MSc Program
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Analysis of Nile Water Scarcity in Egypt

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Vienna, 17.06.2011

Affidavit

I, **AHMED ELNAGGAR**, hereby declare

1. that I am the sole author of the present Master's Thesis, "Analysis of Nile Water Scarcity in Egypt", 70 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

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ABSTRACT

Population growth, economic development and agricultural development have continued to increase in Egypt's water demand. This has severely increased the stress factor on Egyptian policy makers. Sudden governmental moves, such as banning new export licenses for rice crops and making public statements that Egypt will not have enough water by the year 2017, have triggered the topic of Nile water scarcity in Egypt, an issue that was never made public before. However, no research to date has attempted to recalculate at least some of the data that has been publicly available, and summarizes the agricultural water needs just from Nile water. As agriculture is by far the largest water- consuming sector in Egypt, this study will attempt to compute the water consumption of each crop grown in Egypt. Along with data available from other sectors, it will try to predict whether or not there will be a scarcity situation by 2017. The study will also consider the political side of the scarcity issue that can no longer be ignored, and that now must be taken into consideration. Finally, the study will present some options toward a conflict resolution.

1. INTRODUCTION

At first, key background information relevant for this study is highlighted, respectively about water, Egypt, the Nile River and the Aswan Dam. Then, background information emphasizes on the current political and hydrological situation of the Nile River. Lastly, the objective of this study is stated before presenting the methodology.

1.1. Background

1.1.1. Water

The world's oldest civilizations started around rivers and water sources, such as the Egyptian civilization around the Nile. Water is not only used for drinking, but it is also a basic necessity for every aspect of human life: for instance, agriculture, food processing, chemical and mechanical uses, and transportation. Water is a substance that can exist in three different states: solid, as ice, liquid, as water, and in a gaseous state as water vapour. The earth's surface is comprised of 70.9% water and 29.1% land. 97% of it forms oceans. The composition of ocean water is salty, with 2.4% in glaciers, ice caps, and rivers (CIA, 2011b). The importance of water has also been stressed in most world religions, starting with the 'Cimbres' culture 60000-80000 years ago (Rives, 1999).

Lately, the scarcity of water has become not just an environmental topic, but also a very hot political debate that some believe will lead several countries to war in the future. The reason behind that simply, is that water is a necessity for human life and if it gets scarcer, humans will start fighting to survive. Many countries and organizations like the United Nations (UN) have put targets to improve availability of clean drinking water, such as the Millennium development goals, where the claim is that already some 1.6 billion (bil) people have gained access to safe drinking water since 1990. The goal is to provide an additional 1.5 billion people with clean and safe drinking water.

Scarcity of water, as illustrated in *Figure 1*, is just as big a problem as the lack of an available clean drinking source, as stated by the UN, to the point that almost half of the world's population will not have water available in the first place.

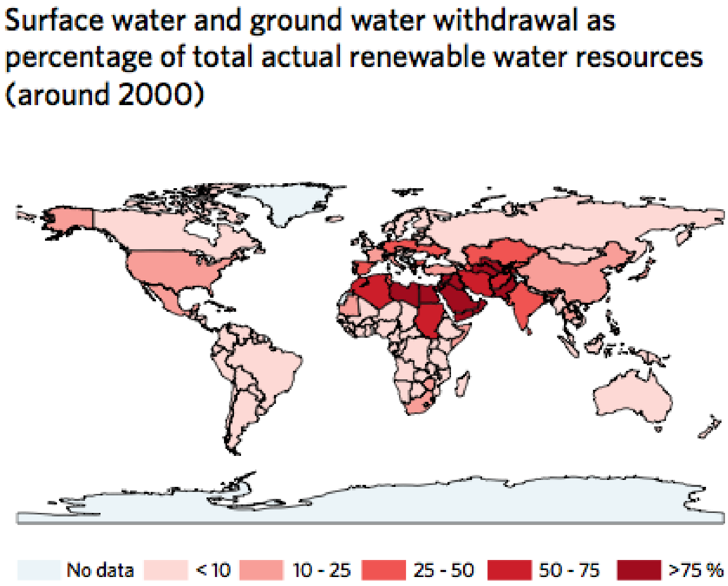


Figure 1: Water scarcity in the world (source: Coleridge, 2006)

1.1.2. Egypt

Egypt's land area is around 1,000,000 km^2 and is mainly situated in North Africa, but also with a significant fraction of its land, the Sinai Peninsula, in Southwest Asia. It is also Africa and the Middle East's most populous country. The Nile played a major role in founding the Egyptian civilization thousands of years ago. Historians even argue that ancient Egyptians could not have existed without the Nile, as Northern Africa hardly gets any rainfall. The majority of historic and cultural discoveries made in Egypt are found along the Nile. Ancient Egyptians farmed and lived along the river; they used the fertile soil for survival, and its water for everything from building to crafting tools, as well as their major drinking source. Major inventions connected to agriculture emerged in Egypt, like wine and beer, for example (Homan, 2004). Ancient Egyptians were also able to produce Papyrus paper made from reeds that grew along the banks of the Nile, allowing them to document their lives. This factor helped historians explain the long and complicated history of the Pharaohs.

Every year for over 7000 years, from June to September during the flooding season, the waters of the Nile rose to irrigate and fertilize the land. This natural process stopped in 1970 after the completion of the Aswan dam, constructed in southern Egypt. It was built to allow flood control and allow irrigation for the entire year, not only for a few months (cf. Egyptian Ministry of Agriculture and Land Reclamation). As of April 2011, Egypt's population was estimated to be around 81,000,000, where in 2006 it had a population of just fewer than 76,000,000 (CIA, 2011a). With the population growing around 2% per year, the impact on water consumption has been growing dramatically, but Egypt's share of 55 billion m^3 Nile water per year, has not changed.

The Nile valley is the centre of economic activity in Egypt, especially since former Presidents Anwar Elsadat and Mohamed Hosni Mubarak opened the Egyptian market for foreign investments in the 1980s. The opening of the market, particularly to foreign investors, has increased the GDP per capita from US$ 510 to US$ 6200 but has also had an impact on water distribution and usage (WB, 2011). The budget deficit climbed to over 8% of GDP, and Egypt's GDP growth slowed to 4.6% in 2009, predominantly due to reduced growth in export-oriented sectors, including manufacturing and tourism, and Suez Canal revenues (CIA, 2011b). In 2010, the government spent more on infrastructure and public projects, and exports drove GDP growth to more than 5%, but GDP growth in 2011 is unlikely to bounce back to pre-global financial recession levels, when it stood at 7%, especially after the events of the 25th of January when the Egyptian president resigned and ordered the Military Council of the Armed Forces (SCAF) to rule the country. It has been 4 months since then and the country is moving in a disastrous path. Crime has soared, especially murder, armed robbery, and kidnapping (Daily Mail Reporter, 2011). Foreign investments are being withdrawn and foreigners leave the country. Any new investments in the current year are most likely postponed until there is at least a new president or a clearer idea of who is in charge of the country.

1.1.3. The Nile River

The Nile River (cf. *Figure 2*) is located in the African continent and is the world's longest river, measuring approximately 6700 km in length. The river has two major tributaries: the Blue and the White Nile. Originating from the Great Lakes region of

Central Africa in southern Rwanda, the White Nile flows north through Tanzania, Lake Victoria, Uganda and finally southern Sudan. The Blue Nile, instead, flows into Sudan from the Southeast starting at Lake Tana in Ethiopia. The two tributaries meet near Khartoum, the capital of Sudan. The White Nile is much longer than the Blue Nile, but it only contributes 15% to the combined Nile flow, while the Blue Nile contributes around 85%. The northern section of the river flows entirely through desert, going from Sudan to Egypt. The flow of the Nile starts to split into two branches north of Cairo. The first branch, called the Rosetta branch, flows to the west, while the second, the Damietta, flows to the east. Both branches form the Nile Delta subsequently flow into the Mediterranean Sea. The drainage basin of the Nile covers approximately 3,254,555 square kilometers, which represents 10% of the land area of Africa (Revenga et al., 1998). The source of the Nile is thought to be Lake Victoria, Africa's biggest lake. On the northern part of Lake Victoria there is a waterfall, the Ripon Falls, which Geologists believe is the beginning of the Nile because it is not proven to 100% certainty. Modern geologists claim that the Kagera River in Burundi is the true source of the Nile.

Overall, the Nile flows through ten African countries: Tanzania, Rwanda, DRC (Democratic Republic of Congo), Ethiopia, Uganda, Burundi, Kenya, Sudan, and Egypt. The official combined population of the 10 basin countries is estimated at 300 million people, of whom 160 million live in the basin area. Egypt has by far the highest reliance on the Nile (most of its fresh water), followed by Sudan.

Egypt's dependence on the river becomes obvious when we consider that most major cities are situated on the Nile: Aswan, Luxor, Suhag, Assiut, Minya, Helwan, and Cairo. The Aswan Dam has had a great impact on the country. On the one hand, it allowed an increase in agricultural area by a third, and has protected Egypt from various droughts in the 1970s and 1980s that instead had devastating effects on other East African countries. On the other hand, the dam has had some negative impacts on agriculture. For example, agricultural fields became waterlogged as a result of silt deposits that build up in the reservoir. The fertility of delta lands has also been reduced because nutrients blocked behind the dam are no longer carried and deposited by the Nile along its shores.

The distribution of water among Nile Basin countries has been governed by treaties dating back to colonial times, and some of them go back to the 19th century. However, some countries would like to see a better redistribution of the Nile water, and this issue has been a source of conflict among them. With an ever-increasing need for water, Egypt would like to get a greater share of the Nile water while other basin countries would like to reduce its share.

Figure 2: The Nile River (source: ADDIS ABABA, 2011)

1.1.4. Aswan Dam

In essence, the Aswan Dam is comprised of two dams located on the Nile River on Egyptian soil. The first dam was built in Aswan in 1902, and was designed for irrigation purposes. The second and most important dam, also called the Aswan High Dam, was built in 1970 a few kilometers upstream from the first dam. It is considered to be one of the world's largest power-irrigation projects.

The initial construction measured 2 km long and 40 m thick. The height of the dam was increased in 1912 and again in 1933 to reach 58.3 m. The Aswan High Dam, measures 111 m in height and 3.2 km in length. One of the world's largest manmade lakes, Lake Nasser, also acts as the dam's reservoir. The water from the reservoir is mainly used to store water and to power turbines with the capacity to generate 2,100,000 kilowatts of electricity.

Construction of the Aswan High Dam was the beginning of both international tensions between Egypt, the United States, and the United Kingdom on one hand, and cooperation between Egypt and the former Soviet Union on the other. When Egypt announced in 1953 that it would build the Aswan High Dam, both the United States and Great Britain offered financial aid for the project only to withdraw their offer in 1956 as a protest against Egypt's plan to purchase weapons from communist Czechoslovakia. Following the conflict with the United States and the United Kingdom, former Egyptian President Gamal Abdel Nasser seized control of the British-owned Suez Canal announcing that he would use the revenues from the canal to build the Aswan High Dam. Simultaneously, he accepted the Soviet Union's offer of significant financial and technical assistance to build the dam.

Construction of the dam began in 1960. There were serious issues at hand given that the work required the permanent flooding of the Nile Valley in Egypt and northern Sudan, including the destruction and flooding of a great number of ancient art treasures and temples dating back to 13 century BC. Under the sponsorship of the United Nations Economic, Scientific, and Cultural Organization, international teams of archaeologists removed as many artefacts as they could before the waters of the reservoir submerged them forever. The Abu Simbel temples were cut into blocks, moved up a cliff, and reassembled above the water line. Some of the relics were given to foreign nations in exchange for aiding Egypt in the effort to save the art treasures of the area (Discovery Communications, 2011).

1.1.5. Developments between Basin Countries

On the 14th of May 2010 four African countries signed a new agreement between them to redistribute their water share of the Nile: Rwanda, Ethiopia, Uganda and Tanzania. Four other countries showed their support for the agreement but didn't sign it. Kenya became the fifth country to sign the agreement on May 18th (SAPA and AFP, 2010). Ethiopian and other African news agencies called the signing of this new agreement a 'wake-up' call for Egypt, as they believe that Egypt considers the Nile to be its own. According to AFP news, Cairo had distanced itself from any discussion that would change the terms of the treaties signed in 1929 and 1959, guaranteeing 90% of Nile water to Egypt.

The new agreement includes terms that would be considered a 'death sentence' for Egypt. Ethiopian Prime Minister Meles Zenawi stressed that his country did not intend to back down from the new agreement over water sharing, and invited Egypt to make concessions. "Some people in Egypt have old-fashioned ideas based on the assumption that the Nile water belongs to Egypt," Zenawi recently told Al-Jazeera television. "The circumstances have changed and changed forever," he said, adding that "the way forward is not for Egypt to try to stop the unstoppable. The way forward is to seek a win-win solution through diplomatic efforts" (de Roquefeuil, 2010).

