).

Hoekstra and Chapagain (2008) define the 'virtual-water content' of a product as the volume of fresh water used to produce the goods or services, summed over the various steps of the production chain. The term 'virtual' refers to the fact that most of the water used to produce a product is not contained in the product. The real-water content of products is generally negligible when compared to the virtual-water content. 'Virtual-water flows' occur when water-intensive products are traded from one place to another or when products move through a supply chain. The 'virtual water content' of a product is almost the same as what is called the 'water footprint' of a product, however, the term 'water footprint', is broader, in the sense that the water-footprint concept gives a spatial and temporal dimension to the concept of 'virtual water content'.

2.8. Characteristics of Farming in Ghana

Ghana's economy is basically agrarian, and agriculture is undoubtedly the largest sector. The rate of the country's economic growth seems to be linked to the performance of the agricultural sector (FAO, 2003).

The major farming systems in Ghana are to a large extent defined by the agro-ecological zones; and they include:

- Rotational Bush Fallow Systems.
- Permanent Tree Crop System (such as cocoa-based system)
- Compound Farming System
- Mixed Farming System (such as maize-yam based system)
- Special Horticultural, and
- Animal husbandry

The rotational bush fallow system is characterized by clearing and burning of the vegetative cover. It is the dominant farming system throughout Ghana. The permanent tree crops farming system is characterized by the cultivation of permanent tree crops usually a monocrop such as cocoa, citrus, oil palm, avocado, rubber, coffee and mango. Cocoa is however the most extensively cultivated tree crop in this farming system. Compound farming systems are practiced mainly in the interior savanna zone where most farms are cultivated within close vicinity of villages. The mixed farming systems integrate the rotational bush fallow system and the permanent tree crop system. This farming system is mainly practiced in the high rain forest and the semi-deciduous forest zones. Horticultural farming systems in Ghana are dominated by crops such as pineapples, pawpaw and exotic vegetables, which are mainly grown for export. The cultivation of these crops entails clearing large hectares of land and application of fertilizers.

Smallholder farmers who cultivate about 2 to 5 acres dominate the agricultural sector, and they account for about 90% of total agricultural output (FAO, 2003). These apply traditional production methods mainly, use simple hand tools for farming activities, and make only limited use of fertilizers and other agrochemicals. Large-scale production is predominant only with the plantation crops such as oil palm, rubber and pineapple, and in a few cases maize and rice. There is an ongoing private sector and government out-grower scheme to link the plantations with smallholder farmers so as to assist these farmers gain access to modern technology, farm inputs and credit.

High taxation of agriculture and low producer prices, particularly in the cocoa sub-sector, have for a long time been a major disincentive to farmers most of whom abandoned their farms and shifted to alternative crops or enterprises. Cocoa output thus declined steadily in the 1970s to the early 1980s, and agriculture generally suffered decline. Cocoa, for example, contributed 14% of total GDP in 1970, but by 1980 and 1982, this share had dropped to 3.5% and 2.6%, respectively. Currently cocoa contributes 13.1% of the total GDP of the agricultural sector which was 35.8% of the national GDP of Ghana (MOFA, 2006).

Agricultural taxation has however declined following the reforms of the 1980s and 1990s. On the other hand, agricultural input subsidies have all been removed by the early 1990s, which has resulted in high production cost to farmers, resulting in limited use of modern inputs. Agriculture remains the mainstay of the Ghanaian economy and is recognized to be the principal sector for economic development and poverty alleviation in the foreseeable future. On the other hand most agricultural commodities are export in the raw form, which result economy return being low as compared to a processed commodity

In 2002, agriculture contributed 36% to national GDP and employed 51% of the labour force. According to the latest Ghana Living Standards Survey (GLSS, 2000), 2.75 million households own or operate a farm or keep livestock, accounting for 43% of households nationwide. Thus, a major focus of the Ghanaian government has been on the export performance of agriculture as part of its agribusiness and export-focused strategy for development (Henson, et al,. 2006).

2.9. Characteristics of Irrigation in Ghana

The total land area suitable for agricultural purpose is estimated to be 13,628,179 ha (57.1% of the total land area of Ghana) out of which 6,904,000 ha (28.9%) is under cultivation. Total land area under irrigation is estimated to be 18,000 ha (0.08%) (MOFA, 2006). The irrigation potential of Ghana is estimated to be 1200000 ha with a gross potential irrigation water requirement of 20000 m^3/ha/yr (MWRWH, 2007).

If the total annual flow to the sea is 40 billion m^3, which exceeds that of the total annual irrigation water requirements for the whole nation (20000 m^3/ha/yr). Ghana has more than the required resources (land area and water) to produce the goods it needs, considering the available arable land and the mean annual flows to the sea.

Under the authority of Irrigation Development Authority (IDA) are 22 major irrigation projects spread across the country with each region having at least two. Nine (9) of these projects irrigate under gravity, two use both pumping and gravity and the rest irrigate by pumping. Almost the entire project has less than half its potential developed and of the developed areas most of this project has less than half of the developed areas used.

CHAPTER THREE

3. METHODOLOGY

3.1. Introduction

This chapter briefly describes the study area and highlights on how the study was conducted. Source of data, method of data collection and analysis and limitation of the study are discussed.

3.2. Study Area

Ghana has an area of about 238000 km² and located on the West Coast of Africa. It lies between latitude 4° 44'N and 11° 11'N and longitude 3° 11' W and 1° 11'E. It shares boundaries with Togo to the East, Burkina Faso to the North, and La Cote d'Ivoire to the West. The south is washed by the Atlantic Ocean. The topography is characterised by rolling plains and hills with elevation below 500m. Over half of the land surface is below 150m with mean annual temperature fluctuating between 24°C and 33°C and humidity ranging between 90% in the coast and 20% in the north (MWRWH, 2006).

