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M.M. Mekonnen
A.Y. Hoekstra

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# MITIGATING THE WATER FOOTPRINT OF EXPORT CUT FLOWERS FROM THE LAKE NAIVASHA BASIN, KENYA

M.M. MEKONNEN[1]

A.Y. HOEKSTRA[1,2]

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[1] Twente Water Centre, University of Twente, Enschede, The Netherlands

[2] Contact author: Arjen Hoekstra, a.y.hoekstra@utwente.nl

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## Content

## Summary

Kenya's cut-flower industry has been praised as an economic success as it contributed an annual average of US$ 141 million foreign exchange (7% of Kenyan export value) over the period 1996-2005 and about US$ 352 million in 2005 alone. The industry also provides employment, income and infrastructure such as schools and hospitals for a large population around Lake Naivasha. On the other hand, the commercial farms have been blamed for causing a drop in the lake level and for putting the lake's biodiversity at risk. The objective of this study is to quantify the water footprint within the Lake Naivasha Basin related to cut flowers and assess the potential for mitigating this footprint by involving cut-flower traders, retailers and consumers overseas.

The water footprint of one rose flower is estimated to be 7-13 litres. The total virtual water export related to export of cut flowers from the Lake Naivasha Basin was 16 $Mm^3$/yr during the period 1996-2005 (22% green water; 45% blue water; 33% grey water). Our findings show that, although the commercial farms around the lake have contributed to the decline in the lake level through water abstractions, both the commercial farms and the smallholder farms in the upper catchment are responsible for the lake pollution due to nutrient load. The observed decline in the lake level and deterioration of the lake's biodiversity calls for sustainable management of the basin through pricing water at its full cost and other regulatory measures.

Despite broad international agreement on the need for full-cost water pricing, unilateral efforts to implement it in the agricultural sector are politically difficult, because farmers have difficulty to accept and local competitiveness may be put at risk. More in particular, the conditions in Kenya are unlikely to result in serious steps to full-cost pricing, since farmers already resist even modest water price increases and government is lacking means of enforcement. In addition, little can be expected from international agreements. The implementation of an international protocol on water pricing requires global agreement among the major players on the global market, which makes it unlikely that such a protocol will be implemented in the near future. As an alternative to an international water-pricing protocol we propose an alternative in this study that can be implemented with a focus on sustainable water use in flower farming around Lake Naivasha alone. The proposal involves a water-sustainability agreement between major agents along the cut-flower supply chain and includes a premium to the final product at the retailer end of the supply chain. Such a 'water sustainability premium' will raise awareness among flower consumers and encourage the flower farms to use water in a sustainable manner. The collected premiums will generate a fund that can be used for financing measures to reduce the water footprint and to improve watershed management. The sustainability premium also reduces the risk of the flower farms losing their competitiveness and avoids business migration from Kenya to other countries with less stringent water pricing and environmental regulations.

## 1. Introduction

Lake Naivasha (Figure 1) is situated 80 km northwest of Nairobi in the Rift Valley of Kenya ($0^0$ 45’S, $36^0$ 20’E). It is Kenya’s second largest freshwater lake without surface outlet and the natural fluctuation in water levels over the last 100 years has been in excess of 12 meters (Mavuti and Harper, 2005). The lake gets its water from the Aberdare / Nyandarua highlands to the east and the Rift Valley, via two main rivers: the Malewa and the Gilgil Rivers, contributing 80 and 20 percent, respectively, to the surface inflow of the lake (Becht et al., 2005). The lake remains fresh due to a significant exchange of groundwater. The lake has international value as a Ramsar wetland.

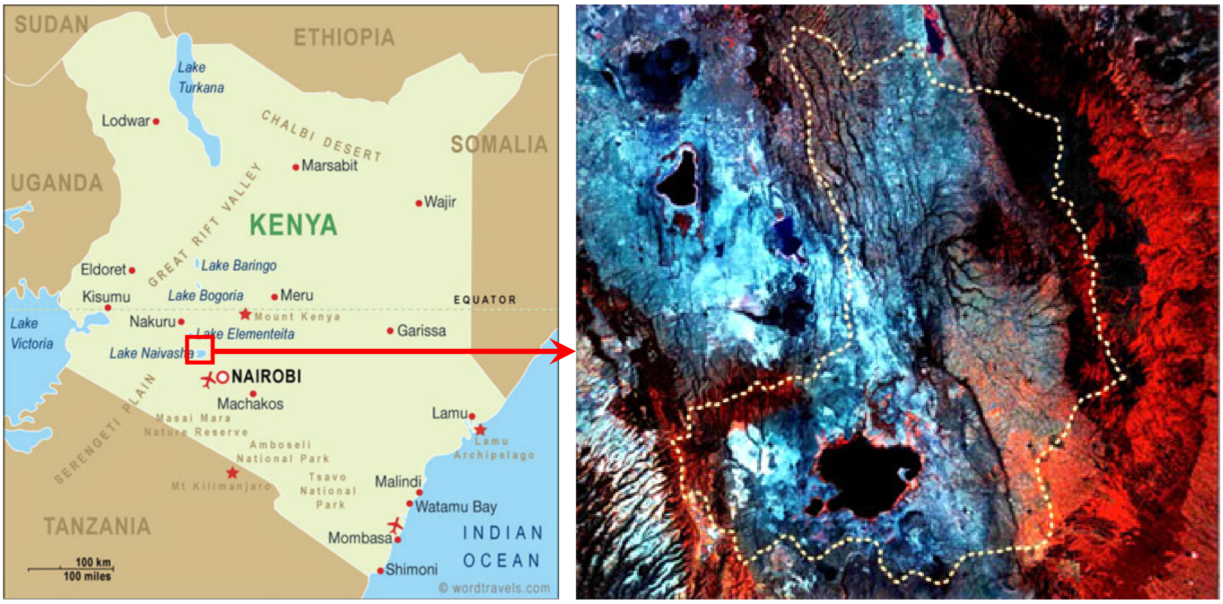


*Figure 1. Kenya (left) and the Lake Naivasha Basin (right). Source of right figure: Becht (2007).*

A pipeline abstracting water from the Turasha River, main tributary of the Malewa, for supply to Gilgil and Nakuru Town, was the first major water abstraction in the basin, operational since 1992. Furthermore, in the last two decades, the area around Lake Naivasha has grown to become the main site of Kenya’s horticultural industry (mainly cut flower), which is the third most important foreign exchange earner after tea and tourism. Since the late 1990s, the flower farms started to expand at a faster rate (Becht et al., 2005). The total irrigated commercial farm area around Lake Naivasha is about 4450 ha. Cut flowers account for about 43% of the irrigated area, followed by vegetables with 41% and fodder with 15% (Musota, 2008).

The major flower varieties grown and exported from Kenya are roses, carnation, alstroemeria, lisianthus, statice and cut foliage. Rose flower dominates the export market, accounting for over 70% of the export volume (HCDA, 2007). The main flower growing regions are Lake Naivasha, Thika and Kiambu/Limuru (EPZA, 2005b), with Lake Naivasha accounting for about 95% of the cultivated area.

The lake has attracted attention and concerns from both national and international organisations. The main stakeholders have shown concern about the health of the lake, mainly related to the decline of the lake level, deterioration of the water quality and reduction of biodiversity. Some of the main stakeholders active around the lake are the Lake Naivasha Riparian Association (LNRA), the Lake Naivasha Growers Group (LNGG) and Kenya Wildlife Services (KWS). The concerns have led to the development of a Management Plan in 1996 by the main stakeholders (Becht et. al., 2005). The Lake Naivasha Management Implementation Committee (LNMIC) was formed to execute the management plan. The plan was officially approved by the Government of Kenya in 1997.

There have been many studies regarding the lake water balance and the aquatic ecology of the lake. Most notably, the International Institute of Geo-Information Science and Earth Observation (ITC), based in the Netherlands, has carried out a number of studies regarding the lake water balance and nutrient load to the lake and is active in developing a geo-information system on the land use around the lake. Leicester University and Earthwatch studied the aquatic ecology of the lake since 1985. Many Kenyan scientists, the Kenya Marine and Fisheries Research Institute (KEMFRI), Kenya Wildlife Services (KWS) and Kenya Agricultural Research Institute (KARI) are also doing research on the lake (Becht et. al., 2005).