Currently, Egypt and Sudan have the backing of other nations, for example Italy, where Prime Minister Silvio Berlusconi reassured former President Mubarak of Egypt, saying: "We pledged... to undertake diplomatic moves towards certain countries, starting with Ethiopia, with whom there are still outstanding problems, primarily with regard to the use of Nile waters." Al-Ahram's (largest Egyptian newspaper) Centre for Strategic Studies responded by saying: "We [Egyptians] owe better understanding to our partners, and to remember that we are also Africans, not only Egyptians or Arabs." This comment was made because it is widely believed that Egypt, as the most powerful and stable nation on the continent, has been neglecting its role in Africa.

As of the 21st of May 2010 the conflict has taken a sharp dive to the worst when Ethiopian Prime Minister Meles Zenawi criticized Egypt's refusal to re-distribute Nile waters between the basin countries. In comments on Al-Jazeera news channel on the 21st of May 2010, PM Zenawi repeated that Egypt does not have the right to decide on the water share of each country, and that Egypt "will not be able to stop Ethiopia or prevent it from building dams on the river" (Hamdullah, 2010). On the same day, the Kenyan Minister of Water Resources, Charity Ngilu, said, "The 1929 treaty is obsolete, and there is nothing to stop us from using the Nile's waters as we please." He also added that Egypt "has no choice except to approve the new agreement." Egypt's Water Resources and Irrigation Minister responded by saying: "Any project that takes away from the river's flow has to be approved by Egypt and Sudan in accordance with international treaties" (Reuters News, 2010). This statement relies on the 1929 treaty that gives Egypt veto powers to block any project on the Nile, basically giving Egypt the right to decide the fate of any water project.

On the 18th of May 2010, Egyptian Foreign Minister Ahmed Nazif said that the Egyptian share of Nile waters "is a settled matter, practical and legal wise." Again, this shows that Egypt feels protected by international law (Zawya, 2010). Other high-ranking Egyptian officials were quoted as saying that “Tana Beles [the dam Ethiopia is planning to build] aims to provoke Egypt’s anger and lead it to taking swift diplomatic behaviour, which would turn global public opinion in favour of upstream Nile countries” (Reuters, 2010). It is also very important to note that Egypt has removed the Nile question from the Ministry of Water Resources and Irrigation and has delegated it to Egypt’s Mokhabarat (the Egyptian Intelligence Agency), as it believes that this has become a matter of national security. This is understandable considering that Egypt depends 95% on Nile water.

Since the arrival of several high-ranking politicians to Cairo to discuss the matter, including the Kenyan president, no new media updates have been available. This could mean that there has not yet been any major breakthrough to ease the conflict. An Egyptian Strategic expert on water security, Nur Abd-Al-mun'im Nur, said, "Egypt will never make an enemy out of a Nile Basin country. It is currently working for the talks and negotiations to continue.” He was also quoted as saying that Egypt “only wants her historical share of Nile waters and this is not making enemies out of the countries which have signed the new agreement. But when donor countries say they will not support these countries and fund any project on the Nile then it is on Egypt's side” (PTI , 2010). In the news of May 23rd 2010 when he was meeting President Mubarak of Egypt, Kenyan Prime Minister Raila Odinga said that neither Kenya nor any of the other Basin countries would take any action (meaning the new signed agreement) that could affect Egypt's water interests. Odinga asked for Egypt to lend Kenya and other countries technical support that would help them to achieve a more efficient water management, well digging, and water conservation (Zawya, 2010).

Egypt is virtually rainless. The inhabited area where rain falls does not exceed 3.5% of the total area, and is limited to a strip that borders the main coastline of the Nile from Aswan in the South to Cairo in the North, and the entire delta area. Agricultural land in Egypt is determined by climate and water availability, and follows the same spatial pattern and irrigation is predominant. As of 2006, Egypt’s per capita share of water was below 1000 cubic meters per year, and is expected to fall to less than 500 before 2030 when its population will exceed 100 million. This is just an estimate that in reality could climb upward of 115 million. Such a problem requires solutions, and puts pressure on agriculture, the main water-using sector (more than 85% of all extractions) (CEEPA, 2006). It will take several years of planning to rearrange crops and redistribute water.

1.2. Objective

As detailed in the previous section, the current situation in the Nile River region is critical. Especially for Egypt, as the situation could cause existential problems for the country.

This paper will examine whether Egypt will have enough water by the year 2017, and whether it is a political issue rather than a scarcity issue. Scarcity will be determined by the flow pattern, i.e. the inflow, or what is consumed and what flows into the Mediterranean Sea as outflow.

2. METHODOLOGY

In order to obtain answers to the problem, the methodology of this paper will consist of three sections, a political, scientific and an economic. This section of the paper will describe the methodological approach, as well as how the obtained and calculated data will be analyzed.

2.1. Political aspect

The political section of this study will try to identify the most important aspects and provide a reasonable interpretation of main treaties that concern water sharing. They will be described in detail, and their legality will be discussed from the viewpoints of the participants in the conflict.

The river Nile, which flows through ten different countries, should be governed under international watercourses conventions. However, the 1997 United Nations Convention on Watercourses, the only one of its kind, has not come into effect as of 2011 because the minimum requirement of having 35 members has not been achieved. This convention tries to establish rules that would allow for effective sharing of a watercourse. Ratification of the countries can be seen in Appendix 1.

Some treaties date back to the 1800s, and were signed under colonial rule in Africa. They specifically identify the rights and obligations of the Nile basin countries, but the problem is that the colonial powers signed the treaties on behalf of the local governments and people, thus positing the current question of their legality, which remains a controversial topic.

The fact that Egypt has been getting the largest share of Nile water for thousands of years is, legally speaking, jus cogens. Jus cogens is “the principles that form the norms of international law that cannot be set aside” (Oxford Dictionary). Therefore, according to international law principles, it could even be argued that Egypt’s use of Nile water has developed into the norm over the years, and that treaties are not necessary to secure Egypt’s share of Nile water. The main sources I intend to use include, the report *African Models for Transnational River Basin Organization in Africa: An Unexplored Dimension*, the treaties themselves, the United Nations website, and various other reports. The key message from the report is that a political problem does exist, and that a solution on a political level must be reached in order to avoid water scarcity problems for Egypt.

Dramatic changes have taken place in the last 20 years that concern two main players in the conflict: Ethiopia and Egypt.

2.2. Scientific aspect

In the scientific section, I will identify and compute data that will help to establish whether or not there will be a Nile water scarcity problem for Egypt. The goals are to create a sound water balance that will show how much water is being drawn from the Nile River, and to make a rough projection for Nile water scarcity for the year 2017.

Egypt's four main water-consuming sectors are agriculture, industry, household, and loss by evaporation, it is assumed that all water needs for these sectors are supplied by Nile water. According to data from the Central Agency for Public Mobilization and Statistics in Egypt, which will be presented in the results section, agriculture is by far the most water-consuming sector. In order to draw a water balance, where the inflow and outflow of Nile water from Egypt, as well as Nile water consumption within Egypt can be shown, I collected and computed some data. These data include computation of total agricultural Nile water consumption, and water usage from industry, household, and loss by evaporation.

Another very important set of data is taken from measurement stations along the Nile in Egypt. Their location can be seen in *Figure 3* (NB: The measuring stations were found in Abdelaziz and Gohar, 2010).

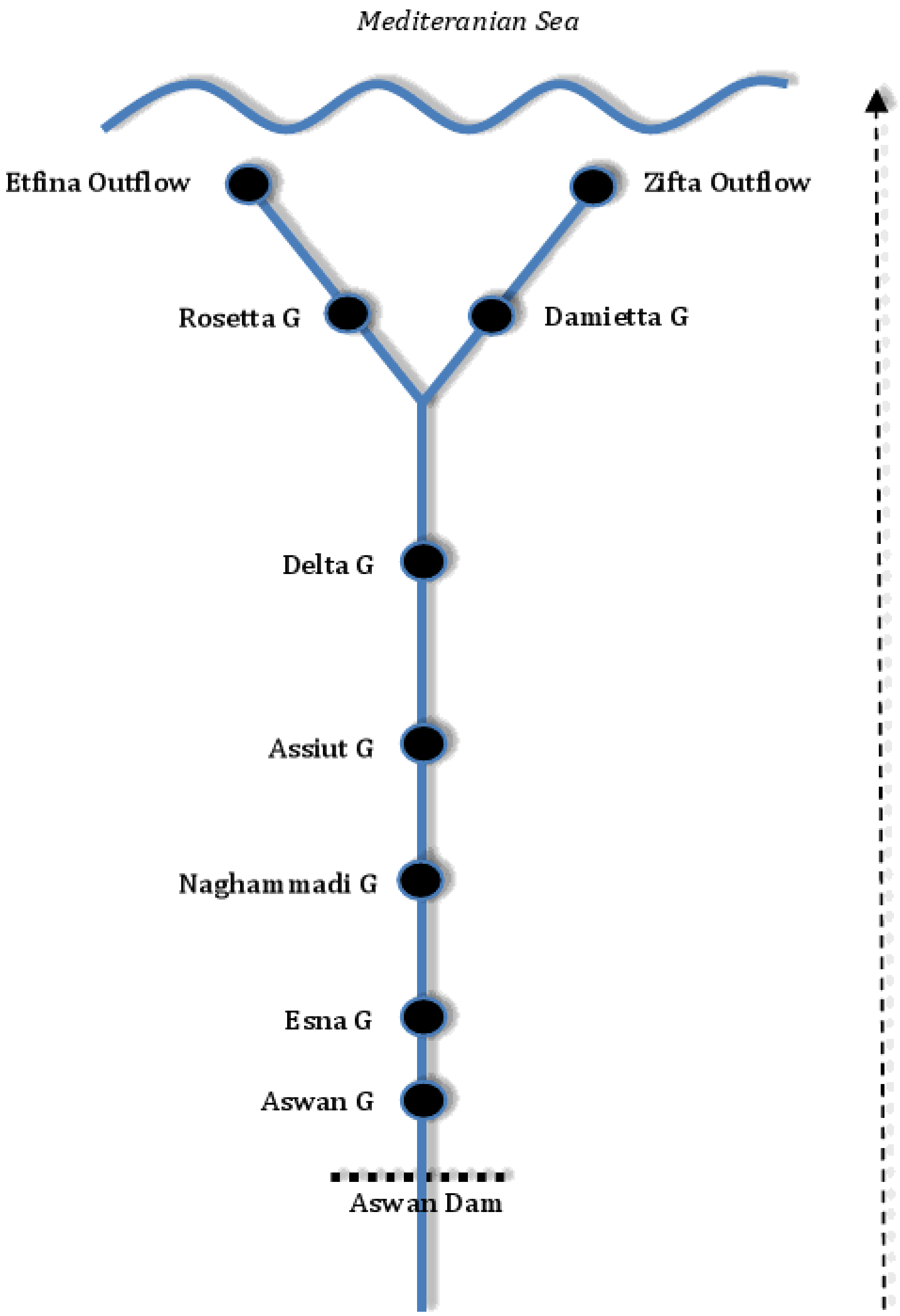


Figure 3: Nile water measuring stations in Egypt (source: own creation)

This section of the Nile River is in Egypt, and the black dots represent the measuring stations that measure flow quantities. To obtain the inflow data I will use the available measurement information from the ASWAN G station, and for the total outflow into the Mediterranean Sea the Edfina and Zifta outflow stations. The average of the previous five years will be taken if a required measurement is missing for one year. This will help in computing the Water balance.

I will consider data that looks at the crops grown in Egypt and the amount of Nile water consumption in m^3 per each ton of the crop's production. To accurately compute the water consumption for the agricultural sector, I will also consider animal products as agricultural crops.

As there is no information provided by the Egyptian Ministry of Agriculture and Land Reclamation about all available crops in Egypt, I will identify them through the Food and Agriculture Organization of the United Nations.

Water consumption is estimated by following the calculation framework in Hoekstra's report (Mekonnen and Hoekstra, 2010). A grid-based dynamic water balance model computes a daily soil water balance and calculates crop water requirements, actual crop water use, and actual yields. The crop water requirements could also be called water footprint of the crops.