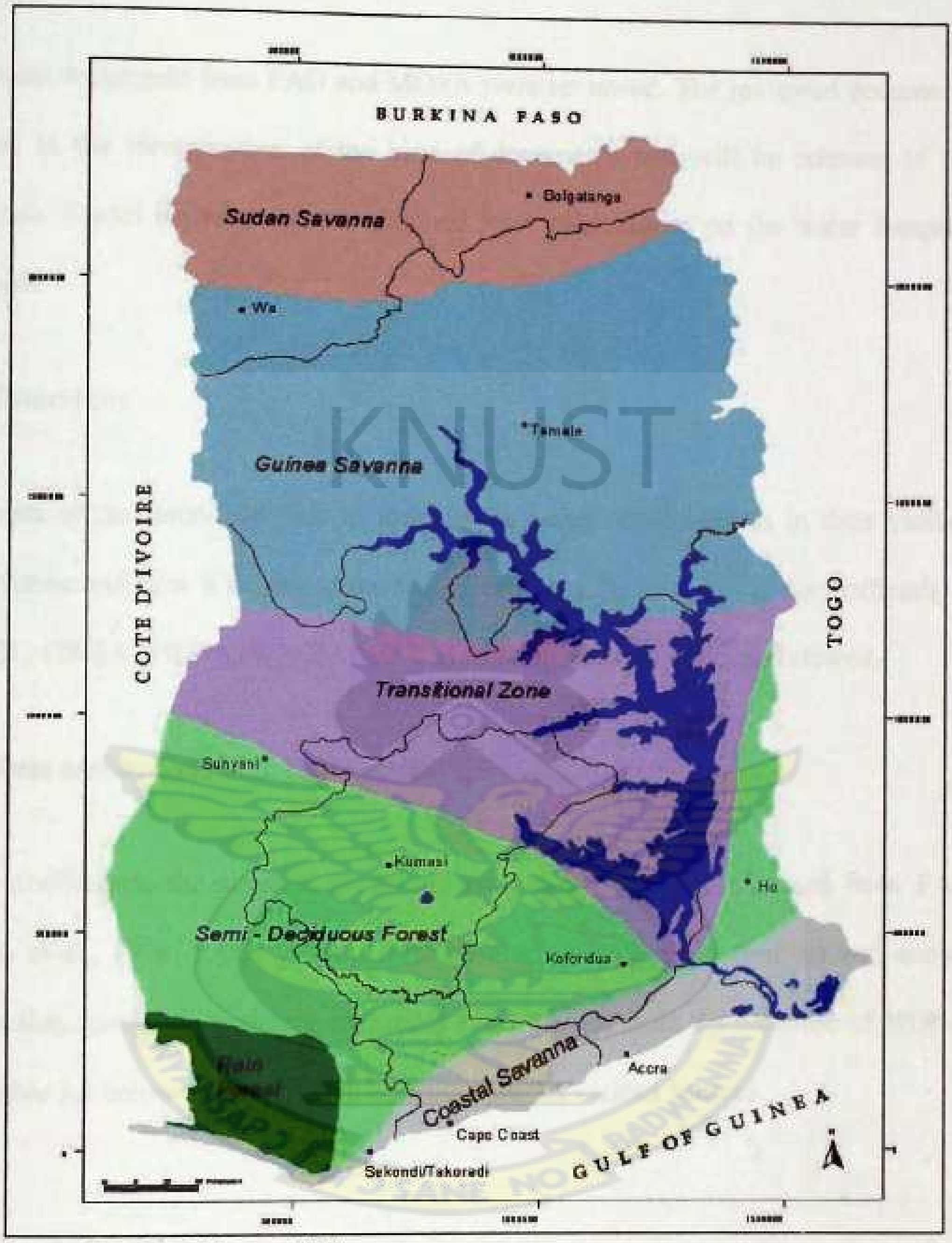
The Climate of Ghana like the rest of the tropical West Africa is dominated by the Inter Tropical Convergence Zone (ITCZ). It is a tropical country consisting of three broad ecological zones, which are the forest, forest-savanna transition, and the savanna zones. These broad categories are further divided into the coastal savanna, rainforest, semi-deciduous forest, forest-savanna transition, Guinea savanna and Sudan savanna. These agro-ecological zones are defined on the basis of climate, reflected by the natural vegetation and influenced by the soils. Rainfall distribution is bimodal in the Forest, Transitional and Coastal Zones, giving a major and minor growing season; elsewhere (Guinea savannah and Sudan savannah), the unimodal distribution gives a single growing season.

The forest zone, comprising the tropical high rain forest and semi-deciduous forest, covers about one-third of the country (79333 km² (8.2 million ha)) and supports two-thirds of the country's population (World Bank, 1988). Most of the economic activities of the country are also situated within this region, including activities associated with cocoa, minerals, oil palm, rubber, and timber. The forest zone has a bimodal rainfall that ranges from 1,300 mm to 2,100 mm annually.

The northern savannah zone covers about 66% (15.7 million hectares) of the country's total area. This zone has a uni-modal rainfall pattern that is erratic and usually unpredictable, and ranges between 900 mm and 1,200 mm per annum. Industrial crops such as cotton and sheanuts, along with food crops such as rice, maize, sorghum, millet and yam are grown in that region.

The forest-savannah transition lies in-between the forest and savannah zones. It is a blend of the forest and savannah zones, and noted for cereals, particularly maize, as well as root and tuber crop production (MOFA, 2006).

Figure 3.1 below shows the various ecological zones with the various colours differentiating the zones



Source: Benneh & Aggyepong (1990)

Figure 3.1 Ghana's Agro-Ecological Zone

3.3. Desk Study

Relevant documents from FAO and MOFA were reviewed. The reviewed documents helped in the identification of the kind of documents that will be relevant to the research. Useful information was obtained from publications on the water footprint website.

3.4. Interviews

The aim of the interviews was to identify the water related issues in their various institutions and how it relates to the water resources in the country. Key officials of GWCL, CWSA, MOFA, WRC, MWRWH and COCOBOD were interviewed.

3.5. Data and sources of data collection

Crop coefficients for different crops and crop calendars were obtained from FAO (Allen et al., 1998; FAO, 2004b). Data on average crop yield (ton/ha) and annual production (ton/yr) per primary crop were also obtained from the database of MOFA. The table 3.1 below shows the data obtained and the various sources.

TABLE 3.1 Data Obtained and their Sources

Data	Sources
Water resources in Ghana	MWRWH and WRC
Rural communities water use	CWSA
Urban water use	GWCL
Industrial water use	GWCL
Annual crop yields and yields per hectare	MOFA, SRID
Annual livestock consumption	Veterinary Services Directorate, MOFA,
Annual imports/exports of agric. goods	Ministry of Trade & Industry.

3.6. Calculations

The most recent, comprehensive and elaborated framework for the analysis available so far is offered by Chapagain and Hoekstra (2004), Chapagain et al. (2005) and Hoekstra and Chapagain (2006). In this research this framework was used with little modification. There are two main methods for the estimation of the water footprint of a nation; estimation of the consumption component of the water footprint and estimation of the consumptive and contaminative component as a unit. The most elaborative method has been estimation of the consumptive component and for the purpose of this study only the consumptive component will be considered.

3.6.1. Calculation of Water Footprint

According to the definition stated above the water footprint, ***WFP*** is

$$WFP = FP^{*} + FP^{**} \quad (1)$$

Where ***WFP*** is the water footprint (m^3/year); ***FP**** is the consumptive component of the water footprint (m^3/year); and ***FP***** is the contaminative component of the water footprint (m^3/year). Only the consumptive component will be estimated in this study.

$$FP^{*} = IW\ FP + EWFP \quad (2)$$

Where ***IW FP*** is the internal water footprint (m^3/year) and ***EWFP*** is the external water footprint (m^3/year).

3.6.2. Calculation of Internal Water Footprint

3.6.2.1. Domestic and Industrial water use (DWW and IWW)

For information on water use in the industrial and domestic sectors, available statistics were used. According to literatures reviewed and the standards of CWSA and GWCL the average per capita water consumption for a rural or urban dweller are 20 l/day and 105 l/day respectively. According to the standards of CWSA (2004), 10-20% of the domestic water demands are for industrial and commercial demands. Considering various literatures (Clarke, 2000) reviewed 15% of the domestic demand is estimated for non-domestic purposes. The industrial water withdrawal includes water required for processing at different stages of production. Domestic water withdrawal incorporates the blue water withdrawn to meet the per capita demand for household and municipal consumption.

$$IW\,FP = AWU + IWW + DWW - VWEx \quad (3)$$

Where ***AWU*** is agricultural water use (m^3/year), ***IWW*** is industrial water withdrawal (m^3/year), ***DWW*** is domestic water withdrawal (m^3/year) and ***VWEx*** virtual water export with respect to agricultural goods only (m^3/year).

3.6.3. Calculation of external water footprint

The external water footprint of a product (***EWFP***) is defined as the volume of water resources used in other countries to produce goods consumed by the inhabitants of the country concerned. It is equal to the virtual water import into the country *minus* the volume of virtual water exported to other countries as a result of re-export of imported products. In summary, the virtual water content of primary crops has been calculated as the crop water requirement at field level (m^3/ha) divided by the crop yield (ton/ha).

$$EWFP = VWI - VWEre\text{-}export \quad (4)$$

EWFP is the external water footprint (m^3/year).