The objective of the present study is to quantify the water footprint within the Lake Naivasha Basin related to horticulture, in particular the flower farms, and assess the potential for mitigating this footprint by involving cut-flower traders, retailers and consumers overseas. In addition, we will explore the idea of a voluntary sustainable-flower agreement between major agents along the flower supply-chain that involves a water-sustainability premium to be paid by the consumers in the countries importing flowers from Kenya.

## 2. Method and data

### *2.1 Method*

The green, blue and grey components of the water footprint of products were calculated following the method of Hoekstra et al. (2009). The water footprint of a crop ($m^3$/ton) is calculated as the ratio of the volume of water ($m^3$/ha) consumed or polluted during the entire period of crop growth to the corresponding crop yield (ton/ha). Water consumption has two components: green and blue water consumption. The grey component of the water footprint of crops ($m^3$/ton) is calculated by dividing the amount of nitrogen that leaches to the water system (kg/ha) by the maximum acceptable concentration of nitrogen (kg/$m^3$) and the crop yield (ton/ha).

The crop water requirements, effective rainfall and irrigation requirement for the different vegetables and cut flower grown around Lake Naivasha were estimated using CROPWAT (FAO, 2007b). The calculation was done using climatic data obtained from CLIMWAT (FAO, 2007c) for Naivasha climate station. The cut flowers and vegetables are grown all over the year with multi-cropping. Therefore, the blue water footprint per month was calculated by running CROPWAT for each multi-cropping.

For the other 22 crops grown in the upper catchment of the Lake Naivasha Basin, a crop water use model (Mekonnen and Hoekstra, 2010) was used to carry out a daily soil water balance and calculate the green, blue and grey water footprint at grid level. The model was run for the whole of Kenya and later the Lake Naivasha Basin area raster was used to extract data applicable only for the basin. The crop area, production and water footprint of the 22 crops is presented in Appendix I.

Virtual water exports ($m^3$/yr) related to exports of cut flowers and vegetables were calculated by multiplying the trade volumes (tons/yr) by their respective water footprint in Kenya ($m^3$/ton).

### *2.2 Data*

The Lake Naivasha Basin can be schematised into two parts: the upper catchment with smallholder farms and the area around Lake Naivasha with big farms producing for export. Grid data on type and size of farms around Lake Naivasha was obtained from the ITC Naivasha database (Becht, 2007) – see details in Appendices II and III. For crops grown in the upper catchment, the crop growing areas with 5 arc minute grid cell resolution were obtained from Monfreda et al. (2008). The grid crop area data was aggregated to a national level and compared with and scaled to fit national average crop harvest area for the period 1996-2005 obtained from FAOSTAT (FAO, 2007a).

The cut-flower production for the period 1996-2005 around Lake Naivasha was calculated from the export data assuming that 95% of the cut-flower production is exported.

The crop parameters (crop coefficients and start and length of cropping seasons) for the different vegetables were taken from Chapagain and Hoekstra (2004). For cut flowers, the crop parameters were adopted from Orr and Chapagain (2006). The evapotranspiration in greenhouse conditions is assumed to be 65% of the outdoor condition as suggested by various authors (Mpusia, 2006; Baille et al., 1994; Orgaz et al., 2005). The average water footprint of cut flowers was estimated based on the weighted average of indoor and outdoor farm areas. About 62% of the cut flowers around Lake Naivasha are grown in greenhouses (Musota, 2008). Table 1 gives the irrigated area and fertilizer application rate for irrigated crops around Lake Naivasha. A leaching-runoff fraction of 10% was assumed, following Hoekstra and Chapagain (2008).

*Table 1. Irrigated crops around Lake Naivasha. Year 2006.*

| Crop | Irrigated area[1] | | Fertilizer application rate (kg/ha)[2] | | |
|---|---|---|---|---|---|
| | Area (ha) | % | N | $P_2O_5$ | $K_2O$ |
| Total flowers | 1911 | 42.8 | 325 | 145 | 303 |
| Roses | 1028 | 23.0 | 325 | 145 | 303 |
| Roses & carnations | 730 | 16.3 | 325 | 145 | 303 |
| Roses, hypercium | 21 | 0.5 | 325 | 145 | 303 |
| Other flowers | 132 | 3.0 | 325 | 145 | 303 |
| Total vegetables | 1824 | 40.8 | 185 | 179 | 55 |
| Babycorn | 205 | 4.6 | 41 | 113 | 0 |
| Babycorn & beans | 143 | 3.2 | 252 | 141 | 81 |
| Babycorn, beans & cabbage | 169 | 3.8 | 235 | 141 | 81 |
| Babycorn, beans & onions | 906 | 20.3 | 244 | 244 | 81 |
| Beans/tomatoes | 21 | 0.5 | 235 | 141 | 81 |
| Cabbage | 374 | 8.4 | 68 | 94 | 0 |
| Cabbage & beans | 6 | 0.1 | 235 | 141 | 81 |
| Total fodder | 665 | 14.9 | 68 | 94 | 0 |
| Grass | 286 | 6.4 | 68 | 94 | 0 |
| Grass & lucerne | 40 | 0.9 | 68 | 94 | 0 |
| Lucerne | 163 | 3.7 | 68 | 94 | 0 |
| Lucerne, babycorn, beans | 176 | 3.9 | 68 | 94 | 0 |
| Macadamia | 50 | 1.1 | 68 | 94 | 0 |
| Eucalyptus | 17 | 0.4 | | | |
| Total | 4467 | 100.0 | | | |

[1] Musota (2008), ITC Naivasha database (Becht, 2007).
[2] Tiruneh (2004), Xu (1999), Ariga et al. (2006).

Grid-based soil moisture data of total available water capacity (TAWC) at 5 arc minute resolution was taken from ISRIC-WISE (Batjes, 2006). An average value of TAWC of the five soil layers was used in the model. The main data source for nitrogen fertilizer application rate per crop for the upper catchment was FAO (2009).

Data on irrigated area per crop was obtained mainly from the AQUASTAT country profile database (FAO, 2005) and Portmann et al. (2008). For rice, data on irrigated area was obtained from EPZA (2005a). The country level irrigated area data is distributed to grid cells according to area equipped for irrigation (AEI). The Global Map of Irrigation Areas version 4.0.1 (Siebert *et al.*, 2007) with spatial resolution of 5 arc minute was used to define the area equipped for irrigation for each grid cell. The distribution was done proportional to the harvested area of each cropped grid cell. For cases where there is no AEI data or the AEI does not match with the irrigated area data, the irrigation area data is distributed proportional to the harvest area of each cropped grid cell.

Average monthly reference evapotranspiration data at 10 arc minute resolution were obtained from FAO (2008). The 10 minute data was converted to 5 arc minute resolution by assigning the 10 minute data to each of the four 5 minute grid cells. Following the CROPWAT approach, the monthly average data was converted to daily values by curve fitting to the monthly average through polynomial interpolation.

Monthly values for precipitation, wet days, minimum and maximum temperature with a spatial resolution of 30 arc minute were obtained from CRU through CGIAR-CSI GeoPortal (Mitchell and Jones, 2005). The 30 arc minute data were assigned to each of the thirty-six 5 arc minute grid cells contained in the 30 arc minute grid cell. Daily precipitation values were generated from these monthly average values using the CRU-dGen daily weather generator model (Schuol and Abbaspour, 2007).

Data on trade in cut flowers and vegetable products in the period 1996-2005 have been taken from the SITA (Statistics for International Trade Analysis) database available from the International Trade Centre (ITC, 2007).

## 3. Water use within the Lake Naivasha Basin related to cut-flower production

### *3.1 The water footprint within the Lake Naivasha Basin related to crop production*

The water footprint related to crop production in the Lake Naivasha Basin is presented in Table 2 below. Two groups of crops are shown: fully irrigated crops grown by commercial farms mainly for export and concentrated around Lake Naivasha, and other crops which are cultivated by small farmers in the upper catchment. The total water footprint related to crop production sums up to 102 $Mm^3$/yr. About 68.7% of the water footprint is related to green water, 18.5% blue water and 12.8% grey water. The commercial crops contribute 41% to the total water footprint related to crop production. About 98% (18.4 $Mm^3$/yr) of the blue water footprint and about 61% of the grey water footprint in the catchment area can be attributed to the commercial farms around the lake. The geographic distribution of the water footprints around the lake is shown in Appendix IV (the blue water footprint alone) and Appendix V (the total water footprint, including green, blue and grey).