For agricultural crops, the water footprint of a product is defined as the total volume of freshwater used to produce the product. There are three types of water footprint data. The blue water footprint refers to the volume of surface and groundwater consumed or evaporated (evapotranspiration) as a result of the production of a good; the green water footprint refers to the rainwater consumed; and the grey water footprint of a product refers to the volume of freshwater required to assimilate the load of pollutants based on existing ambient water quality standards (Mekonnen and Hoekstra, 2010). Although green water footprint will be shown, for the purpose of creating a water balance only data for the blue water footprint will be used. These footprint data, gathered in 2007, are available in a UNESCO-IHE research report published in December 2010 (Mekonnen, M., Hoekstra, A.Y., 2010). They will be used for all years, as it is assumed that no significant change in water footprint for Egypt has taken place. The blue water footprint for each crop (m^3 per ton) is multiplied by total production in tonnes of each crop in Egypt, thus obtaining the total agricultural blue water footprint in m^3 per year. Data about the total production of each crop is found on the website of the Food and Agriculture Organization of the United Nations. The time frame for the agricultural production comprises the years 2000, 2006, 2007, and 2008, beyond which no data is available yet. Crops with the highest blue water footprint are presented in relation to all other crops: this will prove that only a small number of crops are the reason for total high agricultural blue water footprint.

The official data presented by Egypt's Central Agency for Public Mobilization and Statistics will be used (but not computed) to determine industry and household water consumption, and losses by evaporation.

More necessary information is water availability. Nile water readings will be taken from measurement stations, as stated earlier, and data about groundwater, rain and floods, agricultural sewage recycling, and general sewage recycling will be taken from Egypt's Ministry of Agriculture and Land Reclamation. I make the assumptions that 1) 50% of agricultural sewage and sewage-recycled water will return to the Nile; 2) that some groundwater is available due to some rain quantity seeping into the ground and Nile water seeping away; 3) that most of the rain will evaporate.

To calculate the outflow into the Mediterranean Sea, I will apply the following formula: (the measured inflow of Nile water - groundwater availability) - (total agricultural blue water footprint) - (loss by evaporation + 50% of the total recycled sewage water) - (industry water consumption) - (household water consumption) = flow into the Mediterranean Sea. The calculated result of water flowing into the Mediterranean will then be compared to the actual measured outflow. Software called STAN (substance flow analysis) provided by the Technical University of Vienna will be used to perform the material flow analysis in the form of a flow chart.

A graphical model will be built with pre-defined components like flows and processes which can be seen in Figure 6a. The data inputs for the flows will be taken from measurements and calculations, which are mentioned above. Process for the Nile consists of Nile inflow, recycled water from Agriculture and recycled water from household and industry. The outflows are water for agriculture, household and industry, evaporation, Nile outflow, unknown losses and seeped away Nile water into the ground. Process for Groundwater consists of inflows of water from the deep underground, seeped away water from the Nile, seeped away water from Rain. Outflows consist of water flow to agriculture. For the Process Rain the inflows consists of Rain water, of which then the outflows go to the underground, some of it goes to agriculture and some is evaporated. The process household and industry consists of inflows from the Nile, and outflows consist of evapotranspiration Agriculture consists of inflows from groundwater, rain and Nile water. Outflows consist of evapotranspiration and sewage. The process of waste water treatment consist of water flowing in from the household and industry, of which then 50% flows back to the Nile and 50% is evaporated (both are the outflows). The process agricultural sewage recycled is consists of water flowing in from agricultural sewage, of which 50%flows back to the Nile and 50% is evaporated (both are the outflows).

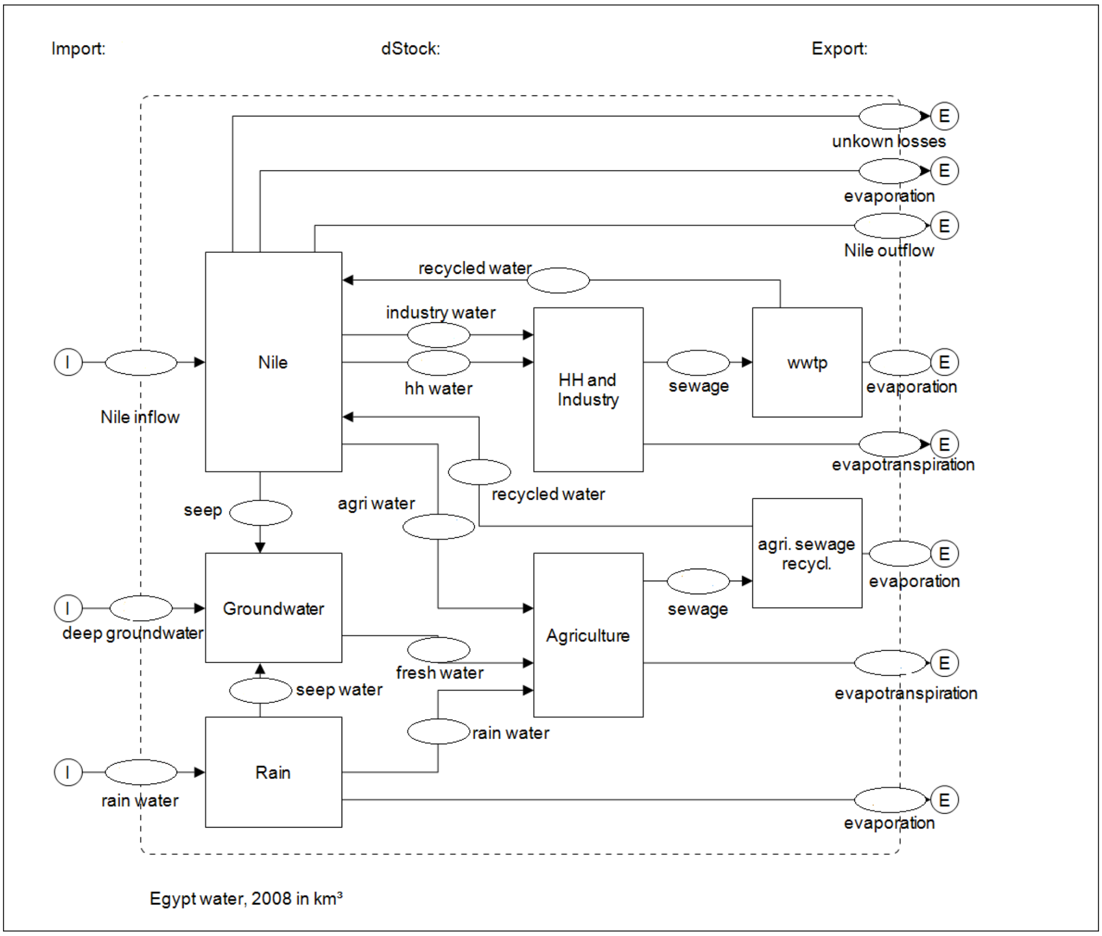


Figure 6a: Water flow Analysis using the STAN software (source: own creation)

Projections that will determine whether or not there will be scarcity by the year 2017 will be computed by considering the growth rate of the total blue water footprint from 2000 to 2008, and assuming that a similar growth rate will take place from 2008 to 2017. The same calculation method used to get the outflow results for the years 2000, 2006, 2007, and 2008 will be used for the year 2017. Since there is no inflow measurement information available for the year 2017 yet, two scenarios will be calculated: one will take into consideration a year with high flow, and the other will simulate a year with a low flow.

After the water balance is completed, I will present a scenario that could help Egypt save Nile water and help it avoid a possible shortage of water by the year 2017. Six crops will be chosen. They will be chosen on the basis of cost per ton, total economic value, and blue water footprint. So for example, if any crop is found to have a very high blue water footprint and a relatively low economic value, it will be eliminated for demonstration purposes. On the other hand, if a crop is found to have high economic value with a relatively low blue water footprint, it will be increased.

2.3. Economic aspect

Economic information regarding crops will be gathered from FAOstat and the Egyptian Ministry of Agriculture and Land Reclamation. The economic data will provide insight into which crops are of greater importance, and will be instrumental to recommend appropriate actions on how Egypt could improve water consumption in the agricultural sector. For instance, it could reduce the cultivation of certain crops with a high blue water footprint, and increase crops with a lower blue water footprint and high economic value. Economic information will include import/export values, as well as the price of per ton of a produced crop in USD. The price per ton will be calculated by dividing the total value of a crop per year by the total production of that same crop per year.

Different scenarios will show how Egypt can save water and still cultivate crops like rice and wheat if it eliminates and/or imports others. Data of the global average price for rice and wheat will be used to obtain import prices. Details regarding the economic sector should also uncover incongruence such as, for example, the illogical import/export of wheat and rice crops. Egypt exports a significant portion of its rice, and yet it imports a lot of rice and wheat from Russia and the USA to cover its own needs.

3. RESULTS AND DISCUSSION

3.1. 1997 United Nations Convention on Watercourses

Around 100 countries joined the United Nations Convention on Watercourses in 1997. It was perceived as a “flexible and overarching global legal framework that establishes basic standards and rules for cooperation between watercourse states on the use, management and protection of international watercourse” (Loures, 2008). The main purpose of the convention was to provide an agreement between watercourse states to avoid conflicts. This is stated in Article 5: “watercourse states shall in their respective territories utilize an international watercourse in an equitable and reasonable manner” (Nahrain, 2011). Article 7 states more specific terms:

> 1. “Watercourse states shall, in utilizing an international watercourse in their territories, take all appropriate measures to prevent the causing of significant harm to other watercourse states.”
>
> 2. “Where Significant Harm nevertheless is caused to another watercourse state, the state whose use causes such harm shall, in the absence of agreement to such use, take all appropriate measures having due regard for the provisions of Articles 5 and 6, in consultation with the affected state, to eliminate and mitigate such harm, and where appropriate discuss the question of Compensation.”

Article 7 attempts to offer guidelines on the balancing of water interests by imposing a threshold of tolerable behaviour. Article 8 urges member states to cooperate on the basis of sovereign equality, territorial integrity, mutual benefit, and good faith by using specific mechanisms or commissions. In reference to the Nile, this was attempted by establishing the Nile Basin Initiative, which will be discussed later. Article 33 calls on the member states to resolve all their conflicts through peaceful means, such as using the International Court of Justice, which is an option for Nile Basin countries.

Some analysts interpret the main point of the convention to be that if countries can agree with each other they are free to regulate their watercourses as they wish. The problem is that in most cases agreement is not reached. As of today, the convention has not come into force because there are only 16 contracting states, and 19 more are required for the convention to come into force and become binding on member states. The main controversy has come from Article 7 point 1 quoted above (UN, 1997). According to Professor Stephen McCaffrey from the University of the Pacific in California, a state that has a transboundary river flowing through it can have legitimate use of the water in its territory, but this can have a negative impact on neighbouring countries where the river also flows. In his book, McCaffrey offers the following example to further explain the controversy on Article 7:

> Suppose...upstream State A has not significantly developed its water resources because of its mountainous terrain. The topography of the downstream states on the watercourse, B and C, is flatter, and they have used the watercourse extensively for irrigation for centuries, if not millennia. State A now wishes to develop its water resources for hydroelectric and agricultural purposes. States B and C cry foul, on the ground that this would significantly harm their established uses (McCaffrey, 1999).

Each of the 10 Nile Basin countries has a different reason for not ratifying the convention. At the United Nations General Assembly, Sudan was the only country in favour, Burundi opposed, Egypt, Ethiopia, Rwanda and Tanzania abstained; Uganda, DRC and Eritrea were not even present at the meeting. Egypt disliked the term “international watercourse” while it liked Article 7; Ethiopia opposed Article 7 but liked Article 5.

Following are some examples of points that caused opposition and statements made by basin countries after the Assembly (Swain, 2007).

- Egypt:

Abstained in the voting. Expressed the hope that its adoption of the Convention would enhance the Assembly's role in codifying and developing international law, with the aim of promoting international peace and security and upholding the rule of law. While the Convention contained some new regulations, they did not modify customary international law.

- Tanzania:

The draft convention could have been better; it was, to some extent, the product of a deadline. He noted that it was to enter into force following the deposit of 35 instruments of ratification or accession. He said that represented a mere 18 per cent of the Organization's current membership of 185 States -- a figure that was even lower if regional economic integration organizations were taken into account. Abstained.

- Ethiopia:

Abstained in the voting because the text of the Convention was not balanced, particularly with respect to safeguarding the interests of upper riparian States. Article 7 and Part III of the Convention (planned measures) were of particular concern. Part III put an onerous burden on upper riparian States.

- Rwanda:

Abstained in the voting. The Convention lacked any reference to the sacrosanct principle of State sovereignty. His Government also had problems with Article 33, on the settlement of disputes, as well as with provisions in Article 2, on the management of underground waters.

All in all, it seems that a ratified agreement by the Nile Basin countries is not going to be achieved in the near future. (See Appendix 1 for the ratification status of the Convention).