VWI = virtual water import (m^3/year)

VWEre–export = volume of virtual water exported to other countries as a result of re-export of imported products (m^3/year).

Virtual water re-export was assumed to be zero due to unavailability of data on such commodities.

3.6.4. Virtual-water flows related to trade

Assessment of the virtual-water flows between Ghana and other nations was estimated as follows; the international trade volumes (ton/year) were multiplied by their associated virtual-water content (m^3/ton) for the 2001-2005 periods. The virtual water content of commodities varies from place to place depending on certain factors. The factors which influence the virtual water content of a product include: climatic conditions, yield, crops species requirements, methods and technology, and irrigation efficiency are only a few of the variables which do have an effect. And not only does the amount of water embedded in food vary, but also the type of water embedded. The industrial products category is so vast and production methods varied. Data on consumption and production is limited. Therefore the global average virtual water content of goods estimated by Chapagain and Hoekstra (2004) was used for processed commodities.

3.6.5. Calculation of agricultural water use

1. Calculation of crop water requirement

The crop water requirement is defined as the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate region, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield. The volume of water used to grow crops in the field has two components: Soil moisture (green water) and irrigation water (blue water). Crop water requirement has been calculated per crop using the methodology developed by FAO (Allen *et al.*, 1998).

The crop water requirement ***CWR*** (in m^3 /ha) is calculated from the accumulated crop evapotranspiration ***ETc*** (in mm/day) over the complete growing period, ***lp*** (Calculations of a ***CWR*** was by summing daily crop evapotranspiration (mm/day) over the growing period of a crop). The crop evapotranspiration ***ETc*** follows from multiplying the 'reference crop evapotranspiration' ***ETo*** with the crop coefficient ***Kc***.

$$\boldsymbol{CWR} = \mathbf{10}\sum_{d=1}^{lp} ETc \qquad (5)$$

The factor 10 is meant to convert mm into m^3/ha. The crop water requirement of rice cannot be calculated directly using equation 5. This is because in addition to evapotranspiration of the rice plant, there is a considerable amount of percolation from the paddy field, which varies with the soil type and ground water table at the farm. Rice is a water loving plant grown in paddies and great volume of water is required to keep the paddies wet all the time.

$$ETc = Kc \times ETo, \qquad (6)$$

Where ***ETo*** is the reference evapotranspiration in (mm); ***Kc*** is the crop coefficient. ***ETo***, ***Kc***, and ***lp*** were taken from Chapagain and Hoekstra, (2004). The concept of 'reference crop evapotranspiration' was introduced by FAO to study the evaporative demand of the atmosphere independently of crop type, crop development and management practices. The only factors affecting ***ETo*** are climatic parameters.

Reference crop evapotranspiration was calculated on the basis of the FAO Penman-Monteith equation (Smith *et al.*, 1992; Allen *et al.*, 1994a, 1994b; Allen *et al.*, 1998). The crop coefficient accounts for the actual crop canopy and aerodynamic resistance relative to the hypothetical reference crop. The crop coefficient serves as an aggregation of the physical and physiological differences between a certain crop and the reference crop.

2. Calculation for the specific water demand

Specific water demand, SWD (m^3/ton) per crop type has been calculated by dividing the crop water requirement, CWR (m^3/ha) by the crop yield, CY (ton/ha).

$$SWD = \frac{CWR}{CY} \tag{7}$$

(Hoekstra and Hung, 2002; Chapagain and Hoekstra, 2004)

4. Calculation of the water use for crop cultivation

The main factors that affect the water use of a crop are the crop water requirement (CWR) and the quantity produced annually. The crop water requirement is used in the estimation of the specific water demand, SWD and the specific water demand against the quantity produced annually results in the volume of water use the cultivation of the crop annually.

$$\mathbf{AWU = SWD \times Quantity} \tag{8}$$

(Quantity refers to the production of crop in ton/yr)

The procedure for the calculation of the water use of a crop is shown in Figure 3.2

This figure also shows the estimation of AWU.

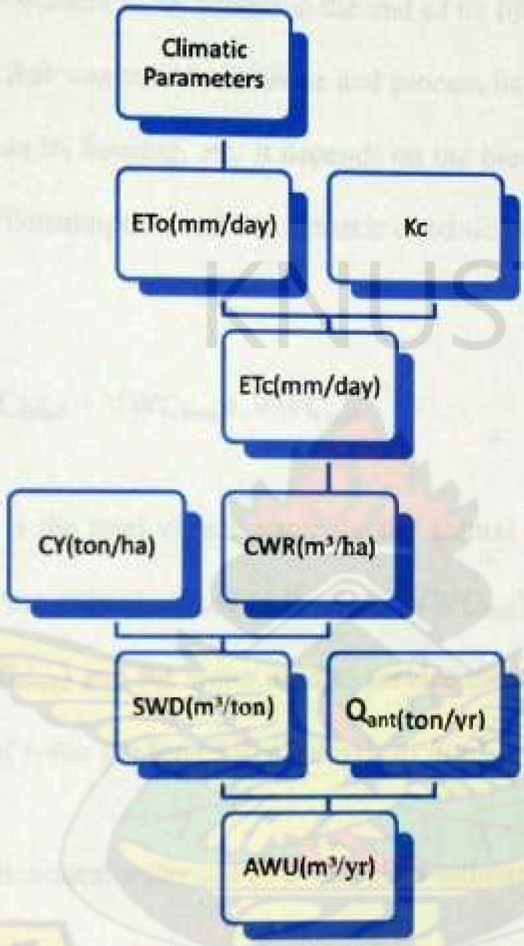


Figure 3.2 Steps in the calculation of agricultural water use

4.1.1. Calculation of Virtual Water of Animal Products

The virtual water content of an animal at the end of its life span is defined as the total volume of water that was used to cultivate and process its feed, to provide its drinking water, and to clean its housing, etc. It depends on the breed of an animal, the farming system, the feed consumption and the climatic conditions of the place where the feed is grown.

$$\mathbf{VWC_{total} = VWC_{drink} + VWC_{feed} + VWC_{serv}} \qquad (9)$$

Where VWC_{total} is the total virtual water for the animal which consist of the virtual water content of the animal related to the feed (VWC_{feed}) intake, water consumed by the animal (VWC_{drink}) and the water used to service the animal (VWC_{serv}), expressed in cubic metres of water per ton of live animal (m^3/ton).

Therefore the agricultural water use of livestock is estimated as follows;

$$AWU_{livestock} = \frac{VWC_{Total} \times value\ fraction}{product\ fraction} \times quantity(product) \qquad (10)$$

AWU_{lives} represent the agricultural water use with respect to animal products, while the value fraction and product fraction was taken from Chapagain and Hoekstra (2004)

CHAPTER FOUR

5. RESULTS AND DISCUSSION

This chapter presents the result and discussions from the analyzed data collected during the study. The study focused primarily on agricultural commodities and, the study also took into account both blue water and green water, though grey water was not considered. For animal products the study included the water necessary to produce feed and to service the animals, and the water the animal consumes. The amount of water embedded in packaging, transport, or retail was not included. The study also considered industrial products generally. Therefore the global average virtual water content of goods estimated by Chapagain and Hoekstra (2004) was used for processed commodities.