*Table 2. Water footprint of crops grown in the Lake Naivasha Basin (large irrigated farms). Year 2006.*

| Land use | Area cultivated* | | Water footprint (1000 $m^3$/yr) | | | |
|---|---|---|---|---|---|---|
| | Area (ha) | Irrigated (%) | Green | Blue | Grey | Total |
| Commercial farms around the lake** | | | | | | |
| Total flower | 1911 | 100 | 3640 | 7576 | 5627 | 16842 |
| Flowers open | 721 | 100 | 3640 | 1770 | 2122 | 7532 |
| Flowers greenhouse | 1190 | 100 | 0 | 5805 | 3504 | 9310 |
| Vegetables | 1824 | 100 | 7887 | 7375 | 1834 | 17097 |
| Fodder | 665 | 100 | 3716 | 3194 | 452 | 7362 |
| Macadamia | 50 | 100 | 278 | 303 | 34 | 615 |
| Total of commercial farms | 4450 | 100 | 15521 | 18448 | 7947 | 41916 |
| Farms in the upper catchment of the basin*** | | | | | | |
| Cereals | 12125 | 1 | 34776 | 82 | 1655 | 36513 |
| Pulses | 2199 | 0 | 3958 | 0 | 2673 | 6631 |
| Others | 3562 | 7 | 15876 | 382 | 809 | 17067 |
| Total of upper catchment farms | 18137 | 2% | 54609 | 465 | 5137 | 60211 |
| Grand total | 22587 | 21% | 70130 | 18913 | 13084 | 102127 |

* Source: Musota (2008); Becht (2007).

** See Appendix VI for details on the water footprint of the commercial farms around the lake.

*** See Appendix I for details on the water footprint of crop production in the upper catchment.

In addition to the irrigated farms which are found around Lake Naivasha, the basin is used mainly for cattle and game rangeland. Smallholder farmers growing mainly maize, vegetables and other crops occupy areas which receive high rainfall. There are about 18,000 ha of farm land in the upper catchment of which only 2% is irrigated. The average water footprint related to the production of these crops over the period 1996-2005 was about 60 $Mm^3$/yr (90.7% green water, 0.8% blue water; 8.5% grey water).

Cut flowers take a large share of the water footprint related to crop production around Lake Naivasha, contributing about 98% and 41% to the blue and total water footprint respectively. The production water footprint related to cut flowers is about 16.8 $Mm^3$/yr (Table 2). Flowers grown in greenhouses are assumed to be fully supplied with irrigation water, while flowers cultivated in the open field get both rainwater and irrigation water. For flowers grown in the open field the blue water component is only 24% of the total water footprint, while for flowers grown in greenhouses the evaporative water consumption is met fully from irrigation water (Figure 2). The average water footprint of cut flowers grown around Lake Naivasha is 367 $m^3$/ton. About 45% (165 $m^3$/ton) of this water footprint refers to blue water, 22% (79 $m^3$/ton) to green water and 33% (123 $m^3$/ton) to grey water, the volume of water needed to assimilate the nitrogen fertilisers that enter the water systems due to leaching or runoff.

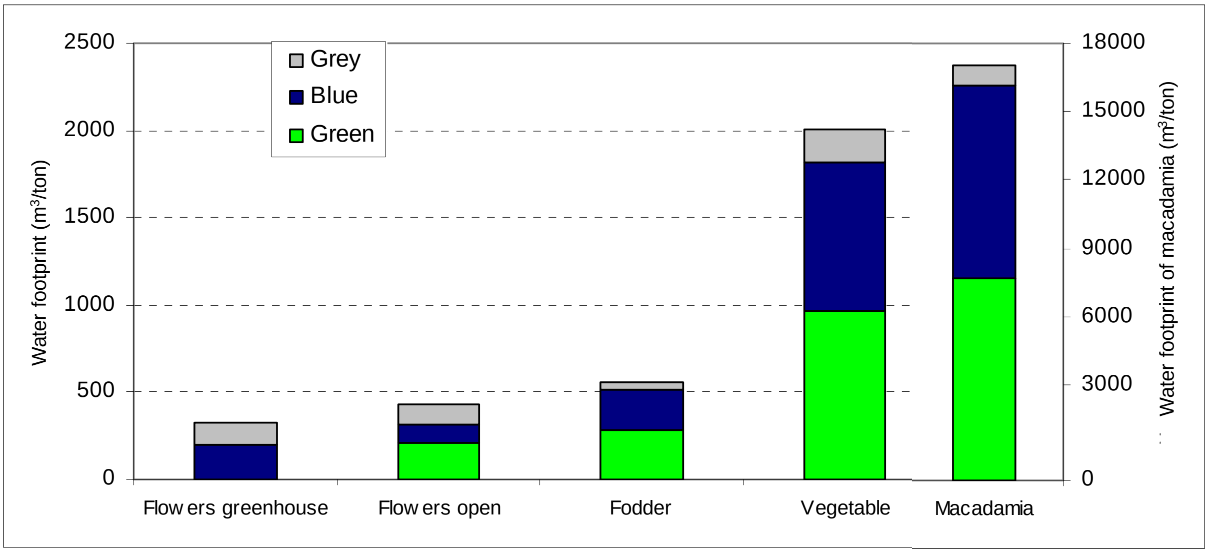


*Figure 2. Water footprint per ton of crop for crops grown around the lake. Period 1996-2005*

The operational water footprint of the different farms around Lake Naivasha cultivating cut flower, vegetables or fodder is presented in Figures 3 and 4. The six big farms – Logonot Horticulture, Delamere, Oserian, Gordon-Miller, Marula Estate and Sher Agencies – account for about 56% of the total operational water footprint around Lake Naivasha and 60% of the blue water footprint related to crop production.

Lake Naivasha is the main source of water for the irrigation around the Lake. About 53% of the blue water footprint related to production of crops comes directly from Lake Naivasha, about 40% from groundwater and the remaining 7% from the rivers flowing to the lake (Table 3).

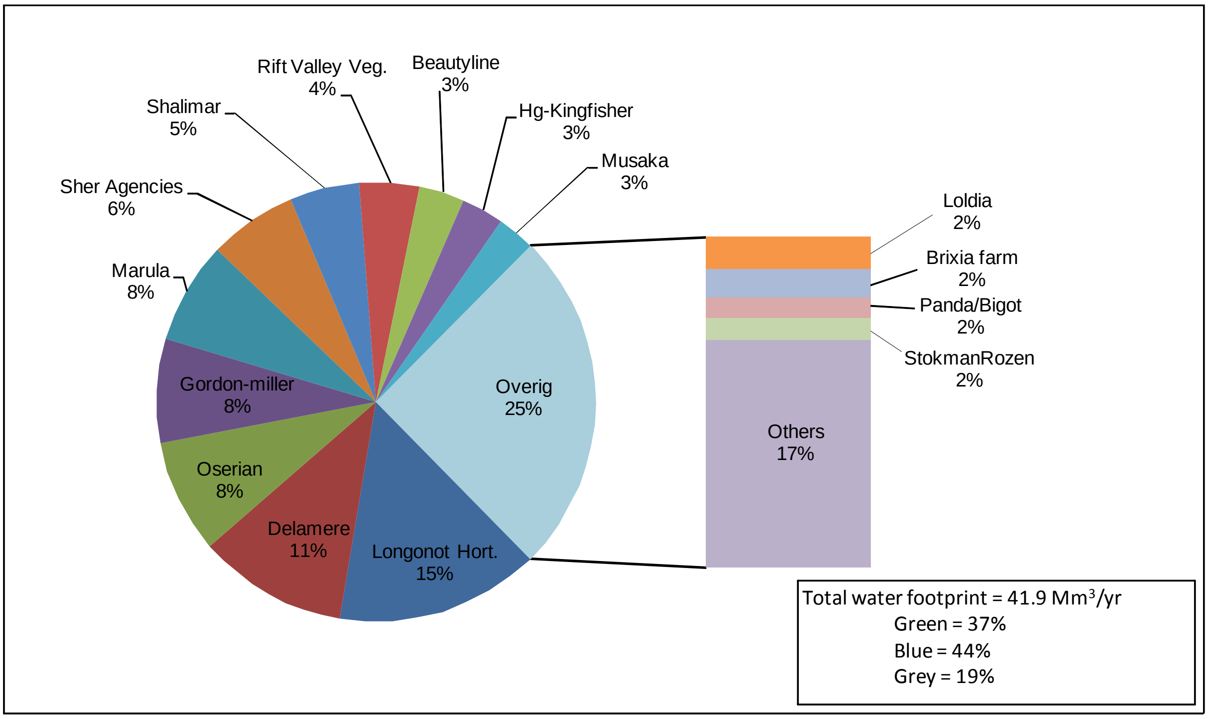


*Figure 3. Contribution of major farms to the total operational water footprint of crop production around Lake Naivasha. Period 1996-2005.*