3.2. Treaties governing the Nile

The following Treaty information comes from (Mekonnen, 1999). There are only a few treaties governing the Nile, and almost all of them date back to colonial times when most African countries were occupied and controlled by foreign forces. The treaties are:

1) April 15, 1891. Article III of the Anglo-Italian Protocol.
2) May 15, 1902. Article III of the Treaty between Great Britain and Ethiopia.
3) May 9, 1906. Article III of the Agreement between Britain and the Government of the Independent State of the Congo.
4) December 13, 1906. Article 4(a) of the Tripartite Treaty (Britain-France-Italy).

5) The 1925 exchange of notes between Britain and Italy concerning Lake Tana.

6) May 7, 1929. The Agreement between Egypt and Anglo-Egyptian Sudan.

7) The 1959 Nile agreement between the Sudan and Egypt for full control and utilization of the Nile waters.

These treaties are respectively detailed in the following sections.

3.2.1. Anglo-Italian Protocol

Article III of the Anglo-Italian Protocol states that "the Italian government engages not to construct on the Atbara River, in view of irrigation, any work which might sensibly modify its flow into the Nile." This provision of the protocol was too vague to provide any specific rights to use the water (Mekonnen M., 1999).

3.2.2. Treaty between Great Britain and Ethiopia

Article III of the Treaty between Great Britain and Ethiopia states that “His Majesty the Emperor Menilik II, King of Kings of Ethiopia, engages himself towards the Government of his Britannic Majesty not to construct or allow to be constructed any work across the Blue Nile, Lake Tana, or the Sobat, which would arrest the flow of their waters, except in agreement with His Britannic Majesty’s Government and the Government of Sudan.”

3.2.3. Agreement between Britain and the Government of the Independent State of Congo

Article III of the Agreement between Britain and the Government of the Independent State of Congo states that "The Government of the independent state of the Congo undertakes not to construct, or allow to be constructed, any work over or near the Semliki or Isango river which would diminish the volume of water entering Lake Albert, except in agreement with the Sudanese Government." At that time the Congo was under Belgium's control, therefore Belgium signed that agreement on behalf of the Congo even though it created great disadvantages for Congolese water usage because this agreement favoured downstream Nile countries.

3.2.4. Tripartite Treaty between Britain, France and Italy

The main outcome of the Tripartite Treaty (Britain-France-Italy) was to deny Ethiopia the right to its share of Nile water. Ethiopia's government strongly opposed this treaty, but its political influence and military powers were not enough to regain control of their share. Article 4(a) of the treaty states: "to act together [...] to safeguard [...] the interests of Great Britain and Egypt in the Nile Basin, more especially as regards the regulation of the waters of that river and its tributaries (due consideration being paid to local interests) without prejudice to Italian interests."

3.2.5. Exchange of notes between Britain and Italy concerning Lake Tana

The exchange stated that "...Italy recognizes the prior hydraulic rights of Egypt and the Sudan... not to construct on the head waters of the Blue Nile and the White Nile (the Sobat) and their tributaries and affluents any work which might sensibly modify their flow into the main river." Egypt's share of the Nile was seen as Egypt's right without exchanges and treaties, i.e. jus cogens. Again the Ethiopian government rejected this exchange, but was too weak to act. However, it notified both the British and the Italian government of its concern. To the Italian government it wrote:

> The fact that you have come to an agreement, and the fact that you have thought it necessary to give us a joint notification of that agreement, make it clear that your intention is to exert pressure, and this in our view, at once raises a previous question. This question which calls for preliminary

> examination must therefore be laid before the League of Nations.

To the British government it wrote:

> The British Government has already entered into negotiations with the Ethiopian Government in regard to its proposal, and we had imagined that, whether that proposal was carried into effect or not, the negotiations would have been concluded with us; we would never have suspected that the British Government would come to an agreement with another Government regarding our Lake.

3.2.6. The Agreement between Egypt and Anglo-Egyptian Sudan

The Agreement between Egypt and Anglo-Egyptian Sudan is one of the two treaties governing the distribution of Nile water today. It states that Egypt gets to utilize 48 billion cubic meters per year, and Sudan gets 4 billion cubic meters. One of its most important points is that the entire Nile water flow from January 20th to July 15th is reserved for Egypt because this is the dry season and Egypt needs the water for irrigation. Another point was that Egypt would be allowed to monitor the flow of the Nile in upstream countries and build Nile related projects without the consent of the other affected countries. Egypt’s veto right concerning all decisions related to the Nile was introduced with this agreement. It basically gave Egypt complete control over the Nile. It also banned the other countries’ rights to their share of water, except for Sudan.

3.2.7. Nile agreement between the Sudan and Egypt for full control and utilization of the Nile waters

The Nile agreement between the Sudan and Egypt for full control utilization of the Nile waters is the second of two important agreements governing the control and distribution of Nile water among basin countries. The controversy on the quantity of average annual Nile flow was settled and agreed to be about 84 billion cubic meters measured at Aswan High Dam, in Egypt. Egypt's annual share of Nile water was increased to 55.5 billion cubic meters and Sudan to 18.5 billion cubic meters. The quantity of water lost each year due to evaporation was agreed to be 10 billion cubic meters, which would then be deducted from the Nile yield before Egypt and Sudan were given their yield. It is unclear how these data were agreed upon and whether Egypt is abiding by them.

Egypt and Sudan then agreed that the Sudan would build projects that would improve the Nile flow and limit yearly evaporation losses. If there were any concerns, claims, or disagreements from other Basin countries concerning the Nile projects, Egypt and Sudan would handle the matter.

The most important right granted to Egypt through this agreement was to build the Aswan dam which could store the annual water flow of the Nile. The agreement also granted the Sudan the right to develop irrigation and hydroelectric power generation through the construction of the Rosaries Dam on the Blue Nile. The final point in the agreement was that a permanent joint technical commission between Egypt and Sudan was to be established to further enhance their cooperation regarding the Nile water flow.

3.2.8. Conclusion on Treaties

The two main treaties governing the distribution of Nile water among basin countries are indeed very old, and circumstances have changed; the colonial period is over, and local governments have been restored. Some basin countries see an urgent need to change those treaties because they believe that it is unfair for them to be bound to something they haven't agreed to, or were forced to agree to. The Nile Basin Initiative has been established to enhance cooperation between all 10 basin countries and resolve the problems. This initiative will be discussed in the next section.

3.3. Nile Basin Initiative

The Nile Basin Initiative (NBI) is the only form of cooperation that has developed between basin countries over the years. It describes itself as a "transitional arrangement until a permanent legal and institutional framework is in place" (NBI, 2001). The Initiative includes a Council of Ministers of Water Affairs (Nile-COM) who established a Technical Advisory Committee (Nile-TAC) that consists of 18 members: a single representative from each country and one alternate. The initiative also has a supportive and permanently present Secretariat (Nile-SEC). The main task of Nile-TAC is to coordinate Nile-COM work and to oversee Nile-SEC's work (Nicole, 2001).

The NBI's approach is process-oriented, and its first aim was to establish a common point of departure for all members, namely the "NBI Vision" The Vision was to institutionalize the tasks within the subsidiary action programs (SAPs) at a sub-basin level. These SAPs aims to "identify and implement investment projects that confer mutual benefits at the sub-basin level and that the riparian agree to pursue cooperative activities" (NBI, 2001). Until today, one of the major successes of the initiative was an institutional innovation, and it was the application of the international law principle of subsidiary, also meaning that the management of the basin would be at the lowest level possible.

The idea to apply the principle of subsidiary was put forth by the Ethiopian government in 2002 during one of the initiate's conferences in Khartoum (NBI, 2010). Therefore the NBI has two institutional sections: the 'Eastern Nile' (Egypt, Ethiopia and Sudan) and the 'Equatorial lakes' (Uganda, Kenya, Tanzania, Rwanda, Burundi and the DRC). The main point of this division is to reduce complexities that could arise during decision-making. Although institutionally divided, the two sections share the same vision: Nile Basin transboundary action, regional power trade, efficient use of agricultural production, water resource planning and management, applied training, confidence-building, stakeholder involvement, socioeconomic development, and benefit sharing.

In the past 10 years, the major interest of the organization has been the collection of good funding for the plans and projects that were to be undertaken by the initiative. This interest by the representatives of the basin countries led to the creation of the International Consortium on the Cooperative Development of the Nile (ICCON) in

June 2001. During the first meeting in Geneva the consortium received pledges from donors of US $120 million over an eight-year time frame. The long-term aim of ICCON is/was to promote more funding and increase international support for the Nile Basin Initiative. The cost to finance the NBI, the Shared Vision Program, and the Subsidiary Action Program is estimated to be around US $180 million yearly. Considering the projects that need to be undertaken and the size of cooperation required to make all those initiatives a success $180 million are not enough (NBI, 2010).

3.4. The Egyptian uprising and its possible effect on the international arena

As I mentioned in the background information, Silvio Berlusconi commented in 2010 that he would take serious diplomatic steps against Ethiopia if it decides to build a dam. After the Egyptian uprising of the 25th of January and the stepping down of President Mubarak, this sentiment might change. Egypt's foreign policy has undergone drastic transformation, and the effects of it have not been observed yet. Ethiopia has decided to build the dam, as stated by Ethiopia's Prime Minister: "The Great Nile dam construction is scheduled to commence presently near the Ethio-Sudan border," Ethiopia's Water and Energy Minister, Alemayehu Tegenu, also said in a press conference that "from this dam alone, Ethiopia expects to generate 5,250MW." Ethiopia's aim is to produce 15,000 megawatts (MW) of power within the next 10 years, part of a 25 year plan to improve the country's weak power-generating capability. Alemayehu added, "Ethiopia will finance the $4.78 billion from its own coffers and from the sale of government bonds because Egypt is pressuring donor countries and international lenders not to fund the project for the dam" (Malone, 2011).

So it already seems that the international arena is building some pressure on Ethiopia not to build the dam because according to international law, the colonial time treaties signed in the 1920s and 1950s are still valid and should not be broken. However, Ethiopia's project seems to be geared toward hydropower generation and not to reduce the flow of the river Nile and take away Egypt's share of water. It also seems that most Western countries are opposing the building of the dam, where some far eastern countries approve. China is involved in various projects to build hydropower-generating dams along the Nile River in many African countries, including Sudan, Zambia, Ethiopia, Mozambique, Nigeria, Ghana, Democratic Republic of Congo, and Gabon.

Sun Yue, Managing Director of the International Department of Sinohydro (a state-owned Hydropower Engineering firm said concerning the dam: "Tekeze Dam is for Ethiopia what Three Gorges is for China." According to the International Rivers Organization:

> At 185 meters, the Tekeze Dam built on the Nile promises to bring the kinds of serious environmental and social problems that Three Gorges ([a dam that was built in China and finished in 2006 and within its first 5 years has been showing huge problems] planners are only now beginning to recognize, five years later. In addition to the familiar environmental problems associated with large dams such as altered hydrology and threatened fisheries, Tekeze will also completely change the face of one of Africa's deepest canyons. The deepness of the canyon walls will likely contribute to major sedimentation at the dam site once the region is flooded. Since the start of construction, a massive landslide has already occurred near the dam site on April 2008, forcing developers to spend an additional US $42 million on retaining walls to keep back the eroding slopes. The situation will also likely reduce the capacity and lifespan of the dam, leading to reductions in irrigation and economic growth. The rural poor will not benefit from the dam project either, since the power generated will go mainly to large cities or sold to neighbouring countries with more developed industries. Local and international groups like Bread for the World recommend an alternative development plan for Ethiopia that includes small and medium dams, reforestation and hill terracing, and development of alternative energy sources, in order to both sustainably tap the natural resources and equitably distribute its benefits. The Tekeze Dam was built to generate 300 MW of electricity, but climate change could dramatically reduce its output. Funding for the estimated US$224 million project is currently being supplied by a joint venture company composed of Chinese and African sources: Sinohydro (49%), China Gezhouba Water and Power Group Ltd (30%), and Sur Construction (21%). Major Chinese companies such as Sinohydro, China Gezhouba Water and Power Group Ltd, and Sinohydro undertake

construction. Tunnel construction began in August 2007, and one of the four planned turbines has been operational since 2009 (Pottinger, 2006).

The World Bank and various other international institutions declined the financing needed to build the dam. Only a loan consisting of 500 million USD was approved by the ICBC Bank in China. The reasons for declining the loan were given as violating international law and creating a huge negative impact on the environment. In spite of Berlusconi's threats, ever since the events of January 2011 Italy took no diplomatic steps against Ethiopia and the topic has disappeared from the Italian press.