5.1. TOTAL WATER AVAILABILITY

Runoffs in Ghana are characterized by wide disparities between the wet season and dry season flows and also in distribution across the country. The readily available water from surface water sources is 39.4 billion m³ per annum. Ghana is endowed with a substantial amount of water resources. Ghana's water resources potential is divided into surface and groundwater sources. The poor coverage of potable water in the country was due to the high cost of infrastructure and not availability of the water resources.

5.2. WATER FOOTPRINT

The consumptive component of the water footprint, FP*, of Ghana was found to be 24.84 billion m^3/yr. The internal water footprint, IWFP, was 22.65 billion m^3/yr and the external water footprint, EWFP, was 2.19 billion m^3/cap/yr. Both the internal and the external water footprint included the use of blue water (ground and surface water) and the use of green water (moisture stored in soil strata).

5.3. INTERNAL WATER FOOTPRINT

5.3.1. Agricultural Water Use

The agricultural water use was estimated to help assess the volume of water withdrawn for the cultivation of crops and for the rearing of livestock. Thus to quantify the volume of nations' water resources that goes into agricultural activities. The agricultural water use (AWU) estimated was 38.91 billion m^3/yr. Crops contribution to the agricultural water use is 38.2 billion m^3/yr (98.2%), while that of livestock is 0.68 billion m^3/yr (1.8%). The agricultural water use includes the water required in the cultivation of the various crops considered and the virtual water content of livestock (calculation was based on the virtual water content of the feed and the volumes of drinking and service water consumed during the lifetime of the livestock).

5.3.1.1. Water Use for Crop Production

The crop water requirement includes both soil moisture and the part of irrigation water used effectively for crop production, excluding the irrigation losses. Water use for crop production was estimated at 38.2 billion m^3/yr. Thirteen (13) crops were considered, these includes cereals (maize, millet, rice, and sorghum) and tubers (cassava, cocoyam, plantain and yam) with four cash crops (cocoa, coffee, cotton and tobacco). Table 4.1 shows the computation of the water used for the cultivation of the various crops considered. Cocoa had the highest agricultural water use (19 billion m^3/yr) followed by plantain (4.65 billion m^3/yr) and cassava (4.54 billion m^3/yr). These three crops are mostly grown under rain fed condition. Thus green water is the resources mainly used in the cultivation of these crops. Mostly peasant farmers in Ghana cultivate their produce under rain fed condition making use of the water stored in the unsaturated soil (soil moisture or green water). Green water cannot really be 'wasted' in the same way as blue water (ground water or irrigation water), nor can green water be managed to the same extent. With green water the options are much more limited: green water can either be left for natural vegetation to survive on, or it can be harnessed for agriculture. Comparatively it is water wise to use the nation's green water to cultivate crops such as cocoa which is of a high value in the world market.

The two key factors considered in the estimation of the agricultural water use was the crop water requirement and the quantity of the crop produced annually. As shown in

Table 4.1 the major portion of the water used for crop cultivation is used for the production of cocoa (19 billion m³/yr), plantain (4.65 billion m³/yr) and cassava (4.45 billion m³/yr).

Table 4.1 Agricultural Water Use of Crops

Crop	CWR(m³/ha) A	CY(ton/ha) B	SWD(m³/ton) C = A/B	Quantity(ton/yr) D	AWU(10^9 m³/yr) E = C*D
Cotton	5259.375	0.8	6574.21875	19666.8	0.13
Cassava	5840.02	12.4	470.9693548	9648300	4.54
Cocoa	14050.96	0.4	35127.4	540922.8	19.00
Cocoyam	6870.05	6.4	1073.445313	1750780	1.88
Coffee	14050.96	1.5	9367.306667	7198.6	0.07
Groundnut	4956.0225	0.9	5506.691667	411080	2.26
Maize	2982.375	1.6	1863.984375	1191200	2.22
Millet	2126.52	0.8	2658.15	153584	0.41
Plantain	16674.76	8.5	1961.736471	2370720	4.65
Rice(paddy)	9271.6875	2	4635.84375	250100	1.16
Sorghum	2710.565	1	2710.565	303980	0.82
Tobacco	4579.84	1.6	2862.4	1849.4	0.01
Yam	3523.84	12.5	281.9072	3814920	1.08

5.3.1.2. Virtual Water Content of Livestock

Water used in the rearing of livestock was about 0.68 billion m³/yr (1.8%). This involves the water necessary to produce feed and to service the animals, and the water the animal consumes. Rearing of livestock in Ghana was and is mainly under the free range system which allows the animal to scavenge for it feed and water needs. Few people practise semi-intensive and intensive system (ranches). Thus semi-intensive and the intensive system are water intensive way of rearing livestock. Table 4.2 show the water use of the various livestock considered. Cattle (0.43 billion m³/yr) accounts for significant portion of livestock water use, followed by poultry (0.13 billion m³/yr) and sheep (0.05 billion m³/yr). Poultry's high volume of water use is largely due to the vast numbers. In the computation of the water use of livestock, two fraction were used, value fraction and production fraction. These are the relative amount of the value and weight of the consumable component of the livestock.

Table 4.2 livestock water use

Livestock	Quantity(ton/yr) A	Virtual water (m^3/ton) B	Value fraction : C	Product fraction: D	AWU (10^9 m^3/yr) E = (A*B*C)/D
Cattle	18677.4	13795	0.87	0.52	0.43
Sheep	13590.2	3386.8	1.00	1.00	0.05
Goats	13825.2	3087.5	1.00	1.00	0.04
Pigs	9994.6	3616.3	1.00	1.00	0.04
Poultry	20157.6	4918.8	1.00	0.78	0.13
Total					0.68

5.3.2. Blue Water Use in Crop Production

There are a number of irrigation project in the country which also contribute to annual crop production. Specific contributions of the irrigation projects to the annual crop were not estimated due to unavailability of data. A number of the irrigation projects in the country are underutilized. Figure 4.1 shows the irrigation potential, developed and used areas of some of the irrigation projects in Ghana. Rice was the main crop cultivated under the various schemes except Weija, Kpando-Torkor and Akumandan.

Rice is a tropical/subtropical grass which relies on large quantities of water for growth. Notwithstanding these, rice contributes about 64.8% of the cereal import into the country. All except Tono, Vea, Akumadan and Afife had the entire developed area used. Ghana is well endowed with the needed resources to produce enough rice to meet the needs of the nation and for export, considering the potential area yet to be developed and the unused developed area of the various irrigation projects in the country.