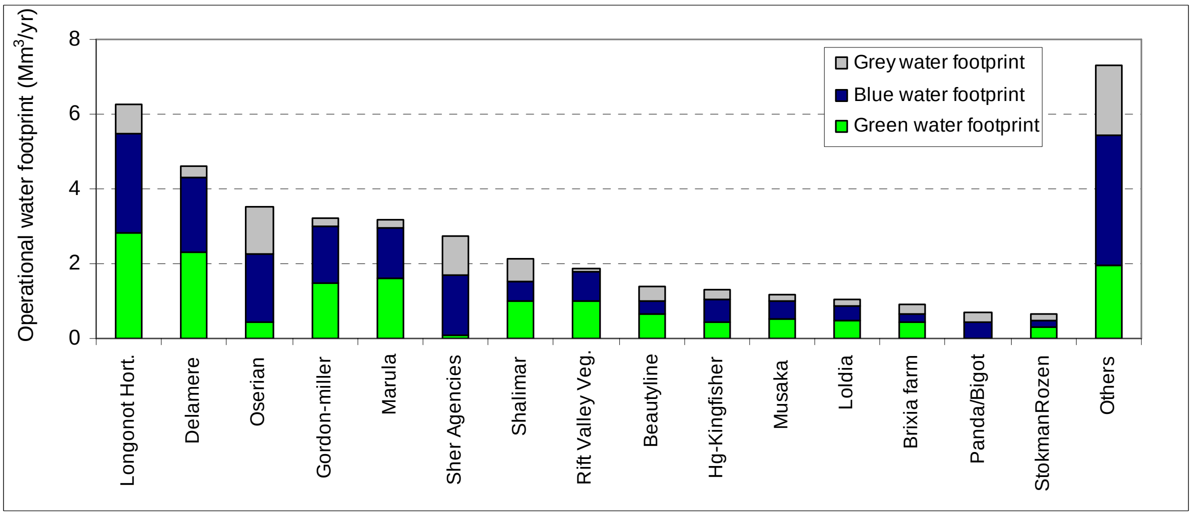


*Figure 4. Operational water footprint of major farms around Lake Naivasha. Period 1996-2005*

*Table 3. Source of irrigation water for crop production around Lake Naivasha. Period 1996-2005.*

| Crops | Blue water footprint by source (Mm$^3$/yr) | | | |
|---|---|---|---|---|
| | Lake | Groundwater | River | Total |
| Flowers | 6.07 | 1.37 | 0.13 | 7.57 |
| Vegetables | 3.79 | 3.36 | 0.23 | 7.38 |
| Fodder | 0 | 2.62 | 0.57 | 3.19 |
| Macadamia | 0 | 0 | 0.30 | 0.30 |
| Total | 9.9 | 7.3 | 1.2 | 18.4 |

### 3.2 The water footprint per cut flower

Depending on the yield and weight of a rose flower stem, the water footprint per stem varies from 7 to 13 litre/stem (Table 4). If we assume an average rose flower stem weights about 25 gram, its green water footprint would be 2 litre/stem, its blue water footprint 4 litre/stem and its grey water footprint 3 litre/stem, resulting in a total water footprint of 9 litre per stem.

*Table 4. The water footprint of a rose flower. Period 1996-2005.*

| Weight of rose (gram/stem) | Water footprint by type (litre/stem) | | | |
|---|---|---|---|---|
| | Green | Blue | Grey | Total |
| 20 | 1.6 | 3.3 | 2.5 | 7.3 |
| 25 | 2.0 | 4.1 | 3.1 | 9.2 |
| 35 | 2.8 | 5.8 | 4.3 | 12.8 |

### 3.3 Virtual water export from the Lake Naivasha Basin

When we assume that about 95% of Kenya's cut-flowers export comes from the area around Lake Naivasha, the average virtual water export from the Lake Naivasha Basin related to export of cut flowers was 16 $Mm^3$/yr in the period 1996-2005 (22% green water, 45% blue water and 33% grey water) (Table 5). The European Union is Kenya's principal market for cut flowers; with the Netherlands, the UK, and Germany together taking over 90 percent of the virtual water export due to export of cut flowers. The Netherlands is the principal market, accounting for 69% of the total export, followed by the UK with 18% and Germany with 7%. The virtual water export in relation to export of cut flowers has shown a significant growth, with virtual water export almost doubling from 11 $Mm^3$/yr in 1996 to 21 $Mm^3$/yr in 2005 (Figure 5).

*Table 5. Major destinations of virtual water export related to export of cut flowers from the Lake Naivasha Basin. Period 1996-2005.*

| Country | Virtual water export (1000 $m^3$/yr) | | | |
|---|---|---|---|---|
| | Green | Blue | Grey | Total |
| Netherlands | 2399 | 4993 | 3708 | 11100 |
| United Kingdom | 611 | 1272 | 944 | 2827 |
| Germany | 230 | 478 | 355 | 1064 |
| Switzerland | 59 | 122 | 91 | 272 |
| South Africa | 37 | 77 | 57 | 171 |
| France | 33 | 68 | 51 | 152 |
| United Arab Emirates | 16 | 33 | 25 | 74 |
| Italy | 10 | 20 | 15 | 45 |
| Others* | 64 | 133 | 98 | 295 |
| Total | 3458 | 7196 | 5345 | 16000 |

* See Appendix VII for an overview of all virtual water exports from Kenya, specified by destination country.

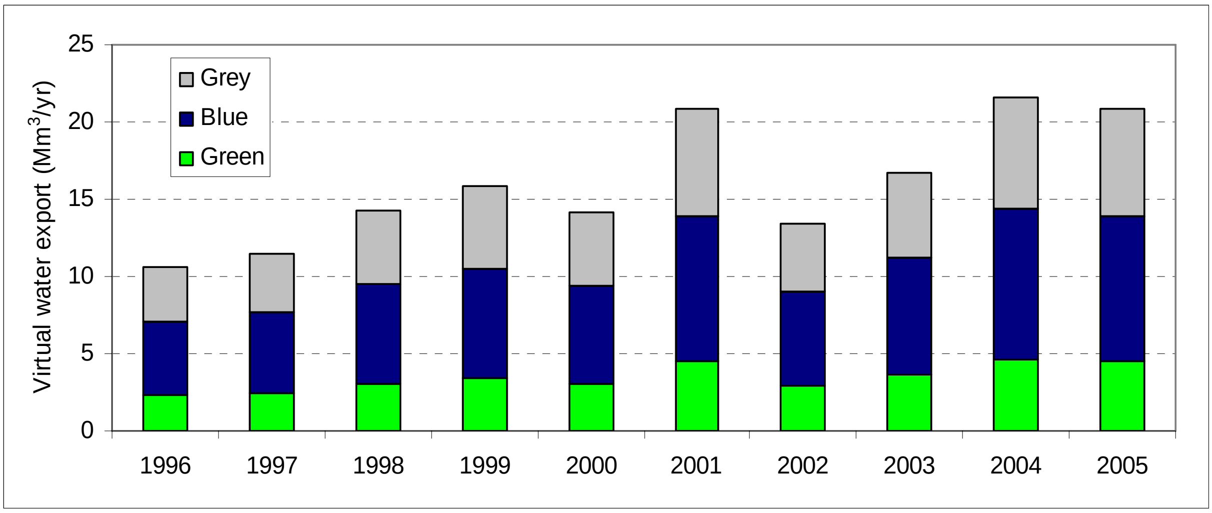


*Figure 5. Virtual water export related to export of cut flower from the Lake Naivasha Basin.*

In addition to cut flowers, vegetables such as beans, sweet corn, tomato, cabbage and onions are produced for both export and domestic consumption. About 50% of the vegetable produced around Lake Naivasha is exported and the remaining is supplied to local markets, mainly to Nairobi. The virtual water export related to vegetable products was 8.5 $Mm^3$/yr. Most of the virtual water related to vegetable products was exported to the United Arab Emirates, France and the United Kingdom. Therefore, for the period 1996-2005, the total virtual water export related to export of cut flowers and vegetable products was 24.5 $Mm^3$/yr.