It seems that Ethiopia is exploiting Egypt's current situation in order to gain bargaining power and the support of other African countries. Egypt's fear of Ethiopia's changing hydropolitics lies in the fact that 85% of the total Nile water resources lie in Ethiopian soil. Ethiopia has been silent before Egypt's uprising and in the past decade because of internal conflict, weak governmental institutions, no water management strategy, and lack of financial resources. But Ethiopia has undergone major political and economic changes in the late 1990s since Meles Zenawi took office. He vastly improved relations with Far Eastern countries, which could explain the good relationship with China, and turned the market into an economically oriented one. These factors allowed Ethiopia to start debating Nile issues that were largely ignored by Egypt's former regime. Now Ethiopia feels it has enough power to pursue its goals of building hydropower dams.

Ethiopia's frustration with Egypt in recent years is justified, as it tried many times to cooperate with Egypt through the Nile Basin Initiative on a new legal agreement that would make the old treaties obsolete. Now Ethiopia has made it very clear that in the absence of an agreement it will move ahead with any project it deems necessary, even if it is against international law (Cascao, 2009). Before the Egyptian uprising, Egypt and the international community that supported it would have ignored a statement like this; an Egyptian military strike against any illegal dams would very likely have taken place. In my opinion, this has drastically changed, especially as Egypt's foreign relations with the United States, China, and Israel are reshaping, and such an attack on an illegal project might bring Egypt more headaches than it can bear.

Currently, the Egyptian army has to manage the country's international affairs and cannot start an international conflict. It makes more sense for Egypt to begin negotiations with Ethiopia on possible support for the project to build the dam. For example, as of April 21st 2011, Egypt's ambassador to Ethiopia said: "We shouldn't look back to the past, it would be very healthy and good for us to be very transparent and be very open and discuss everything. This will lead us to finding this win-win situation" (Kemendae, 2011). This seems to be a very clear sign that Egypt's transitional government, led by the High Council of the Armed Forces, is willing to negotiate with Ethiopia on the matter to bring change.

On the 1st of April 2011, Ethiopia also made an "olive branch" offer to Egypt concerning their dispute over water that included joint ownership of the project if Egypt were to agree to build the Ethiopian hydropower dam (Heinlein, 2011). Zenawi explained: "We need the support of all our partners [Egypt] to build the dam, as our savings are inadequate." He added:

> If our partners are deterred from doing so because of the noisy campaign of environmental extremists and some politicians with old-fashioned ideas, they will in effect be condemning millions of Africans to poverty. That cannot be just. That cannot be fair. I am still hopeful that the current government in Egypt will recognize that this project has nothing but benefits to Egypt … I believe the Sudanese understand this has nothing but benefits to them. If there is reconsideration, there will be time to consider many issues, including possibly joint ownership of the project itself. We are open to such ideas.

The Egyptian uprising has not only changed Egypt's point of view and negotiation tactics, but Ethiopia has also changed realizing that Egyptians are willing to work to solve the conflict. In fact, an agreement seems to be currently on the way (April-June 2011). Negotiations alone are a very positive step forward in this conflict, and something that has never been part of river basin management in the past.

3.5. Agricultural crops and their water footprint

According to CAPMAS, the Central Agency for Public Mobilization and Statistics, Egypt has three types of crops that grow in various seasons. There are winter, summer, and Nile crops. While winter and summer crops are seasonal, Nile crops are harvested all year long. The main winter crops are wheat, local beans, barley, lentil, linen, onion, clover, garlic, sugar beet, and chick peas. Summer crops are cotton, rice, sorghum, maize, soy bean, sugarcane, peanuts, potatoes, sesame, and onions. Nile crops are rice, sorghum, maize, potatoes and vegetables. Data about the crops, and their blue water footprint can be found in *Table 1*. More detailed data can be found in Table 13 of Appendix IV. Here is a summary of the total agricultural blue water footprint for the years 2000, 2006, 2007 and 2008.

Table 1: Agricultural blue water footprint (source: own creation)

	(billion m³/year)			
Year	2000	2006	2007	2008
Agriculture	38.8	45	46.8	47.0

Figure 4 shows a yearly increase of around 2.13% in the blue water footprint.

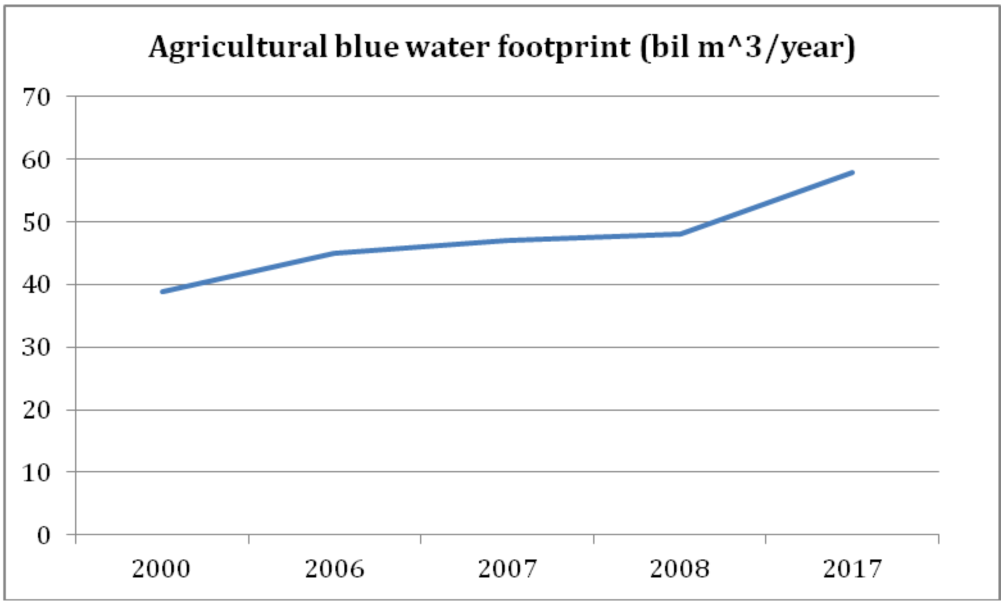


Figure 4: Agricultural blue water footprint (source: own creation)

The current results only display the total blue water footprint for all agricultural crops, and the data used for the total production in tonnes is only an estimate, as stated by the Food and Agricultural Organisation of the United Nations. Production in tonnes of the various agricultural crops can be found in Appendix 2. The most significant crops are: rice, wheat and maize. They represent around 32% of the total agricultural blue water footprint, as can be seen in *Figure 5*. Just to give an example of their significance in water consumption, rice alone consumes more than 10% of the consumed water resources for Egypt. So more than 23% of Egypt's water goes to rice and wheat crops.

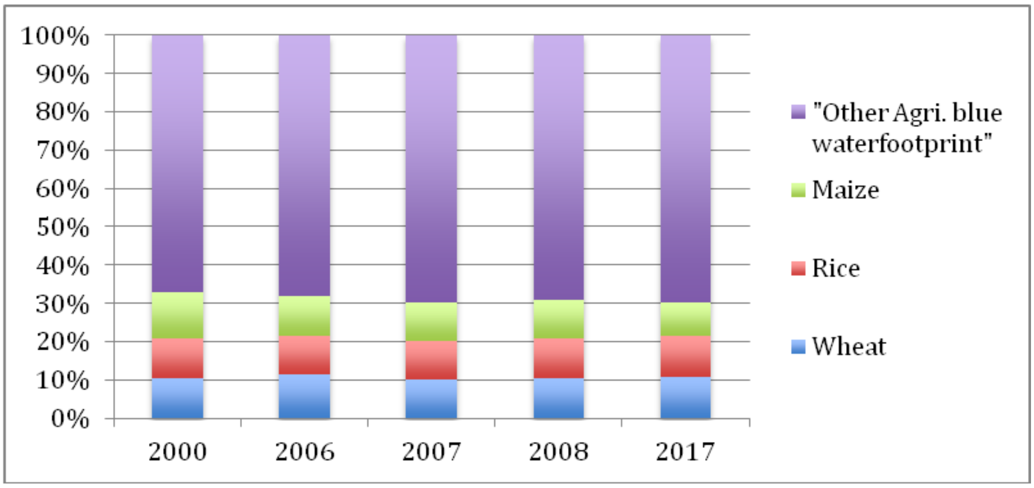


Figure 5: Water footprint per selected crop category in Egypt (source: own creation)

There are other crops that only consume water associated with the green footprint, and the most significant are dates and grapes, and their production volumes are very low (for detailed figures please check *Table 12* in the Appendix).

Although it has been found that Egypt's share of rainwater is a meagre 3.5%, the results surprisingly show that there are certain types of crops that use more than 15% of needed rainwater (this can been seen in the green water footprint fraction, Table 3 in the Appendix) and in some cases even more than 30%. These crops include wheat 19%, barley 27%, rye 100%, sorghum 28%, sweet potato 34%, peas 20-30%, vetch 41%, sunflower seeds 33%, cucumbers 23%, okra 18%, vegetables 24%, peaches and apricots 17%, grapes 100%, watermelons 38%, cantaloupe 19%, and dates 100%, though these do not represent the major crops. Blue and green water footprint, and the green water footprint fraction for Egyptian crops in m^3 per ton can be seen in Appendix 3.

3.6. Availability of water distribution and Nile river flow

As of 2008, Egypt's official figures have been a total of 72.4 bil m^3 of water consumed; 55.5 bil m^3 came from the Nile river, 6.2 bil m^3 from underground water.

The figure of groundwater from the Nile Delta is around 10% of Egypt's total water need, and it is rarely mentioned as an important source of water. It is assumed that the groundwater comes from rain, which in Egypt is around 150mm/m ^{2} per year only the Delta (2.4% of Egypt's area), where most agricultural activity takes place. The rest of Egypt receives average of 19mm/m^2 (BBC, 2011), i.e. 0.15m x 24,000,000,000m^2 = 3,600,000,000 m^3 of rain per year, for the rest of Egypt it is as follows: 0.019 x 976,000,000,000m^2=18,544,000,000. So a total of around 20 bil m^3 of rain water. So some is stored in Lake Nasser seeps away into the ground. Official figures say that rains and floods provide Egypt with 1.3 bil m^3 of water, which is 1.8% of the total (around 80 bil m^3); 8 bil m^3 come from agricultural sewage water recycling and, according to the data from the Central Agency for Public Mobilization and Statistics, it has been increased by 37% over a period of only 4 years. The problem is that no information is available on sewage water recycling, which makes the figure questionable. For purposes of calculating the Nile water flow later on, I will assume that 50% goes back to the Nile and the rest is evaporated. The last source of water, one that is not yet fully developed, is seawater desalination, which provides Egypt with 0.06 bil m^3 of water per year. These data can be seen in *Table 2*.

Table 2: Egypt Water Resources by Source (source: CAPMS, 2010)

	05/06	06/07	07/08	08/09	05/06	06/07	07/08	08/09
	%	Quantity (billion m^3/year)	%	Quantity (billion m^3/year)	%	Quantity (billion m^3/year)	%	Quantity (billion m^3/year)
Nile River	79.8	55.5	79.3	55.5	76.7	55.5	76.7	55.5
Underground water in Valley & Delta	8.8	6.1	8.7	6.1	8.6	6.2	8.6	6.2
Agricultural sewage water recycling	7.4	5.1	8.1	5.7	11.1	8	11.1	8
Sewage water recycling	1.6	1.1	1.9	1.3	1.8	1.3	1.8	1.3
Rains & Floods	1.9	1.3	1.9	1.3	1.8	1.3	1.8	1.3
Sea water desalination	0.1	0.06	0.1	0.06	0.1	0.06	0.1	0.06
Total	100	69	100	69.9	100	72.4	100	72.4

Consumed water is divided in three main sectors. As of 2008, the official figure is 85.9% to the agricultural sector, representing 62.2 bil m^3 of water. Households in Egypt use around 9.1 %, representing 6.6 bil m^3. The industrial sector, with the least amount of water needs, uses 1.8%, representing 1.33 bil m^3 of water. There is also a significant amount of water lost through evaporation, 2.9% of the total water, representing 2.1 bil m^3, as shown in *Table 3*. (The assumption is that all water lost through evaporation is from the Nile River.) Assuming that the data is accurate since there was no significant change between 2005 and 2009, climate change had no real effect on water losses due to evaporation over the four-year period. This is also an indication that it should not be a problem until the year 2017.

Table 3: Official water consumption figures for Egypt (source: CAPMS, 2009)

	05/06		06/07		07/08		08/09	
	%	Quant. (bil. m³/year)	%	Quant. (bil. m³/year)	%	Quant. (bil. m³/year)	%	Quant. (bil. m³/year)
Agriculture	86.4	59	85.6	59	85.4	60	85.9	62.2
Loss by Evaporation	3.1	2.1	3.1	2.1	3.0	2.1	2.9	2.1
Household	8.5	5.8	8.9	6.5	9.4	6.6	9.1	6.6
Industry	1.7	1.15	1.7	1.15	1.9	1.33	1.8	1.33
Rivers Navigation	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.2
Total	100	68.25	100	68.95	100	70.23	100	72.43

I will use the newly computed blue water footprint for agricultural and animal products, and the official figures for industry, household, and loss by evaporation to find the scarcity of the Nile. Therefore, Table 4 shows Egypt's total blue water consumption. (Detailed total agricultural blue water footprints can be found in Appendix 4).