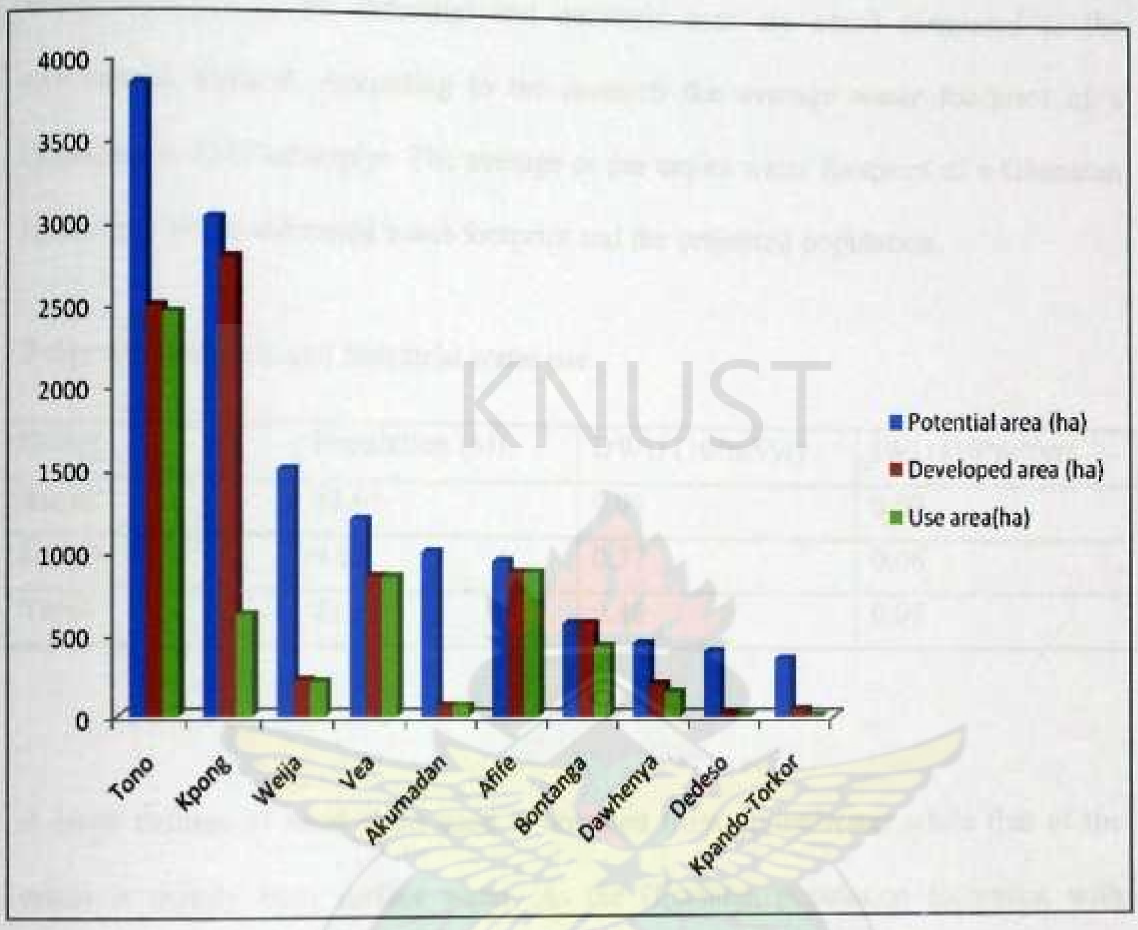


Figure 4.1 Irrigation potential of some selected projects in Ghana (GIDA, 2008)

Just like most developing nations agriculture is the dominant user of water resource in Ghana. This is because agricultural water use contributes the highest portion of the estimated water footprint and most crops considered are grown under rain fed condition.

5.3.3. Water use in the domestic and industrial sector

Water withdrawals for industrial and domestic uses are small compared to the agricultural demand. According to the research the average water footprint of a Ghanaian is 1145 m^3/cap/yr. The average or per capita water footprint of a Ghanaian is the ratio of the estimated water footprint and the projected population.

Table 4.3 Domestic and Industrial water use.

Sector	Population (M)	DWU ($10^9 m^3$/yr)	IWU ($10^9 m^3$/yr)
Rural	12.01	0.09	0.02
Urban	9.68	0.37	0.06
Total	21.69	0.46	0.07

A large volume of rural water used is obtained from groundwater while that of the urban is mainly from surface water. As the Ghanaian population increases, with people adopting water demanding lifestyles, and more people keep on moving into urban areas, household water withdrawals will undoubtedly increase. Notwithstanding the availability of water to meet water supply, there are deficits in coverage. While urban water supply coverage was estimated at 55% in 2004 (MWRWH, 2007), the rural and small town coverage was 51.6% (CWSA, 2004). The industrial (agro processing firms) water use was estimated to be 0.07 billion m^3/yr. Most industries receive their water needs from GWCL. Some on the other hand meet their water needs by the use of ground water. Domestic water consumption was estimated to be 0.46 billion m^3/yr. The main source of domestic and industrial water is mainly blue water, though occasionally rain water is harvested for domestic purposes.

5.4. EXTERNAL WATER FOOTPRINT

The study shows that Ghana exports more water in the virtual form (embedded in the agricultural commodities) than it imports, which makes the nations less dependent on water resources elsewhere in the world. In the period 2001-2005 Ghana imported 2.19 billion m³/yr of water in virtual form (in the form of agricultural commodities), while it exported 16.79 billion m³/yr (both raw and processed commodities). The export commodities include agricultural produces in the raw state and processed agro-based products.

5.4.1. Virtual Water Flows in Relation to the Trade in Agricultural Goods

Table 4.4 Main Agricultural Exports

CROP	CWR(m³/ha) A	CY(ton/ha) B	virtual (m³/ton) C = A/B	Quantity(ton/yr) D	Volume(10^9 m³/yr) E = C*D
Pineapple	5667.50	50.00	113.35	48993.60	0.01
Cotton Seed	5259.38	0.80	6574.22	9661.60	0.06
Yam	3523.84	12.50	281.91	13034.80	0.00
Oranges	10483.98	35.00	299.54	5488.80	0.00
Tinda	6870.05	6.40	1073.45	1176.33	0.00
Tomatoes	5932.91	7.50	791.05	2895.20	0.00
Pepper/Chillies	5413.36	6.50	832.82	3081.40	0.00
Garden Eggs	4949.03	8.00	618.63	1099.00	0.00
Banana	16674.76	8.50	1961.74	1738.00	0.00
Mangoes	14657.00	11.00	1332.45	275.00	0.00
Pawpaw	11359.63	45.00	252.44	2429.40	0.00
Cocoa	14050.96	0.40	35127.40	460982.50	16.19
Total					16.28

Table 4.3 shows the export commodities considered in the research. These include products that are exported in the raw state. The export of cocoa bean was responsible for 16.19 billion m³/yr of the virtual water export. Cotton seed (0.06 billion m³/yr) and pineapple (0.01 billion m³/yr) were crops exported in significant volumes.

The production of cocoa has a positive impact on the economy of the country. Cocoa generates economic benefits to the country with the use of the resource (rainwater or green water) that has relatively low opportunity cost (if compared to ground- and surface water). Although rainwater appropriated for cocoa will often have fewer alternative use (e.g. production of another crop or natural vegetation) that might provide higher economic return. Most of the exported pineapples were produced by agro-business under irrigation scheme (blue water). The export of pineapple means the export of a portion of nations blue water.

Table 4.5 Virtual Water Flows in Relation to the Trade in Industrial Goods

Processed goods	Virtual (m^3/ton) A	Quantity(ton/yr) B	Product Fraction C	Value Fraction D	Volume (10^9 m^3/yr) E = (A*B*D)/C
Cashew Nuts	10610.91	15380.00	1.00	1.00	0.16
Cocoa Waste	35127.40	8908.67	1.00	1.00	0.31
Raw/ Lint Cotton	6574.22	12335.60	0.63	0.21	0.03
Robusta Coffee	9367.31	1279.60	1.00	1.00	0.01
Total					0.52

Cocoa waste is the main contributor of the industrial goods consisting of 59.6% (0.31 billion m^3/yr). Cashew nuts and lint cotton also showed significant volumes. The total volume of virtual water export through the export of processed goods was 0.52 billion m^3/yr. The import of cereals was responsible for 1.9 billion m^3/yr of virtual water import. Other agricultural commodities responsible for significant virtual water import to Ghana were livestock production (0.29 billion m^3/yr).