The cut-flower industry is an important export sector, which contributed an annual average of US$ 141 million foreign exchange (7% of Kenyan export value) over the period 1996-2005, and US$ 352 in 2005 alone. Hence, Kenya is generating foreign exchange of (141/16=) 8.8 US$/$m^3$.

### *3.4 Sustainability of water use in the Lake Naivasha Basin*

The horticulture sector in Naivasha employs some 25,000 people directly and the same number of people is indirectly dependent, both as dependents and service providers (Becht et al., 2005). Most of the farms pay more than the legal minimum wage. The farms also provide housing, free medical services, schools for children of farm workers and social and sport facilities. Some of the larger farms also participate in the community development such as provision of clinic and ambulance services, water management and tree planting and watering of the community trees. A continued supply of freshwater to sustain the economy is a concern, however.

Lake Naivasha has been used for irrigation since the 1940s. Water is extracted directly from the lake, but also from groundwater and the rivers feeding the lake. Beside the irrigation water used for crop production, water from the basin is used for drinking water supply and since 1992 a pipeline became operational pumping 20,000 $m^3$ per day from Malewa sub-basin to Gilgil and Nakuru Town (Becht and Nyaoro, 2006; Musota, 2008). A study made for the Lake Naivasha Riparian Association estimated the total water abstraction for potable water use in the Lake Naivasha Basin and for Olkaria Geothermal Power Plant at the end of 1980s-early 1990s to be

37 $Mm^3$/yr and 15 $Mm^3$/yr respectively (Becht and Harper, 2002; UNESCO, 2007). Altogether, the blue water footprint within the Lake Naivasha Basin is estimated at 45 $Mm^3$/yr (Table 6).

*Table 6. The blue water footprint in the Lake Naivasha Basin.*

| | Blue water footprint ($Mm^3$/yr) | Contribution to the total blue water footprint (%) |
|---|---|---|
| Cut flower | 7.58 | 17 |
| Vegetable and macadamia | 7.68 | 17 |
| Grass and fodder | 3.19 | 7 |
| Upper catchment crops | 0.47 | 1 |
| Nakuru and Gilgil town[1] | 7.30 | 16 |
| Olkaria geothermal[2] | 15.00 | 33 |
| Lake Naivasha Basin potable water[2] | 3.70 | 8 |
| Total | 44.92 | 100 |

[1] Source: Becht and Nyaoro (2006); Musota (2008).

[2] Sources: Becht and Harper (2002) and UNESCO (2007); the estimated potable water use in the Lake Naivasha Basin was 37 $Mm^3$/yr. We assumed a 90% return flow and 10% of the abstraction actually consumed.

The rainfall regime within the Lake Naivasha Basin is influenced by the rain shadow from the surrounding highlands of the Aberdare range to the east and the Mau Escarpment to the west. The long-term rainfall varies from about 600 mm at Naivasha town to some 1700 mm on the slopes of the Nyandarua Mountains (Becht et al., 2005). Two rainy seasons are observed in the basin, with the 'long rains' occurring in April to June and the 'short rains' in October and November. Most of the rain is received during the 'long rains'. Relief controls the rainfall pattern, with much more rainfall in the higher altitudes than the lower altitudes. Total basin rainfall and evapotranspiration are estimated at 2790 $Mm^3$/yr and 2573 $Mm^3$/yr respectively (Becht, 2007). The annual runoff generated in the Lake Naivasha Basin is estimated at 217 $Mm^3$/yr (Becht and Harper, 2002). The long-term average annual water balance of the basin is presented in Table 7.

*Table 7. The long-term average annual water balance of Lake Naivasha Basin.*

| | Basin water balance ($Mm^3$/yr) | Fraction (%) |
|---|---:|---:|
| Rainfall | 2790 | 100 |
| Evapotranspiration of rainwater from land | 2573 | 92.2 |
| Evapotranspiration from the lake | 256 | 9.2 |
| Groundwater outflow | 56 | 2.0 |
| Blue water footprint | 45 | 1.6 |
| Closing error | -140 | -5.0 |

Source: Becht (2007); blue water footprint own calculation.

Sustainability of the water footprint related to the production of horticultural and other crops, domestic and industrial water uses in Lake Naivasha Basin can be assessed by comparing the blue water footprint with the available blue water resources (Figure 6). The available blue water for human use is the difference between the annual runoff (R) and the environmental flow requirements (EFR), which is set at 80% of runoff (Hoekstra et al., 2009). For the Lake Naivasha Basin the total blue water footprint is about 20% of the annual average runoff, which leaves only 80% of the runoff for meeting environmental flow requirement. When we take the blue and grey water footprint together, they make 27% of the annual average runoff.

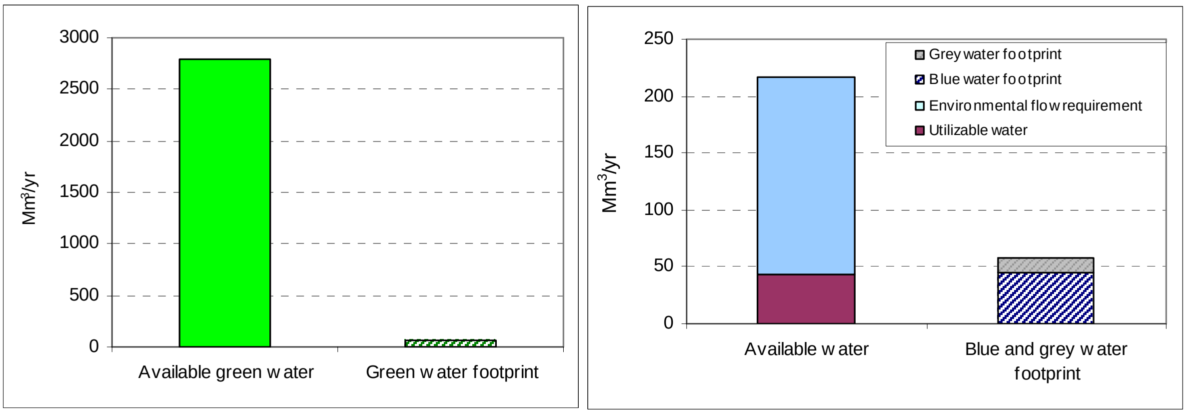


*Figure 6. Comparison of water availability and water footprint.*

Comparing the blue-grey water footprint with the blue water available for human use at annual basis hides the seasonal variation, which is relevant particularly in basins with highly variable flow regimes. Therefore, it is quite important to do the comparison on a monthly basis. The long-term average monthly runoff and environmental flow requirement and the monthly blue-grey water footprint within the Lake Naivasha Basin are presented in Figure 7. The long-term average monthly runoff data for the basin for the period February 1932 to June 1981 was obtained from the ITC Naivasha database (Becht, 2007). The monthly blue-grey water footprints were derived from the current study, taking into account the growth seasons of the various crops. In the dry period Jan-March, the generated runoff is fully appropriated for either consumptive water uses or assimilation of pollution. In the period Oct-March, the blue water footprint exceeds the environmental flow requirement; in the period June-July, the blue water footprint nearly exceeds the environmental flow requirements.