Table 4: Water Abstraction (source: own creation)

	(bil m³/year)			
Type	2000	2006	2007	2008
Agriculture	38,8	45,1	46.8	47,9
Industry	0.9	1.1	1.1	1.3
Household	5	5.8	6.5	6.6
Loss by Evaporation	2.1	2.1	2.1	2.1
Total	46.8	54.1	56.5	57.9

These figures reveal that in the year 2008 a total of 57.9 bil m³ per year of blue water was consumed by all Egyptian industries.

Data from the Nile flow, especially the inflow which is measured after the Aswan dam, will give us a basis for calculating an outflow into the Mediterranean, and hopefully a prognosis for the year 2017.

Table 5: Measured Nile flow data in bil m³/year
(source: Abdelaziz and Gohar, 2010)

	2001	2002	2003	2004	2005	2006	5 year average
Inflow	67.2	61.8	56.6	57.8	57	57.6	59.6
Outflow	No data	No data	No data	No data	No data	No data	3.6

The measurement reveals an average inflow of around 59.6 bil m³ per year. This figure will also be used for the years 2007 and 2008, since there is no measurement information for these years. The measured inflow figure of 57.6 bil m³ year was used to compute the outflow into the Mediterranean for the year 2006. Measured (*Table 5*) and computed figures (*Table 6*) of the outflow also reveal two different results. The differences could lie in many factors; for example, that Gohar never specified in the report which years were considered to arrive at the average outflow, so I assumed that the they were for the same period as the inflow, but it must be noted that even in the 5 years of inflow measurements there were huge variations, as *Table 5* illustrates. In the year 2001 there was inflow of 67.2 bil m³ of water, while in the year 2006 only 57.6 bil m³ were measured. Although I took into consideration all the possible industries and all found crops, another aspect could be that something is missing. *Table 6* shows the computation of water flow into the Mediterranean.

Table 6: Computed water flow into the Mediterranean Sea (source: own creation)

(bil m³ per year)	2000	2006	2007	2008
Inflow + recycled water	64+2.7	57+3.1	59.6+3.5	59.6+4.6
Agriculture and animal products - groundwater	38.8-6	45.1-6.1	46.8-6.2	47.9-6.2
Industry	0.9	1.1	1.1	1.2
Household	5	5.8	6.5	6.6
Loss by evaporation	2.1	2.1	2.1	2.1
Flow into the Mediterranean	29.9	12.7	12.8	12

To sum up the previous figures and numbers to make them clearer, the flow chart presented in *Figure 6* will show water consumption processes and flows of Nile water for the year 2008. It shows the ∑of all inputs-∑of all outputs = calculated Nile outflow.

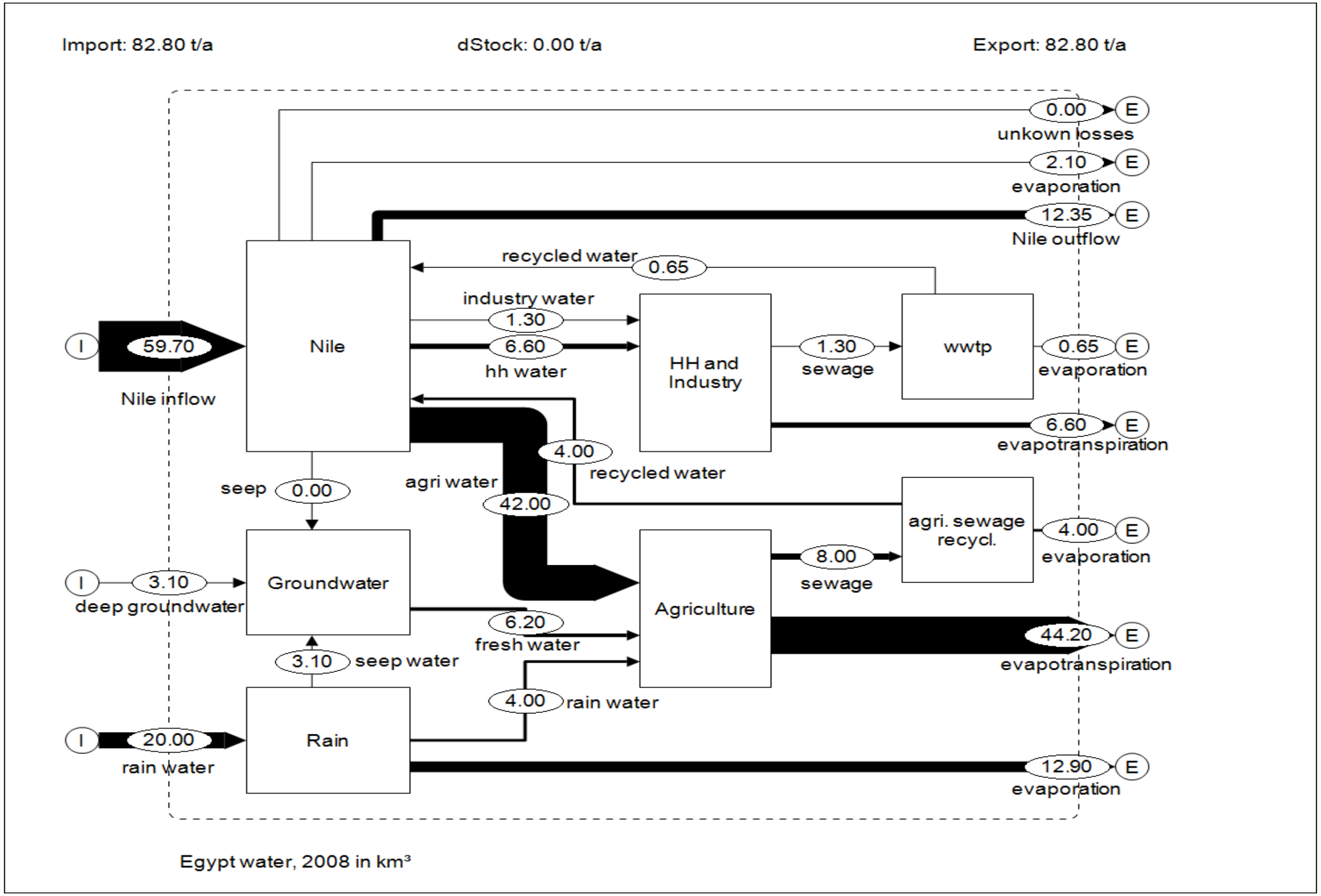


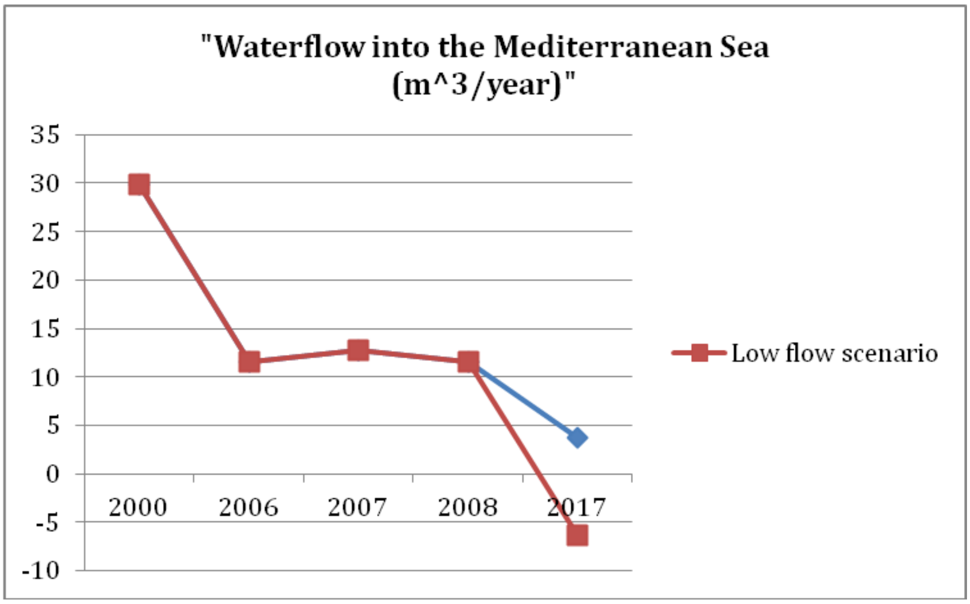
Figure 6b: Water flow analysis using STAN for the year 2008 (source: own creation)

The flow analysis clearly shows the inflows from Nile water of 59.7 bil m^3 per year and the Nile outflow which ends in the Mediterranean at 12 bil m^3 per year, which is the same result that was computed in Table 7. Usually the number written in the flows represents the amount of water going or returning from a process, but in some cases where there is no number known, a 0 is put, which does not mean that nothing flows; it just means that the value is unknown, or insignificant.

3.7. Projections for water usage in 2017

A high and low scenario will be used for the Nile water outflow into the Mediterranean to make predictions for the year 2017 in terms of water usage. The high figure represents the highest measurement taken from 2001-2006, which was 67 bil m^3, and the lowest which was 57 bil m^3 per year. As of 2008, Egypt needed 57.9 bil m^3 of blue water to cover its needs, of which 86% were intended for agricultural use. The total estimated population of Egypt was around 80,000,000 people, which in reality could be much higher, but that would be pure speculation. Egypt's population by the year 2017 is estimated to be 90,000,000 (considering that its average yearly population growth rate between 2000 and 2009 was 2.2%), an increase of 11% compared to 2008 (UN, 2011). Also considering that the total blue water footprint increased by 20% between 2000 and 2008, I will assume that the footprint will increase by another 20% in 2017. This does not take into account the possible effects of global warming and changes in agricultural trends, and assumes that Egypt's inflow of the Nile will not change significantly, i.e. stay in the range of 57-67 bil m^3 per year.

With the two scenarios of high and low flow, and with increased total blue water footprint of 20% from the year 2008, the total blue water footprint should be around 69.48; and by subtracting 6.1 bil m^3 of groundwater, i.e. 63.38 bil m^3/year, we can estimate the outflow into the Mediterranean as illustrated in *Figure 7*.



Legend: The blue line represents the high flow scenario and the red line represents the low flow scenario.

Figure 7: Waterflow into the Mediterranean Sea (own creation)

The graph clearly shows that, if the water inflow is at 57 bil m^3 per year, there is a high chance that there will not be enough Nile water flowing into the Mediterranean Sea by the year 2017. If we take the high scenario with a flow of 67 bil m^3 per year, around 4 bil m^3 should flow back into the Mediterranean. In the case of low flow, even if we take an error of +/- 10% there still won't be any water flowing.

3.8. Alternative water saving scenarios

This section will only describe one alternative scenario as an example of what can be done to save water. *Table 7* will display three crops with a very high blue water footprint, and four crops with medium to low water footprints. The footprint will also be shown in relation to the total yearly value of these crops, in order to identify their economic importance.

Table 7: Rice, Wheat, Maize, Oranges Tangerines, Lemon and Okra - 3 year averages 2006-2008 (source: own creation)

	Rice	Wheat	Maize	Oranges	Tangerines	Lemon	Okra
USD/ton	203.5	128	33.5	175	226	261	413
Blue Water footprint (bil m^3/year)	7.1	7.1	6.8	1	0.48	0.16	0.027
Total mil USD/year	1476	1012	213.5	375.8	171.6	86.158	43.219

The table reveals that, especially in the case of maize, the relation between total yearly value and the blue water footprint are illogical. This type of crop seems to use too much water for what it is worth. Oranges and tangerines are a lot more profitable because they have a much lower blue water footprint and high economic value.

An alternative scenario could look as presented in *Table 8*.

Table 8: Alternative scenario that doubles the cultivation of oranges and eliminates all maize crops (source: own creation)

	Rice	Wheat	Maize	Oranges	Tangerines	Lemon	Okra
Blue Water footprint (bil m^3/year)	7.1	7.1	0	2	0.48	0.16	0.027
Total mil USD/year)	1476	1012	0	751.6	171.6	86.158	43.219

As mentioned before, only 213 million USD/year are necessary to cover the needs for maize crops. So, doubling the cultivation of orange crops will bring in 751.6 Million USD and only 2 bil m m^3 of water will be consumed. Assuming that Egypt's consumption of oranges is only half the figure shown, 375 million USD, the other half could be exported, giving Egypt a budget of 375 million USD to import maize. In the case of 2008, Egypt would only need maize worth 213 million USD, therefore leaving a profit of 162 million USD/ year. However, the most significant savings would be in 5 billion m^3 of water per year.