5.5. VIRTUAL WATER BALANCE

The virtual-water export (outflow, 16.79 billion m³/yr) of Ghana is the volume of virtual water associated with the export of goods or services from the country. It is the total volume of water required to produce the goods for export. The virtual-water import (inflow, 2.19 billion m³/yr) of Ghana is the volume of virtual water associated with the import of goods or services into the country. It is the total volume of water used (in the exporting countries) to produce the products. From the viewpoint of Ghana, this water is an additional source of water that comes to add up to the domestically available water resources, so in effect Ghana partially depends on water resources elsewhere.

The net import of virtual water (14.60 billion m³/yr) is equal to the gross import of virtual water minus the gross export. A positive virtual-water balance implies net inflow of virtual water into the country from other countries. A negative balance means net outflow of virtual water. The net import of virtual water estimated was negative which implies more water flows out of Ghana than what flows into the country (in the form of agricultural commodities).

It should be noted however that most of the export products depends on the nation's green water which is one of the best use we could put that resources. Also it should be noted that international trade in agricultural commodities depends on a lot more factors than just water, such as availability of land, labour, knowledge and capital, competitiveness in certain types of production, domestic subsidies, export subsidies and import taxes.

CHAPTER FIVE

6. CONCLUSION AND RECOMMENDATIONS

6.1. CONLUSIONS

The estimated water footprint of Ghana is 24.84 billion m^3/yr. The use of domestic water resources accounts for 22.65 billion m^3/yr (91.2%) of the estimated water footprint. While 2.19 billion m^3/yr of the water consumed is from foreign water sources. The majority of the water that is consumed is embedded in crop. The consumptive component of the per capita water footprint of a Ghanaian was found to be 1145 m^3/cap/yr. This implies on the average a Ghanaian consumes 1145 m^3/yr through the consumption of the goods and services considered.

The estimated domestic water use and industrial water use are 0.46 billion m^3/yr and 0.07 billion m^3/yr respectively. The main source of domestic and industrial water is mainly blue water. The estimated agricultural water use is 38.91 billion m^3/yr. Green water is the resource mainly used in the cultivation of the crops considered. Water used in the rearing of livestock is made up of both blue and green water. The agricultural water use is greater than the national water footprint because, out of the 38.91billion m^3/yr of water used in the production of the agricultural commodities 16.79 billion m^3/yr is exported out of the country. The components of the estimated water footprint indicate that the nation depends more on its green water than the blue water.

The virtual water balance estimated was 14.60 billion m^3/yr. The virtual water balance is the difference between the gross virtual water import and export. In totality 14.60

billion m³/yr of water is exported out of the country annually through the exportation of the commodities considered. The highest volume of water exported is through the exportation of cocoa beans and cocoa related products. The study results indicate that most of the export products depend on the nation's green water.

6.2. RECOMMENDATIONS

Based on the study conducted the following recommendations are hereby made;

1. Decision makers should be introduced to the concept of water footprint and virtual water to help them in policy formulation.

2. Ghana Irrigation Development Authority, Ministry of Food and Agriculture and Water Resources Commission should encourage the construction of reservoirs downstream where feasible to harness the excess blue water that flows to the sea annually.

3. Further studies should be carried out on the water footprint of the nation considering also the contaminative component and non-edible goods.

4. Green water (soil moisture) can be harnessed for agriculture. The management of green water is really more about land management than conventional water management, there is therefore the need for Water Resources Commission to increase education on tree planting and bush fire control.

5. It is necessary for various industries to assess their water footprint. Such an activity will ensure better water resources planning and thus an improvement in Water Resources Management (WRM).

REFERENCE

Allan, J.A., (1993). Fortunately there are substitutes for water otherwise our hydro-political futures would be impossible. In: Priorities for water resources allocation and management, ODA, London, pp 13–26

Allan, J.A., (1994). Overall perspectives on countries and regions. In: Rogers P, Lydon P (eds) Water in the Arab World: perspectives and prognoses. Harvard University Press, Cambridge, Massachusetts, pp 65–100

Allen, R.G., Pereira, L.S., Raes, D., Smith, M., 1998. Crop Evapotranspiration Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper, vol. 56. FAO, Rome.

Asuming-Brempong S., (2003). Roles of Agriculture Project International Conference. National Report Ghana. Agricultural and Development Economics Division (ESA)
Food and Agriculture Organization of the United Nations. Pp 3-4.

Buiteman, J. P. (LN 0087/07/1). Water Treatment Processes and Plant Parts 1-Introduction and Design Aspects. UNESCO-IHE, Institute of Water Education. Lecture Material, p. 2.1

Chapagain A. K. And Hoekstra A. Y. (2004). Water Footprint of Nations. Volume One: Main Report. Value of Water. Research Report Series No.16. Pp. 25-30. Accessed on 20/10/2008

Chapagain A. K. And Hoekstra A. Y. (2004). Water Footprint of Nations. Volume Two: Appendices. Value of Water. Research Report Series No.16. Pp. 25-30. Accessed on 20/10/2008

Chapagain AK, Hoekstra AY, Savenije HHG (2005a) Saving water through global trade. Value of Water Research Report Series No. 17, UNESCO-IHE, Delft, the Netherlands. Online: http://www.waterfootprint.org/Reports/Report17.pdf. Accessed on 08/07/2008

Chapagain AK, Hoekstra AY, Savenije HHG, Gautam R (2005b). The water footprint of cotton consumption. Value of Water Research Report Series No. 18, UNESCO-IHE, Netherlands. Online: http://www.waterfootprint.org/Reports/Report18.pdf. Accessed on 07/08/2008

Clarke, B., (2000). Performance Evaluation of a Water Distribution Network with the Help of a Computer Model; A Case Study at Breman Asikuma in the Central Region Ghana. Pp. 25, appendix III.

Cobuild C. (2004). Advanced Learner's English Dictionary. New Edition. HarperCollinsPublishers, the University of Birmingham, UK. 1696 pp.

Community Water and Sanitation Agency, CWSA (2005). Small Communities Water and Sanitation Policy. Design Guidelines. Pp. 6

Debrah E. R. (2006). Borehole Management. A Case Study of the Overseas Area of West Mamprusi. University for Development Studies. Tamale. 1pp.

Falkenmark, M., 2003. Freshwater as shared between society and ecosystems: from divided approaches to integrated challenges. Philos. Trans. R. Soc. Lond., B Biol. Sci. 358, 2037–2049.

FAO (2004b): Review of global agricultural water use per country, Food and Agriculture Organization, Rome. Online: http://www.fao.org/landandwater/aglw/aquastat/water use/index5.stm. Accessed on 08/07/2008

Ghana Irrigation Development Authority, GIDA (2008). Inventory of Irrigation and Drainage Facilities. FAPIM: The Project for Promotion of Farmers' Participation in Irrigation Management Inventory of Irrigation and Drainage Facilities. Ghana.

Ghana Irrigation Development Authority, GIDA (2003). Outline of Ghana Irrigation Development Authority Schemes.

Ghana Statistical Services, GSS (2000). 2000 Population Census.

Ghana Statistical Service, GSS (2000). Poverty Trends in Ghana in the 1990s. Accra, Ghana.