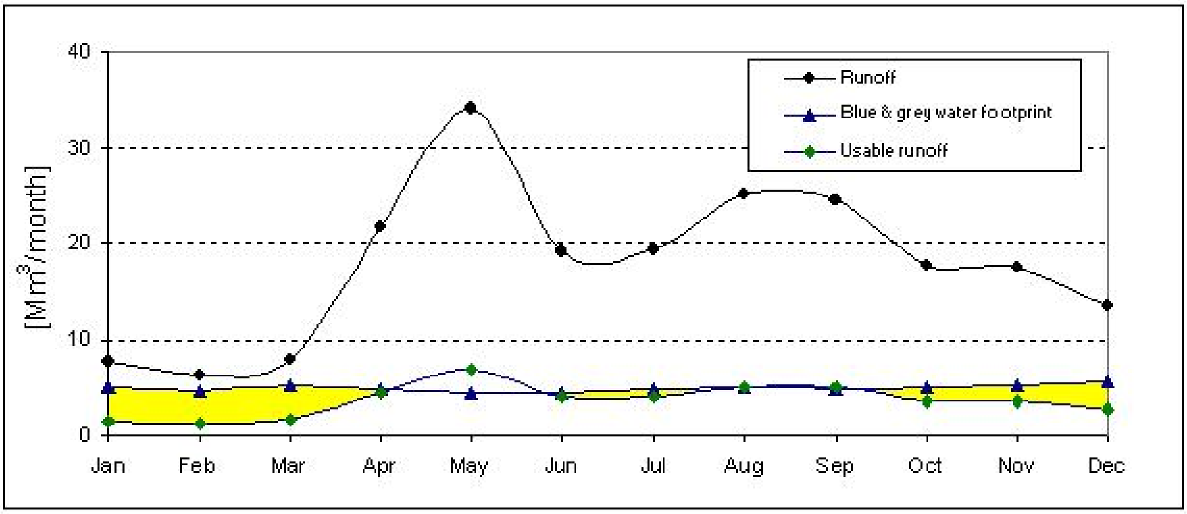


*Figure 7. Long term average monthly runoff, blue-grey water footprint and environmental flow of the Lake Naivasha Basin. Sources: runoff from the ITC Naivasha database (Becht, 2007); water footprint from own calculation.*

The long-term water balance of Lake Naivasha prior to water abstraction was estimated by Becht and Harper (2002) and is presented in Table 8. The Lake Water Requirement (LWR) is defined as the amount of water required to maintain the lake at its natural level. The LWR is calculated by adding the lake evapotranspiration and the groundwater outflow and subtracting the rainfall on the lake surface. Therefore, the LWR is equivalent to the surface water inflow of 217.4 $Mm^3$/yr.

*Table 8. The long-term average annual water balance of Lake Naivasha prior to large-scale water abstractions.*

| Water flow | $Mm^3$/yr |
|---|---|
| Surface water inflow | 217.4 |
| Rainfall | 93.9 |
| Evapotranspiration | 256.3 |
| Water loss (groundwater outflow) | 56 |
| Sum (error) | 1 |

Source: Becht and Harper (2002)

A fluctuating lake level is a natural phenomenon for Lake Naivasha and a necessity for the functioning of the ecosystem. The climate, physical attributes and geographic context set the background for a hydrological cycle that results in natural lake level variability reaching above 12 meters over the last 100 years (Becht et al., 2005). However, Becht and Harper (2002) and again Becht et al. (2005) show that the more recent decline in the lake level coincides with and can be explained by the commencement of horticulture crops in the area in 1982 (Figure 8). Becht and Harper (2002) show that in late 1998, the lake was 3.5 meters lower than it would have been had it followed the hydrological records. On the other hand, according to Harper and Mavuti (2004), the current level of water abstraction has not led to a greater lake level fluctuation than as was recorded in the past, and there is no evidence that lake level fluctuations themselves risk biodiversity losses. Becht (2007) suggested that at a constant rate of water abstraction the lake will establish a new equilibrium lake level. He goes further by arguing that the question as to how much a drop in the lake level is acceptable is a societal and political one.

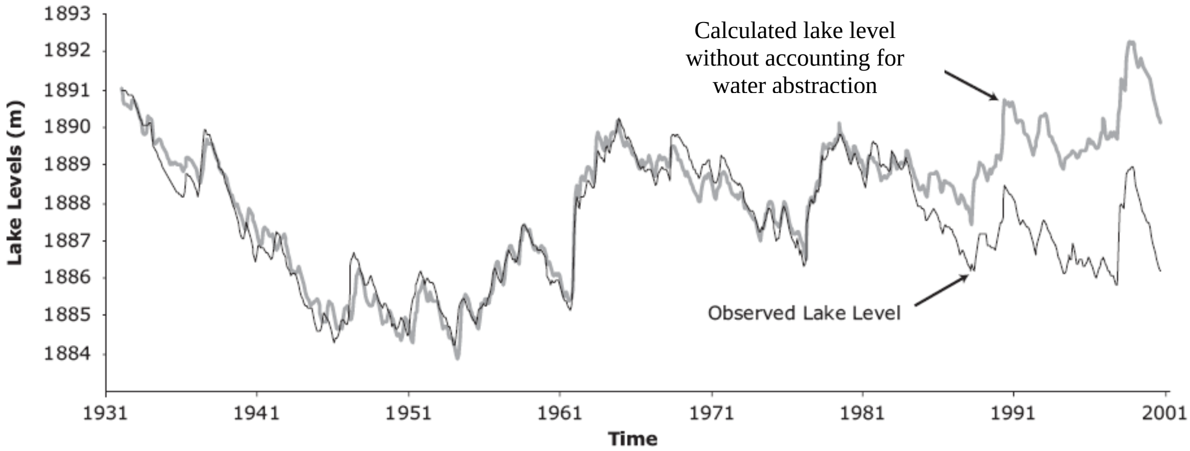


*Figure 8. Long-term water level change in Lake Naivasha. The calculated lake level represents the case without water abstraction (reproduced from Becht et al, 2005).*

Although the recent reduction in the lake's water level can be attributed mainly to the commercial farms around the lake, the deterioration of the lake water quality as a result of the inflow of nutrients is due to both the commercial farms and the farm activities in the upper catchment. This finding is supported by Kitaka et al. (2002) and Gitachi (2005), who also showed that a large amount of nutrient load to the lake originates from the upper catchments and municipal sewage through surface runoff. The nutrient transport from the upper catchments is mainly through surface runoff, while for the riparian agriculture nutrient transport is mainly through leaching to the groundwater.

There is a big and well-founded concern as to whether the lake can sustain a continued increase in irrigation water demand. The long-term protection of the lake ecosystem and the economic and social benefits that depend on the lake require a sustainable use of Lake Naivasha and its catchment. The most pressing issue is the unsustainable water abstraction for horticulture crops, domestic water use and the Olkaria Geothermal Power Plant, which has led to a decline in the lake level (Becht and Harper, 2002). Another issue that requires close attention is the decline in the lake's ecosystem due to the introduction of exotic species, particularly the Louisiana crayfish (Harper and Mavuti, 2004). Finally, there is the concern about eutrophication of the lake due to an increase in agricultural nutrients inflow both from the commercial farms and from the upper catchment. The increase in nutrients is probably the combined effect of the loss of riparian vegetation, which acts as a buffer to trap sediments, an increase in the sediment flow from the catchment and an increase in fertilisers leaching and running off to the water system. The situation got worse by the increase in subsistence farming even on steep slopes right down to the river edge which destroyed the riparian zone (Everard et al. 2002).

Long-term gains from a sustainable and wise use of water require a coordinated action at the catchment scale. There is a need to define the maximum allowable water abstraction level at the basin scale. Although equitable allocation of water is required, decisions should also take into account the difference in economic water productivity among different crops. Cut flowers generate more economic return than the low-value fodder crops and grasses. Indoor flowers are more efficient compared to outdoor flowers; therefore greenhouse cultivation coupled with rainwater harvesting should be encouraged. The use of blue water for the production of water-intensive products such as beans and low-value products such as grass and fodder should be discouraged. Wise use of rainwater, in particular in the upper catchment, for growing fodder and grass needs to be encouraged. Controlling of unlicensed and illegal water abstraction through legal means and community involvement is quite essential.

There is a need to reduce the flow of sediments and agricultural nutrients to the lake both from the commercial farms around the lake and subsistence farmers in the upper catchment. The sedimentation problem is aggravated due to the loss of riparian vegetation that could have acted as a buffer in trapping sediments and increasing infiltration. An urgent and coordinated action is needed to stop the destruction of vegetation along the river banks and lake caused by cultivation and overgrazing. Therefore, prohibition of cultivation in the riparian areas is important.

## 4. Reducing the water footprint in the Lake Naivasha Basin: involving consumers, retailers and traders along the supply chain

### *4.1 Current water regulations in the Lake Naivasha Basin*

Kenya's water sector reform has gone a long way before the adoption of the Water Act in 2002. The first water sector reform in Kenya was in 1974, when the first National Water Master Plan was launched (Kisima, 2007). The publication of the 'Sessional Paper No. 1 of 1999 on National Policy on Water Resources Management and Development' led to a new momentum (Owuor and Foeken, 2009). The Water Act 2002 has introduced comprehensive and, in many instances, radical changes to the legal framework for the management of the water sector in Kenya (Mumma, 2005). The National Water Resources Management Strategy document specifies ten 'specific objectives'. Among these are the following (Owuor and Foeken, 2009):

- Manage the water demand in a sustainable way. This includes market-based and technology-based strategies. The two major market-based strategies are water pricing (the 'user pays principle', with special treatment of the low-income users) and effluent charges (the 'polluter pays principle').
- Water pricing that recognises water as an economic good. In the past, social and political considerations outweighed economic considerations in the setting of tariffs. The need to have a different view on the pricing of water becomes urgent, so water is increasingly viewed as an economic good. This necessitates the development of appropriate tariff structures and cost recovery measures. In order to gain acceptance, the water pricing system should be developed with the full consultation of water users.