Of course, this is only an example because many aspects were not taken into consideration, such as what type of soil is necessary to grow oranges, the time necessary for doubling the area of cultivated orange crops, and transportation costs of maize for import.

3.9. Alternative findings

As of 2007, almost half of Egypt's agricultural imports were cereals: maize, wheat, barley, sorghum, and rice. The total value of cereal imports alone was 2.5 bil USD, while the total value of all agricultural products was 5.4 bil USD. These figures show the importance of cereal products for Egyptians. Total cereal exports for the same year were 410,000,000 USD. Although it does not make sense to export cereal products at all, there is a reason which will be further discussed in the next section. According to CAPMAS, rice accounts for almost 75% of cereal exports, and yet, Egypt imports rice every year. On the other hand, fruits had a very low import value of 35,800,000 USD, while exports in total were around 206,400,000 USD. Also, a significant chunk of imports were due to oil products which amounted to 416,00,000 USD, while exports were only at 13,000,000 USD (FAO, 2011). Import-export values can be seen in *Table 9*.

Table 9: Egypt's Imports and Exports (source: FAO, 2011)

	Imports (000 USD)					Exports (000 USD)				
	94-96	99-01	05	06	07	94-96	99-01	05	06	07
Cereals	1,366,510	1,268,680	1,636,603	1,520,169	2,541,699	85,132	115,118	319,556	311,550	410,121
Oils	543,760	407,869	519,607	515,830	416,197	5,354	22,808	21,672	14,940	13,209
Pulses	76,324	123,915	165,985	165,794	180,932	6,927	16,436	15,266	19,490	38,755
Sugars	199,130	151,164	145,045	148,400	135,131	2,079	3,225	26,723	29,215	58,725
Fruits	14,389	33,899	36,341	39,478	35,855	22,577	35,454	114,481	117,606	206,463
Potatoes	32,848	29,534	46,399	29,723	60,899	69,514	34,391	77,446	65,350	108,092
Other	1,104,039	1,496,939	1,398,020	1,470,606	2,069,307	344,417	347,568	593,856	529,849	667,635
Total Agriculture	3,337,000	3,512,000	3,948,000	3,890,000	5,440,000	536,000	575,000	1,169,000	1,088,000	1,503,000

Legend: According to the FAO, these are estimates. The values in red colour represent invalidated data.

Potatoes are an example of sudden extreme increase or decrease in imports and exports without an apparent reason from 2006 to 2007, where both import and export values nearly doubled. Fruit exports almost doubled that year.

Although it does not make much sense for a country to export so much cereal, especially rice, it becomes obvious that the reasons are purely economic. Egyptian medium grain rice commands high prices in the export market that can sometimes reach as high as 900 USD per ton. Therefore, rice farmers sell their crops abroad rather than to the Egyptian government, which in turn offers it at subsidized prices to the people. The domestic price must be decoupled from the international price to maintain low domestic prices.

The government of Egypt has recently introduced an export tax and further export restrictions to achieve the decoupling of prices. The previous government took note of the problem in 2008 and stopped issuing new rice export licenses. As of October 2010, Egypt has also banned auctions for existing rice export licenses, which used to sell for astronomic numbers, although I could not verify the exact information. The most recent developments show that the current government aims to pursue immediately two much publicized policies of the previous administration: restrict planting to reduce water use, and keep domestic prices low to maintain consumer welfare and reduce financial pressures. The issue is that definite quantities have never been discussed or publicized, so how much it will restrict the planting remains to be seen.

The burden of these measures falls largely on the farmers who receive low prices for their paddy rice.

> ‘The Ministry of Trade and Industry suspended auctions of rice export licenses until the new crop appears in the market in October 2010. Egypt has exported 560 TMT in 2009/10 so far, and is expected to export the full 600 bil tonnes for which export licenses have been issued. Rice exports were officially banned in 2008 (Decree #258). In February 2009, the Ministry of Trade and Industry allowed rice exports of quantities not exceeding 600 bil tonnes per year given two conditions: 1) the exporter must supply matching quantities to the government through an auction system, and 2) the exporter must pay $175/ton in export fees to the government. With this measure the government hopes to stabilize prices in the local market by encouraging

traders to release stocks they had anticipated exporting. During 2009-2010, the Ministry of Trade and Industry allowed rice exports through auctions in quantities equivalent to those procured by the General Authority for Supply Commodities (GASC) to supply the quantities needed for ration card holders' (Masour and Guven, 2010).

3.10. General data findings from external sources

By far, the most water-consuming crops are corn, rice, and wheat. Egypt has argued that these crops are used mostly for local needs, as Egypt needs to be self-sufficient and meet most of its needs locally. Wheat represents the most important crop, especially in the form of bread as part of everyday meals for rich or poor. According to a report from the International Food Policy Research Institute, more than one third of the daily calorie intake of the average Egyptian comes from bread.

Wheat is also a strategic commodity in Egypt: it is very cheap (even for Egyptian standards, less than 1 US cent) and filling (Reeder et al., 2001). The government subsidizes bread, and any shortage or interruption in wheat production immediately results in strikes and major problems because unlike rice, Egyptians completely rely on bread. This is the reason why the Egyptian government has not made any policies to reduce wheat crops.

The fact that cereal exports in 2007 did not include wheat is indicative that all of it was consumed. On the other hand, 77% of cereal imports for the same year, valued at a total of 2,550,000,000 USD, was wheat. Egypt imports its wheat mainly from Russia and the United States of America. According to the USDA, Egypt will try to decrease its wheat imports in 2011 from 13m tonnes to 9.5 at the end of 2012, and increase local crops. Egypt will still be the top wheat importer, well ahead of Brazil, currently at 6.4m tonnes per year. It would be very difficult to make a recommendation to cut down on wheat production because it is a necessary staple for Egypt. The country cannot afford to risk a bad year because of bad foreign relations, transportation problems, or crop disease, therefore it makes more sense that Egypt continue to grow its quantities of wheat.

Rice on the other hand, consumes a lot of water even though it seems to be very profitable for Egyptian farmers to export. The recent ban on issuing new license for export could potentially induce farmers to find illegal ways to export their rice (unlikely), or they could switch to other crops. This is the ideal scenario that would drastically reduce the blue water footprint. It would allow for the cultivation of other crops, such as fruit and potatoes, which would also be very profitable for the export market. Furthermore, it would provide the financial needs to import the needed quantities of rice, and in the process save much needed water for the future.

The government faces a great dilemma: simply asking for a larger share of water from other Nile basin countries would seem to be the optimal solution. It would allow Egypt to continue to cultivate its crops, and cover its local needs without having to depend too much on imports. But getting a larger share of water seems very unlikely, and new solutions have to be found. Many more factors need to be taken into consideration in order to provide possible scenarios that may solve the dilemma.

4. RECOMMENDATIONS AND FUTURE RESEARCH

4.1. Recommendations

Recommendations, also based on the study's findings, are addressed to both Egypt and Ethiopia. Egypt has to make a number of adjustments in the way agricultural crops are cultivated. Also changes to irrigation techniques such as spray irrigation and drop irrigation and upgrades to the water supply networks could help. The alternative scenario presented in the results and discussion section clearly shows that the country can save huge amounts of water with very simple steps. Therefore, the Egyptian government should take steps to address that issue rather than relying on the possibility that African countries, especially Ethiopia, might allow Egypt to increase its share of Nile water, by simply improving the Nile water flow before the Aswan dam. The Egyptian government also needs to work on transparency. For example, ministries and statistics organizations do not provide enough information regarding the true flow of water, crop production, or all the types of crops available. If this information is available, Egyptian farmers may reconsider the need to plant certain crops. Profitability plays an important role, as in the rice example above, but currently, it seems that farmers are not well informed on the best crops to grow.

One of the positive outcomes of the uprising of January 2011 was that Egypt recognized the need to dialogue with Ethiopia and other African countries regarding the water issue. Now Egypt has to continue that dialogue, especially after Ethiopia has shown willingness to involve it in its national projects as a way to reassure Egypt that it is not looking to decrease its Nile water share. On the legal side, Egypt also needs to stress the jus cogens factor of its historic right to water, and not just the treaties that are regarded as legal but unfair. As Egypt could have never become what it is today without the Nile water

Ethiopia needs to reconsider its aggressive attitude of threatening to ignore international law that will make other countries loose sympathy for its cause. I recommend involving Egypt in every aspect of the planning because this will be the only way to grant its support. Ethiopia also needs to make public its projects that involve Basin countries, as some of them were secretive until the Chinese revealed them in 2011.

The Pulp Mills case was a similar situation that found a solution in 2010. Argentina and Uruguay entered in a conflict over sharing the waters of the Uruguay River that passes through both countries. This is one of the few cases in which the International Court of Justice was used to solve an issue concerning trans-boundary water sharing. Argentina filed in Registry of the court and application against Uruguay "with respect to a dispute concerning the breach, allegedly committed by Uruguay, of obligations under the Statute of the River Uruguay (United Nations, Treaty Series (UNTS), Vol. 1295, No. I-21425, p. 340), a treaty signed by Argentina and Uruguay at Salto (Uruguay) on 26 February 1975, and having entered into force on 18 September 1976 (hereinafter the "1975 Statute").

In the application, Argentina stated that this breach arose out of "the authorization, construction, and future commissioning of two pulp mills on the River Uruguay," with reference in particular to "the effects of such activities on the quality of the waters of the River Uruguay and on the areas affected by the river" (ICJ, 2010). Argentina claimed that pollution from the mills caused serious environmental damage, and that the mills breach the 1975 border treaty, the Statute of the River Uruguay (UN, 2010).

This dispute has severely affected tourism, business relations, transportation, and the generally warm connection the two countries enjoyed. "On April 2010, the ICJ ruled the pulp mill in Uruguay could keep operating. It also stated that Uruguay failed to negotiate with Argentina over the plant, but said it would not be appropriate to make Uruguay pay damages or dismantle the operation" (Ortiz, 2010). The judgment of the ICJ may not have pleased both parties, but it will at least cool down diplomatic tensions between them.

In the case of the Nile Basin countries, a submission to the ICJ could help direct the countries to negotiations, but in order to avoid such a situation, both parties should revive the Nile Basin Initiative. This could be the example of an organization that would oversee the discussion and the progress on this topic. Citizens of both countries also need to be involved in the Nile Basin Initiative. Only then it can succeed in achieving its goals. Last, would be the need to educate citizens of all involved countries about the scarcity of water and this, in the case of Egypt, will foster understanding and tolerance. Egypt and Ethiopia should present the necessary information to the public so they can have a discussion based on facts. Although I believe they already have the necessary information, they do not want to publicize it, especially in the case of Egypt, as it does not want to worry the public of a possible scarcity by the year 2017.

4.2. Future research

This paper identifies whether a Nile water scarcity seems likely for Egypt by 2017. There are many topics that need further research in order to find short term and quick solutions for Egypt. Work still needs to be done to compute Egypt's self-sufficiency for products like wheat, rice, and maize, as this is not easy to identify from available data. For example, how much rice Egypt actually needs to survive needs to be established. Now it is very unclear: some is consumed, some exported, and some imported again.

More information is also needed on the measuring stations that measure the Nile water flow. There should be yearly results up to the current year because this information will help in making more accurate computations regarding Nile water outflow into the Mediterranean Sea.

Most importantly, work needs to be done to research the soil types in Egypt, thus, to seek out more propitious ways in which crops can grow, as shown in the alternative scenario section. Another research aspect could include, which irrigation methods would be more suitable and water saving for Egypt.

5. CONCLUSION

The sharp increase in water consumption per year is largely due to the agricultural trends, and only few crops are responsible for drastic usage of water. For example, as mentioned in the results section, rice and wheat alone consume more than 20% of the available water. In the year 2017, if the Nile has a low water flow scenario, there will be around 6 bil m^3 of water missing, and no water will flow in the Mediterranean Sea. In a high flow scenario, Egypt will have around 5 billion m^3 of water flowing into the Mediterranean.

It seems that Egypt's water needs will increase by 2017, but the figures are only estimates, just as all the data used from CAPMAS, FAOSTAT, Central Agency for Public Mobilization and Statistics, and the Egyptian Ministry of Agriculture and Land Reclamation. The only valid conclusion that can be made is that there will be an increase in water usage and a high likelihood of scarcity in case of a low flow. Therefore, Egypt needs to take immediate drastic measures to reshuffle some crops and save water.