Hoekstra AY, Hung PQ (2002) Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade. Value of Water Research Report Series No. 11, UNESCO-IHE Institute for Water Education, Delft, the Netherlands. Online: http://www.waterfootprint.org/Reports/Report11.pdf. Accessed on 08/07/2008

Haddadin MJ (2003). Exogenous water: A conduit to globalization of water resources. In: Hoekstra AY (ed) Virtual water trade: Proceedings of the International Expert Meeting on Virtual Water Trade. Value of Water Research Report Series No. 12, UNESCO-IHE, Delft, the Netherlands. Online: http://www.waterfootprint.org/Reports/Report12.pdf. Accessed on 27/ 08/2008

Henson S., Anim-Somauah H., and Asuming-Brempong (2006). Market Access and Private Standards: Case Study of the Ghana Fruit Markets. Pp-5

Minta A. A. (2006). ECA Africa Water Workshop on Developing Guidelines for Inter-Basin Water Transfer for Policy Makers in Africa, A Case Study from Ghana. Ministry of Water Resources, Works and Housing, Ghana. Pp. 61

Ministry of Food and Agricultural (MOFA), Ghana (2006). Agricultural in Ghana, Facts and Figures. Pp 1-54.

Ministry of Food and Agriculture (MoFA), 1991. "Agriculture in Ghana: Facts and Figures", PPMED, Accra.

Ministry of Water Resource, Works and Housing (MWRWH), Ghana (2007). National Water Policy. 2-5 pp.

Oki, T. and Kanae, S. (2004): Virtual water trade and world water resources, Water Science & Technology, 49(7), 203–209.

Postel, S.L., Daily, G.C., Ehrlich, P.R., 1996. Human appropriation of renewable fresh water. Pp 271, 785–788.

Shiklomanov, I.A., 2000. Appraisal and assessment of world water resources. Water International 25 (1), 11–32.

Vörösmarty, C.J., Green, P., Salisbury, J., Lammers, R.B., 2000. Global water resources: vulnerability from climate change and population growth. Science 289, 284–288.

World Bank, (1988). Ghana Forest Resource Management Project (Staff Appraisal Report). Western Africa Division, World Bank, Washington D.C.

Pixdaus.com/single.php?id=1740. Accessed on 20/02/2009

Zygmunt J. (2007), Waterwise. HIDDEN WATERS. Online: www.waterwise.org.uk. Accessed on 12/10/2008

APPENDIX

APPENDIX A

List of Persons/Organization Contacted / Interviewed

Water Resources Commission Mr. Aaron Aduna White Volta Basin Officer-WRC, Bolga Cell: 0242074137 Tell: 072 23391 Email: aaronaduna@yahoo.com	Ghana Cocoa Board Mr. Francis Osei-Owusu Research, Monitoring and Evaluation Dept. Cell: 024 2156380/020 8212678 Tell: 021 674296 Email: fosei-owusu@cocobod.gh
Ghana Water Company Limited Mr. Francis Lamptey Cell: 024 4252414	Community Water and Sanitation Agency Dr. Ing. Philip Gyau-Boaky Chief Executive Cell: 020 8170581 Tell: 021 518401/518404 Email: pgboakye@yahoo.com
Ghana Water Company Limited Mr. Christian Siawu Cell: 024 2354981	Community Water and Sanitation Agency Miss Charlotte A. Engmann Water and Sanitation Co-ordinator Cell: 024 3571116 Tell: 021 775737 Email: cengmann2001@yahoo.co.uk
Ghana Irrigation Development Authority Mr. Kwabena Boateng Director, Project Development Cell: 024 2320697 Tell: 021 662050/ 668661 Email: kwabenaboateng07@yahoo.com	Ghana Irrigation Development Authority Mr. Daniel Lampter
Ministry of Food and Agricultural Statistics, Research and Information Directorate Mr. Benjamin Cell: 020 8824365	Produce Buying Company Limited Mr. A. Frimpong Chief Accountant Cell: 020 8121019 / 024 4111311 Tell: 021 783889 Email: kingfrimp@yahoo.com
Ministry Works and Housing Mr. Wise Ametefe Head of Drainage Cell: 024 4384254 Tell: 021 666694 Email: valencewise@hoymail.com	Participant Consulted Mr. E. S. Kogo Mr. D. Yamaoh-Antwi Mr. E. Abaka-Yankson

APPENDIX B Crop Water Requirement

	Length of growth stages(days)						Crop coefficient			
Crop	Ini	Dev	Mid	Late	ETo(mm/day)	Kc ini	Kc mid	Kc end	ETc(mm)	CWR(m³/ha)
Maize	20	35	40	30	15-Jun	0.3	1.2	0.5	298.2375	2982.375
Rice(paddy)	30	30	80	40	15-May	1.05	1.2	0.6	927.16875	9271.6875
Millet	15	25	40	25	15-Jun	0.3	1	0.3	212.652	2126.52
Sorghum	20	35	40	30	01-Jun	0.3	1	0.55	271.0565	2710.565
Cassava	20	40	90	60	01-Apr	0.3	1.1	0.5	584.002	5840.02
Cocoyam	20	40	90	60	01-May	0.5	1.1	0.95	687.005	6870.05
Yam	25	30	25	10	01-Mar	0.5	1.1	0.95	352.384	3523.84
Plantain	120	60	180	5	01-Feb	1	1.2	1.1	1667.476	16674.76
Groundnut	35	45	35	25	01-Nov	0.4	1.15	0.6	495.60225	4956.0225
Cocoa	120	60	180	5	15-May	0.9	0.95	0.95	1405.096	14050.96
Coffee	120	60	180	5	15-May	0.9	0.95	0.95	1405.096	14050.96
Cotton S	30	50	60	55	01-Jun	0.35	1.2	0.6	525.9375	5259.375
Tobacco	20	30	30	30	15-Feb	0.5	1.15	0.8	457.984	4579.84

APPENDIX C Specific Water Demand

	SPECIFIC WATER DEMAND		
		Yield per ha(ton/ha)	
Crop	CWR(m³/ha)	CY(ton/ha)	SWD(m³/ton)
Maize	2982.375	1.6	1863.984375
Rice(paddy)	9271.688	2	4635.84375
Millet	2126.52	0.8	2658.15
Sorghum	2710.565	1	2710.565
Cassava	5840.02	12.4	470.9693548
Cocoyam	6870.05	6.4	1073.445313
Yam	3523.84	12.5	281.9072
Plantain	16674.76	8.5	1961.736471
Groundnut	4956.023	0.9	5506.691667
Cocoa	14050.96	0.4	35127.4
Coffee	14050.96	1.5	9367.306667
Cotton S	5259.375	0.8	6574.21875
Tobacco	4579.84	1.6	2862.4

APPENDIX D Crop Yield Per Hectare

Crop	Yield (Mt/Ha)	Achievable Yield (Mt/Ha)[2]
Cassava	12.4	48.7
Plantain	8.5	20.0
Yam	12.5	49.0
Cocoyam	6.4	8.0
Maize	1.6	6.0
Rice (Paddy)	2.0	6.5
Cowpeas	0.8	2.6
Soybean	0.8	2.3
Groundnut	0.9	2.5
Millet	0.8	2.0
Sorghum	1.0	2.0
Sweet Potato	8.0	24.0
Taro	9.5	12.0
Cocoa	0.4	1.0
Coffee	1.5	-
Cashew	0.8	1.8
Orange	35.0	-
Pawpaw	45.0	75.0
Mango	11.0	-
Pineapple	50.0	72.0
Cotton	0.8	-
Rubber	0.8	-
Tobacco	1.6	-
Tomato	7.5	15.0
Garden eggs	8.0	15.0
Pepper	6.5	32.3
Oil Palm	6.2	