Kenyan government considers water as both a social and economic good, to be available for all Kenyans and at a price reflecting its market value. This principle is reflected in the different water sector strategies and water resource management rules. Among the strategies pursued are demand management, the re-allocation of water to where it has high return and efficient allocation of water through appropriate pricing.

As water is becoming an increasingly scarce resource, full-cost pricing of water is recognized as an effective tool for water management. The need to have full-cost pricing of water has received worldwide acknowledgement since the International Conference on Water and the Environment held in Dublin, 1992. The fourth principle of the so-called Dublin statement says that 'Water has an economic value in all its competing uses and should be recognized as an economic good. [...] Past failure to recognize the economic value of water has led to wasteful and environmentally damaging uses of the resource. Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources.' (ICWE, 1992). Agenda 21 of the United Nations (UN, 1992) further supported the internalization of environmental costs and the use of economic instruments for rational use of water resources. The World Water Commission (2000) stated that 'the single most immediate and important measure that we can recommend is the systematic adoption of full-cost pricing for water services'. Hoekstra (2006) and Rogers et al. (2002) argue that sustainable and efficient use of water requires full-cost pricing of water use, including all cost components: the operation and maintenance costs, capital costs, opportunity costs, scarcity rent and externality costs of water use.

However, there are few successful examples of implemented full-cost pricing of water (Cornish et al. 2004; Rosegrant and Cline, 2002; Dinar and Subramanian, 1998). In most OECD countries, let alone in developing countries, the implementation of water pricing policies has been slow and uneven (Molle and Berkoff, 2007; Perry, 2003; Rosergrant and Cline, 2002). The World Bank (2004) acknowledged the complexity of water pricing reform (both in theory and practice) for irrigation. It further advocates a 'pragmatic but principled' approach that respects principles of efficiency, equity and sustainability while recognizing that water resources management is intensely political and that reform requires the articulation of prioritized, sequenced, practical and patient interventions.

Lack of funding is one of the main challenges in the Lake Naivasha Basin for implementing community-based basin rehabilitation and lake conservation (Becht et al. 2005). Under such condition, raising enough funds would be an additional objective of water pricing, besides creation of an incentive for efficient and sustainable use of water. However, the implementation of full marginal-cost pricing under the existing conditions in Kenya and around Naivasha is highly unlikely. The flower farms feel that they are already overtaxed and burdened with a number of remittances and some even have threatened to relocate to Ethiopia if local authorities force them to pay more tax (Riungu, 2007). An attempt by the Naivasha Municipal Council to collect a tax from the flower farms was stopped by court after the Kenya Flower Council file petition. The Naivasha Municipal Council claims that the estimated tax of Ksh 320 million ($4.8 million) is only one percent of the farm's annual earnings and would provide necessary infrastructure and services to support the ballooning population. Attracted by a number of incentives including 10 year tax-holidays, better security, duty-free import of capital goods and low land price, five major flower companies have already made the switch to Ethiopia with more to follow (ARB, 2007).

According to the 2007 Water Resource Management Rules, domestic water users have to pay 0.50 Kenyan Shilling per $m^3$ and non-domestic water users have to pay 0.75 Kenyan Shilling per $m^3$. Major water users need a license to abstract water and need to install water meters. Implementation of the regulation is actually hampered, however, by reluctance of many water users to follow the regulation and difficulties government encounters in enforcing the regulation. The current water pricing policy has several weaknesses. One is that illegal water abstractions from both ground- and surface water are very common (see Figure 9). In practice it is difficult for the government to check whether farmers have actually installed water meters as legally required, due to a lack of cars and fuel for the staff responsible for control. Despite the fact that farmers have indicated that the newly introduced water tariff is too high, the tariff actually does by far not cover full economic cost of the water. As a result, the funds generated by the current water pricing scheme are very small. The level of water price increase that would be required to have a significant impact on demand would be politically very difficult to enforce.

*Figure 9. Illegal water abstraction through by-passing the water meter by a water user abstracting water from Lake Naivasha (photo: Hoekstra).*

Under such conditions, the implementation of full-cost water pricing at the source is not feasible. A unilateral implementation of a stringent water pricing strategy by a country could affect the competitiveness of its local companies in the global market (Hoekstra, 2006; Cornish et al. 2004). To address this problem, Hoekstra (2006) and Verkerk et al. (2008) have proposed that national governments negotiate on an international protocol on water pricing. Such scheme would reduce the disadvantage of unilateral implementation of a full-cost pricing strategy. However, the implementation of an international protocol on water pricing requires global agreement among the major players on the global market, which makes it unlikely that such a protocol will be implemented in the near future. As an alternative to the international protocol involving national governments we propose an alternative here that can be implemented with a focus on sustainable water use in flower farming around Lake Naivasha alone. The proposal involves a water-sustainability agreement between major agents along the cut-flower supply chain and includes a premium to the final product at the retailer end of the supply chain.

### *4.2 A sustainable-flower agreement between major agents along the cut-flower supply-chain*

Given the recent emergence of more environmentally conscious consumers, combined with an increased interest at the side of traders and retailers in providing environmentally sustainable consumer products, involving consumers and other stakeholders forms an opportunity to achieve sustainable water use in cut-flower production. Consumers are becoming more and more concerned with how their consumption behaviour is affecting the world around them. This is reflected in the growing consumption of fair-trade products and organic produce. Annual growth rates of 20 percent or more in market volume have been observed for many years for both organic and fair-trade products (Poisot et al. 2007; Krier, 2005). Several studies show that consumers are willing to pay more for products that are environmentally and socially responsible (Aizaki and Sato, 2007; Arnot et al. 2006; Didier and Lucie, 2008; Pelsmacker et al. 2005).

In this section we describe the possible characteristics of a 'sustainable-flower agreement' between major agents along the flower supply-chain focused on sustainable water use. The agreement should include two key ingredients: a fund-raising mechanism at the consumer-end of the supply chain, which will raise the funds for making water use in flower production sustainable, and a labelling or certification scheme, which will provide the guarantee that the funds are properly spent and that the flower production actually moves in the direction of sustainable water use.

Funds. The premium collected when selling cut flowers from the Lake Naivasha Basin to consumers in the Netherlands, the UK etc. should be used to invest in better watershed management and, most in particular, in reducing the water footprint of the flower farmers. Clear criteria need to be formulated for how collected funds can or should be spent. The criteria could be formulated such that also small farmers belong to the beneficiaries of the funds, because particularly smallholder farmers have generally more difficulty than the large farmers to comply with environmental standards or raise funds to be able to comply.

There is a need to provide institutional infrastructure through which the funds could flow back to the basin and be used in environmental protection, watershed management, support of farmers to improve their water management and community development. Fair-trade organisations can be instrumental in making sure that funds raised at the consumer end flow back to the watershed for the support of local programmes for improved watershed management and support to farmers to reduce their water footprint. Figure 10 is a visual representation of the cut-flower supply chain and contrasts the current approach of local water pricing with the approach of collecting a water-sustainability premium at the end of the chain.