The arguments for and against legality of the treaties described above remains an open and controversial topic. Both sides of the conflict have good reasons. Ethiopia needs more hydropower projects to help it develop its economy; Egypt is worried that this might have an effect on its share of Nile water. It seems that the Egyptian uprising had a very positive effect, as it got both parties to talk publicly to search for solutions together, and it seems that both parties are on the verge of coming to an agreement. The 'olive branch offer' made by Ethiopia invites Egypt to be a part owner in its dam. However, the gesture may be in vain because the current Egyptian government is only an interim government, and the one to be elected next year could have a completely different policy.

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Appendix I

Table 10: Status of the Convention in 2006 (source: UN, 2006)

Participants	Signature (S)	Ratification (R)	Acceptance (A)	Accession (a)	Approval (AA)
Côte d'Ivoire	25 Sep 1998				
Finland	31 Oct 1997		23 Jan 1998		
Germany	13 Aug 1998				
Hungary	20 July 1999				26 Jan 2000
Iraq				9 July 2001	
Jordan	17 Apr 199	22 June 1999			
Lebanon				25 May 1999	
Libyan Arab Jamahiriya				14 June 2005	
Luxembourg	14 Oct 1997				
Namibia	19 May 2000	29 Aug 2001			
Netherlands	9 Mar 2000		9 Jan 2001		
Norway	30 Sep 1998	30 Sep 1998			
Paraguay	25 Aug 1998				
Portugal	11 Nov 1997	22 June 2005			
Qatar				28 Feb 2002	
South Africa	13 Aug 1997	26 Oct 1998			
Sweden				15 June 2000	
Syrian Arab Republic	11 Aug 1997	2 Apr 1998			
Tunisia	19 May 2000				
Venezuela (Bolivarian Republic of)	22 Sep 1997				
Yemen	17 May 2000				

Legend: Status quo from 2006 until today.

Appendix II

Table 11: Egyptian agricultural production data in tonnes per crop (source: FAO, 2011)

	Production (T)			
	2000	2006	2007	2008
Sugar cane	15705800	16656300	17014300	16469900
Tomatoes	6785640	8576070	8639020	9204100
Wheat	6564050	8274230	7379000	7977050
Rice	6000490	6755000	6876830	7253370
Maize	6474450	6374300	6243220	6543640
Sugar beet	2890360	3904970	5458210	5132590
Potatoes	1769910	2312790	2760460	3567050
Oranges	1610520	2122005	2054630	2138430
Onions	762993	1119890	1485930	1728420
Grapes	1075100	1431970	1485010	1531420
Watermelons	1785280	2025190	1912990	1485940
Dates	1006710	1328720	1313700	1326130
Eggplants	708840	1180280	1160620	1242670
Bananas	760505	855090	945429	1062450
Sorghum	941188	887000	843840	866948
Tangerines	No data	730900	748395	758105
Cantaloupes	800000	745953	829779	757677
Cotton seed	329532	327000	320800	240000
Beans green	201628	259610	330257	247336
Anise/badian/corian	22000	22000	22000	22000
Apricots	67000	100799	101139	106165
Artichokes	87968	140000	172701	176372
Broad beans/horse beans	353909	247490	301770	244109
Cabbages	563952	585580	616670	638690
Cauliflower	109751	125720	115620	124680
Chilies and Peppers dry	45600	45600	45600	45600

Chilies and Peppers green	428066	550000	651822	703408
Cow Peas dry	7429	5378	5378	7500
Cucumbers	566980	802644	671468	595732
Figs	187698	295510	262307	304110
Flax fiber and tow	14000	9000	9514	8228
Garlic	266555	164220	234570	258608
Jute	2200	1978	1915	1656
Lemon and Lime	274484	316011	324509	329741
Lettuce	174588	125000	115413	111666
Linseed	30000	9602	12226	11879
Lupins	4264	2800	2885	2384
Mangoes	298880	597760	532422	466436
Nuts	6650	7125	6102	7000
Okra	76000	109490	117940	104690
Olives	281745	500000	507053	480071
Peaches	240193	427639	425273	399416
Peas green	339994	222703	262987	285074
Pumpkins	719909	698606	724579	651859
Sesame seed	36811	41530	42212	36882
Spinach	47970	49848	61378	66665
Strawberries	70612	128349	174414	200254
Taro	42392	125387	138099	151971
Vetches	1700	1600	1562	1800
Walnuts	20440	27000	27000	27000
Poultry Meat	618812	720556	816694	733199
Sheep and Goat Meat	75000	62569	66908	65038
Bovine Meat	543594	622929	620426	634970
Cheese	462250	733750	941750	1039120
Butter	96700	120264	119930	116541
Eggs	176665	240000	292600	294790
Milk	3776710	4126584	5936397	5979684

Appendix III

Table 12: Blue and Green water footprint for Egyptian crops in m³/ton produced (source: Mekonnen and Hoekstra, 2010)

Crop Number	Crop Name	Country Average Green	Country Average Blue	Rainwater Fraction
7	Wheat	215	904	19%
16	Dry Pastam(Wheat)	217	914	19%
19	Wheat groats and meal(Wheat)	239	1007	19%
31	Rice paddy or rough	59	1003	5%
49	Barley	619	1695	27%
67	Maize	141	1078	11%
91	Rye	505		100%
112	Grain (Sorghum)	195	496	28%
154	Potato	21	289	7%
172	Sweet Potato	62	122	34%
193	Taro (coco yam)	36	122	23%
199	Salad beetroot (Yams)	106	634	14%
211	Sugar cane	14	144	9%
220	Refined sugar (Sugar cane)	120	1227	9%
223	Maple sugar and maple syrup (Sugar cane)	120	1227	9%
226	Glucose/Fructose (Sugar cane)	120	1227	9%
241	Sugar beet	15	168	8%
256	Beans,small red/kidney beans/dried beans (Beans)	315	1892	14%
268	Broad beans&horse beans dried (Broad Beans)	243	1546	14%

271	Peas dry	449	1826	20%
274	Chickpeas dried	539	1233	30%
283	Lentils	661	4673	12%
289	Vetches	760	1079	41%
292	Lupins	565	2795	17%
298	Pulses nes	481	2516	16%
316	Walnuts	547	2714	17%
337	Nuts	1010	5010	17%
340	Soyabeans	330	1551	21%
370	Groundnuts	259	1853	12%
430	Olives	338	1584	18%
451	Sunflower seeds	457	905	33%
478	Sesame Seed	1250	1957	39%
493	Seed cotton	154	3805	4%
532	Linseed	855	1288	40%
562	Cabbages	33	209	14%
565	Artichokes	62	846	7%
571	Lettuce	16	166	9%
577	Spinach	23	235	9%
583	Tomatoes	25	148	14%
607	Cauliflowers	20	181	10%
613	Pumpkins	61	184	25%
616	Cucumbers	62	204	23%
622	Eggplants	38	289	12%
625	Chilies and peppers	82	163	33%
628	Onions	38	231	14%
637	Garlic	33	287	10%
643	Beans Green	53	265	17%
649	Peas Green	75	469	14%
658	Carrots	43	272	14%
664	Okra	53	247	18%
676	Vegetables	43	136	24%
697	Bananas	40	472	8%
703	Oranges	86	512	14%
712	Tangerines	107	642	14%

715	Lemons	82	494	14%
718	Grapefruit	116	691	14%
724	Citrus Fruit	104	622	14%
739	Apples	135	689	16%
748	Pears	225	1149	16%
751	Apricots	198	948	17%
766	Peaches	249	1193	17%
769	Plums	187	956	16%
784	Strawberries	21	296	7%
814	Berries	79	753	10%
817	Grapes	111		100%
850	Watermelons	61	99	38%
853	Cantaloupe	40	175	19%
856	Figs	233	1393	14%
859	Mangos	226	1741	11%
871	Dates	92		100%
883	Fruit, tropical fresh nes	266	2050	11%
886	Fruit Fresh nes	311	1080	22%
976	Anise, badian,corian	796	7607	9%
1000	Flax fiber and tow	1312	10886	11%
1018	Jute	254	2951	8%
-	Cheese	-	2037	-
-	Butter	-	3560	-
-	Eggs	-	1813	-
-	Milk (cow&buffalo)	-	676	-
-	Poultry Meat	-	1888	-
-	Bovine Meat	-	4851	-
-	Sheep and Goat Meat	-	590	-

Appendix IV

Table 13: Total blue water footprint for agricultural crops (source: own creation)

	Blue Water footprint m³			
Crop	2000	2006	2007	2008
Sugar cane	2,261,635,200	2,398,507,200	2,450,059,200	2,371,665,600
Tomatoes	1,004,274,720	1,269,258,360	1,278,574,960	1,362,206,800
Wheat	5,933,901,200	7,479,903,920	6,670,616,000	7,211,253,200
Rice	6,018,491,470	6,775,265,000	6,897,460,490	7,275,130,110
Maize	6,979,457,100	6,871,495,400	6,730,191,160	7,054,043,920
Sugar beet	485,580,480	656,034,960	916,979,280	862,275,120
Potatoes	511,503,990	668,396,310	797,772,940	1,030,877,450
Oranges	824,586,240	1,086,466,562	1,051,970,560	1,094,876,160
Onions	162,517,509	258,694,590	343,249,830	399,265,020
Grapes	0	0	0	0
Watermelons	176,742,720	200,493,810	189,386,010	147,108,060
Dates	0	0	0	0
Eggplants	204,854,760	341,100,920	335,419,180	359,131,630
Bananas	358,958,360	403,602,480	446,242,488	501,476,400
Sorghum	466,829,248	439,952,000	418,544,640	430,006,208
Tangerines	449,400,000	469,237,800	480,469,590	486,703,410

Cantaloupes	140,000,000	130,541,775	145,211,325	132,593,475
Cotton seed	1,253,869,260	1,244,235,000	1,220,644,000	913,200,000
Beans green	53,431,420	68,796,650	87,518,105	65,544,040
Anise/badian/corian	167,332,000	167,332,000	167,332,000	167,332,000
Apricots	63,516,000	95,557,452	95,879,772	100,644,420
Artichokes	74,420,928	118,440,000	146,105,046	149,210,712
Broad beans/horse beans	547,143,314	382,619,540	466,536,420	377,392,514
Cabbages	117,865,968	122,386,220	128,884,030	133,486,210
Cauliflower	19,864,931	22,760,000	20,443,220	22,567,080
Chilies and Peppers dry	7,432,800	7,432,800	7,432,800	7,432,800
Chilies and Peppers green	69,774,758	89,650,000	106,246,986	114,655,504
Cow Peas dry	13,565,354	9,820,228	9,820,228	13,695,000
Cucumbers	115,663,920	163,739,376	136,979,472	121,529,328
Figs	261,463,314	411,645,430	365,393,651	423,625,230
Flax fibre and tow	152,404,000	97,974,000	103,569,404	89,570,008

Garlic	76,501,285	47,131,140	67,321,590	74,220,496
Jute	6,492,200	5,837,078	5,651,165	4,886,856
Lemon and Lime	135,595,096	156,109,434	160,307,446	162,892054
Lettuce	28,981,608	20,750,000	19,158,558	18,536,556
Linseed	38,640,000	12,367,376	15,747,088	15,300,152
Lupins	11,917,880	7,826,000	8,063,575	6,663,280
Mangoes	520,350,080	1,040,700,160	926,946,702	812,065,076
Nuts	33,316,500	35,696,250	30,571,020	35,070,000
Okra	18,772,000	27,044,030	29,131,180	25,858,430
Olives	446,284,080	792,000,000	803,171,952	760,432,464
Peaches	286,550,249	510,173,327	507,350,689	476,503,288
Peas green	159,457,186	104,447,707	123,340,903	133,699,706
Pumpkins	132,463,256	128,543,504	133,322,536	119,942,056
Sesame seed	72,039,127	81,274,210	82,608,884	72,178,074
Spinach	11,272,950	11,714,280	14,423,830	15,666,275
Strawberries	20,901,152	37,991,304	51,626,544	59,275,184

Taro	5,171,824	15,297,214	16,848,078	18,540,462
Vetches	1,834,300	1,720,000	1,720,000	1,900,000
Walnuts	55,474,160	73,278,000	73,278,000	73,278,000
Poultry Meat	1,168,317,056	1,360,409,728	1,541,918,272	1,384,279,712
Bovine Meat	2,636,974,494	3,021,828,579	3,009,686,526	3,080,239,470
Cheese	941,603,250	1,494,648,750	1,918,344,750	2,116,687,440
Butter	344,252,000	428,139,840	426,950,800	414,885,960
Eggs	320,293,645	435,120,000	530,483,800	534,454,270
Milk (cow & Buffalo)	2,553,055,960	2,789,570,784	4,013,004,372	4,042,266,384
Sheep and Goat Meat	44,250,000	36,915,710	39,475,720	38,372,420
Total	38,842,147,802	45,127,874,188	46,765,386,767	47,916,591,475

Legend: Average increase in agricultural blue water footprint (2000-2008): 2.13% per year