Soures : MOFA, 2007

APPENDIX E Annual Crop Production

Crop	2001	2002	2003	2004	2005	Average	Quantity(ton/yr)
Maize	938	1400	1289	1157.6	1171.4	1191.2	1191200
Rice(paddy)	253.2	280	239	241.8	236.5	250.1	250100
Millet	134.4	159.12	176	143.8	154.6	153.584	153584
Sorghum	279.7	316.1	337.7	287.4	299	303.98	303980
Cassava	8965.8	9731	10239.3	9738.2	9567.2	9648.3	9648300
Cocoyam	1687.5	1860	1804.7	1715.9	1685.8	1750.78	1750780
Yam	3546.7	3900	3812.8	3892.3	3922.8	3814.92	3814920
Plantain	2073.8	2278.8	2328.6	2380.8	2791.6	2370.72	2370720
Groundnut	286.8	520	439	389.6	420	411.08	411080
Cocoa	389,772	340,563	496,846	736,975	740,458	540922.8	540922.8
Coffee	1,379	1,464	2,100	11,050	20,000	7198.6	7198.6
Cotton S	17,506	22,851	16,822	20,155	21,000	19666.8	19666.8
Tobacco	1,233	2,155	2,150	2,359	1,350	1849.4	1849.4

APPENDIX F Agricultural Water Use With Respect To Crop

Crop	SWD(m^3/ton)	Quantity(ton/yr)	AWU(m^3/yr)	AWU(billionm^3/yr)
Maize	1863.984	1191200	2220378188	2.220378188
Rice(paddy)	4635.844	250100	1159424522	1.159424522
Millet	2658.15	153584	408249309.6	0.40824931
Sorghum	2710.565	303980	823957548.7	0.823957549
Cassava	470.9694	9648300	4544053626	4.544053626
Cocoyam	1073.445	1750780	1879366584	1.879366584
Yam	281.9072	3814920	1075453415	1.075453415
Plantain	1961.736	2370720	4650727886	4.650727886
Groundnut	5506.692	411080	2263690810	2.26369081
Cocoa	35127.4	540922.8	19001211565	19.00121156
Coffee	9367.307	7198.6	67431493.77	0.067431494
Cotton S	6574.219	19666.8	129293845.3	0.129293845
Tobacco	2862.4	1849.4	5293722.56	0.005293723

APPENDIX G Domestic Meat Production (Metric Tons)

Livestock	2001	2002	2003	2004	2005
Cattle	19,053	18,288	18,486	18,686	18,874
Sheep	12,780	13,149	13,568	14,004	14,450
Goats	12,037	12,597	13,884	15,308	15,300
Pigs	9,653	10,416	10,181	9,979	9,744
Poultry	14,580	19,401	21,116	22,982	22,709

APPENDIX H Agricultural Water Use With Respect To Livestock

Livestock	Quantity(ton/yr)	Virtual (m^3/ton)	Value fraction	Product fraction	AWU (m^3/yr)
Cattle	18677.4	13795	0.87	0.52	431076188
Sheep	13590.2	3386.8	1.00	1.00	46027289.4
Goats	13825.2	3087.5	1.00	1.00	42685305
Pigs	9994.6	3616.3	1.00	1.00	36143472
Poultry	20157.6	4918.80	1.00	0.78	127116927

APPENDIX I Import Of Livestock and Livestock Product

Type	2001	2002	2003	2004	2005
Beef	73.2	901.3	1112.4	2586.8	6331.7
Buffalo	81	162.2	249.6	1169.2	2257.1
Chicken	6731.5	19986	32939	39088.6	40591
Turkey	74.1	766.3	1164.5	1268.7	1697.2
Duck	2	0	4.1	0	0
Milk	1548.5	865.5	349.4	203.3	1555.1
Mutton	478.2	1285	2122.3	2053.4	3640.8
Pig	1166.1	7737.5	9882.3	7756.4	10286.8
Processed meat	80.4	133.9	0	256.2	270.4

APPENDIX J Volume of Virtual Water Import

Type	Quantity(ton/yr)	Virtual H_2O content (m^3/ton)	Product Fraction	Value Fraction	AWU(m^3/yr)
Beef	2201.08	13795	0.52	0.87	50801138
Buffalo	783.82	13795	1.00	1.00	10812797
Chicken	27867.22	4918.8	0.78	1.00	175734977
Turkey	994.16	6319	0.78	1.00	8053970.6
Duck	1.22	6319	0.78	1.00	9883.5641
Milk	904.36	1914.3	0.10	0.18	3116189.4
Mutton	1915.94	3862	0.77	1.00	9609558.8
Pig	7365.82	3616.3	1.00	1.00	26637015
Processed meat	148.18	14464.7	1.00	1.00	2143379.2

APPENDIX K Cereals Import

Crop	virtual(m^3/ton)	Quantity(ton/yr)	Product Fraction	Value Fraction	AWU(m^3/yr)
Wheat	1334	390299	0.79	0.89	5.87E+08
Rice	2291	485113	0.90	1.00	1.23E+09
Maize (Yellow	909	56667	1.00	1.00	51510303
Sorghum	2853	9933.12	1.00	1.00	28339191
Soya bean	1789	1125	0.85	1.00	2367794

APPENDIX L Volume of Virtual Water Export

CROP	CWR(m^3/ha)	CY(ton/ha)	Virtual(m^3/ton)	Quantity(ton/yr)	Volume(m^3/yr)
Pineapple	5667.5	50	113.35	46,694	5292765
Cotton Seed	5259.4	0.8	6574.2	7,355	48353379
Yam	3523.8	12.5	281.91	18,377	5180609
Oranges	10484	35	299.54	5,846	1751124
Tinda	6870.1	6.4	1073.4	1,136	1219434
Tomatoes	5932.9	7.5	791.05	4,369	3456118
Pepper/Chillies	5413.4	6.5	832.82	483	402254.1
Garden Eggs	4949	8	618.63	124	76709.89
Banana	16675	8.5	1961.7	1,117	2191260
Mangoes	14657	11	1332.5	407	542309
Pawpaw	11360	45	252.44	3,212	810825
Cocoa	14051	0.4	35127	531350	1.87E+10

APPENDIX M Volume of Virtual Water Export

Processed & Industrial	virtual (m^3/ton)	Quantity(ton/yr)	Product Fraction	Value Fraction	Volume(m^3/yr)
Cashew Nuts	10610.91	15380	1.00	1.00	163195738.1
Cocoa Waste	35127.4	8908.666667	1.00	1.00	312938297.5
Raw/ Lint Cotton	6574.219	12335.6	0.63	0.21	27032310.94
Robusta Coffee	9367.307	1279.6	1.00	1.00	11986405.61

APPENDIX N Major Irrigation Projects in Ghana

Project Site	Potential area (ha)	Developed area (ha)	Used area(ha)	Irrigation type
Tono	3840	2490	2450	Gravity
Kpong	3028	2786	616	Gravity
Weija	1500	220	210	Pump
Vea	1197	850	850	Gravity
Akumadan	1000	65	65	Pump
Afife	950	880	880	Gravity
Bontanga	570	570	430	Gravity
Dawhenya	450	200	150	Pump
Dedeso	400	20	8	Pump
Kpando-Torkor	356	40	6	Pump
Mankessim	260	17	17	Pump
Amate	203	101	80	Pump
Ashaiman	155	155	56	Gravity
Anum valley	140	89	76	Gravity &Pump
Subinja	121	60	6	Pump
Tanoso	115	64	64	Pump
Okyereko	111	81	42	Gravity &Pump
Golinga	100	40	16	Gravity
Aveyime	80	60	0	Pump
Sata	56	34	24	Gravity
Libga	40	16	16	Gravity
Kikam	27	27	0	Pump