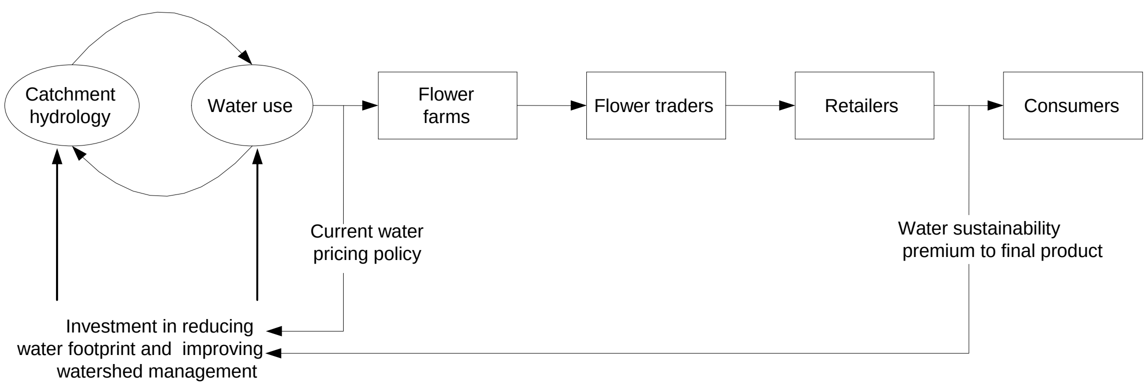


*Figure 10. Schematization of the flower supply-chain. Local water pricing is a mechanism applied at the beginning of the chain; a water-sustainability premium is raised at the end of the chain. Due to the increase of the price per flower along the supply-chain, generating funds is easier at the end of the chain.*

The funds that can be raised through adding a water-sustainability premium at the end of the supply chain (at the consumer end) are much larger than the funds potentially raised from the current local water-pricing policy (Table 9). Currently, the water abstraction fee in Kenya for non-domestic consumers is 0.75 Kenyan Shillings per cubic meter of water abstracted (0.01 €/m$^3$). On average, flower farms consume about 4.1 litre of blue water to produce one stem of cut flower (see Table 4). Suppose that consumptive blue water use (evaporated irrigation water) is about 75% of blue water abstraction, farms abstract, on average, 5.5 litre of blue water per cut flower. They will thus pay, on average, 0.000055 € per stem of cut flower for abstracting irrigation water. The total blue water footprint of the flower farms around the lake is 7.6 Mm$^3$/yr (Table 3); the total water abstraction will then be about 10 Mm$^3$/yr. With a water abstraction fee of 0.01 €/m$^3$, this would raise 0.1 million €/yr. This is a very optimistic estimate, because as explained before, the conditions are not such that government is actually able to enforce farmers to pay. On the other hand, if we assume a water sustainability premium of 0.01 € per stem of cut flower at the retailer, to be paid by the consumer, one would raise 16.9 million €/yr (Table 9). When we look at the capability of generating funds for watershed management, we find that a water-sustainability premium raised at the consumer end of the supply-chain will yield hundred to two hundred times the amount of money potentially raised through local water pricing.

*Table 9. Comparison of revenue collection through the current water-pricing policy and through a water-sustainability premium per cut flower sold to the consumer.*

| | Current water pricing | Water sustainability premium to final product at retailer |
|---|---|---|
| Water abstraction fee (€/m$^3$) | 0.01 | |
| Total blue water footprint flower farms (Mm$^3$/yr) | 7.6 | |
| Total blue water abstraction flower farms (Mm$^3$/yr)[a] | 10 | |
| Revenue per stem of flower (€/stem) | 0.000055 | 0.01 |
| Flower export[b] (tons/yr) | | 42300 |
| Flower export[b,c] (stems/yr) | | 1.69E+09 |
| Estimated revenue (€/yr) | 0.1E+06 | 16.9E+06 |

[a] Assumed that consumptive blue water use (the blue water footprint) is 75% of the blue water abstraction.
[b] Average for the period: 1996-2005.
[c] Assumed 25 gram/stem.

Certification/labelling. Collecting a water-sustainability premium at the lower end of the supply chain needs to go hand in hand with a mechanism for certification of the farmers that deliver the premium-flowers and a mechanism for labelling the premium-flowers. Labelling can be interpreted here in physical sense – where indeed a consumer-oriented label is attached to a flower – but it can also get the shape of ‘attached information’ to whole batches of flowers. Customers can be encouraged to buy flowers from certified farms or labelled flowers and pay an agreed premium to contribute to the sustainability of production and consumption. Certification and labelling would help to segregate environmentally sustainable products from other products and provide consumers with the quality assurance. The success depends on a transparent, credible monitoring and certification systems. Farmers would benefit by having an advantage on the market by achieving standards of production that are internationally recognized.

The certification of farmers and labelling of products could be carried out by the already existing institutional setup of Global Good Agricultural Practices (GlobalGAP). Good Agricultural Practices are "practices that address environmental, economic and social sustainability for on-farm processes, and result in safe and quality food and non-food agricultural products" (FAO, 2003). The water-sustainability standards can possibly be integrated into the existing standards of GlobalGAP. The concept of Good Agricultural Practices (GAP) has evolved in recent years as a result of the concerns and commitments of a wide range of stakeholders about food production and security, food safety and quality, and the environmental sustainability of agriculture. GAP is already applied in many developed and developing countries including Kenya. Farmers who have complied with the GlobalGAP have benefited in the form of increased access to market, increased productivity and reduced cost of production through careful application of pesticide and fertilizer.

The approach sketched here would encourage flower farmers to comply with criteria on sustainable use of water resources. The costs involved in certification and labelling should be covered by the funds raised, but should be small relative to the funds raised, since the funds are primarily meant to promote sustainable water use within the catchment. This is a serious concern when implementing a water-sustainability agreement, because when costs become too high the instrument looses its effectiveness.

Parties involved in the agreement. In its most modest form, a water-sustainability agreement would involve one major retailer in the Netherlands (the most important destination country for Kenyan flowers), one trader and one of the major farmers. In a more ambitious setting, several retailers, traders and farmers could be involved. Retailers, traders or farmers could also be represented by their respective branch organisations. In the case of the flower farmers this could be the Lake Naivasha Growers Group or the Kenyan Flower Council. In the Netherlands, the flower market is organised by FloraHolland, which may take a central role in facilitating an agreement.

Apart from the funds raised to reduce the water footprint in the Lake Naivasha basin, an additional advantage of a water sustainability premium to the final consumer product at the retailer is that it helps to create awareness regarding the value of water along the supply chain down to the consumers. An advantage of raising funds at the consumer end over local full-cost water pricing is that the latter would reduce local competitiveness and diminish profitability. This may lead to a shift of flower farming out of Kenya to other countries, like Ethiopia, which currently experiences a growth in the horticulture sector.

Success of the water-sustainability premium depends on all stakeholders' commitment to reach agreement and effectively implement it. Further, a clearly defined certification procedure and institutional arrangements for the flow of fund back to the basin is required.

## 5. Discussion

Cut flowers are an important export sector in Kenya. Next to their contribution to the gross domestic product and foreign exchange earnings, the commercial farms provide employment, housing, schools and hospitals, free to employees and their families. Losing the cut-flower business means over 25,000 workers and their dependence will lose everything. On the other hand, the treatment of Lake Naivasha as a free ‘common pool’ resource will be at the cost of the lake’s sustainability and the corporate image of the commercial farms. Therefore, sustainable management of the water resources of the Lake Naivasha Basin is needed. One will need to decide on the maximum allowable drop in the lake water level as a result of water abstractions and on the maximum allowable blue and grey water footprint in the basin. The use of greenhouse flower production (as opposed to production in the open field) needs to be encouraged, coupled with rainwater harvesting. The production of water-intensive products such as beans and low-value products such as fodder and grass around the lake should be discouraged. In the upper catchment, the use of rainwater for the production of fodder and grass should be promoted. The flow of sediments and agricultural nutrients to the lake, both from commercial farms around the lake and farms in the upper catchment, needs to be reduced. The flow of sediment is aggravated due to the loss of riparian vegetation that could have acted as a buffer in trapping sediments. Therefore it is important to create awareness among farmers to protect the riparian zone vegetation and prohibit cultivation in the riparian area.

Pricing water at its full marginal cost is important, but probably difficult to achieve under current and near-future conditions in Kenya. The alternative of a water sustainability premium to flowers sold at the retailer may be more effective. It will generate a larger fund than local water pricing, a fund that can be used for financing improved watershed management and measures that reduce the blue and grey water footprint within the Lake Naivasha Basin. Besides, it would create awareness among consumers on the value of water. The mechanism of a water-sustainability premium will reduce the risk of Kenya losing its business in the long term. An added value of the water-sustainability premium includes the aspect of fairness, since currently the overseas consumers of cut flowers get the benefit but do not cover the environmental cost of the flowers. The mechanism can enhance the green image of the commercial farms and increase chances in the market for sustainable products. Successful implementation of the water-sustainability premium to cut flowers sold by the retailer depends on the commitment of all stakeholders: governments, civil society organizations, private companies and consumers.

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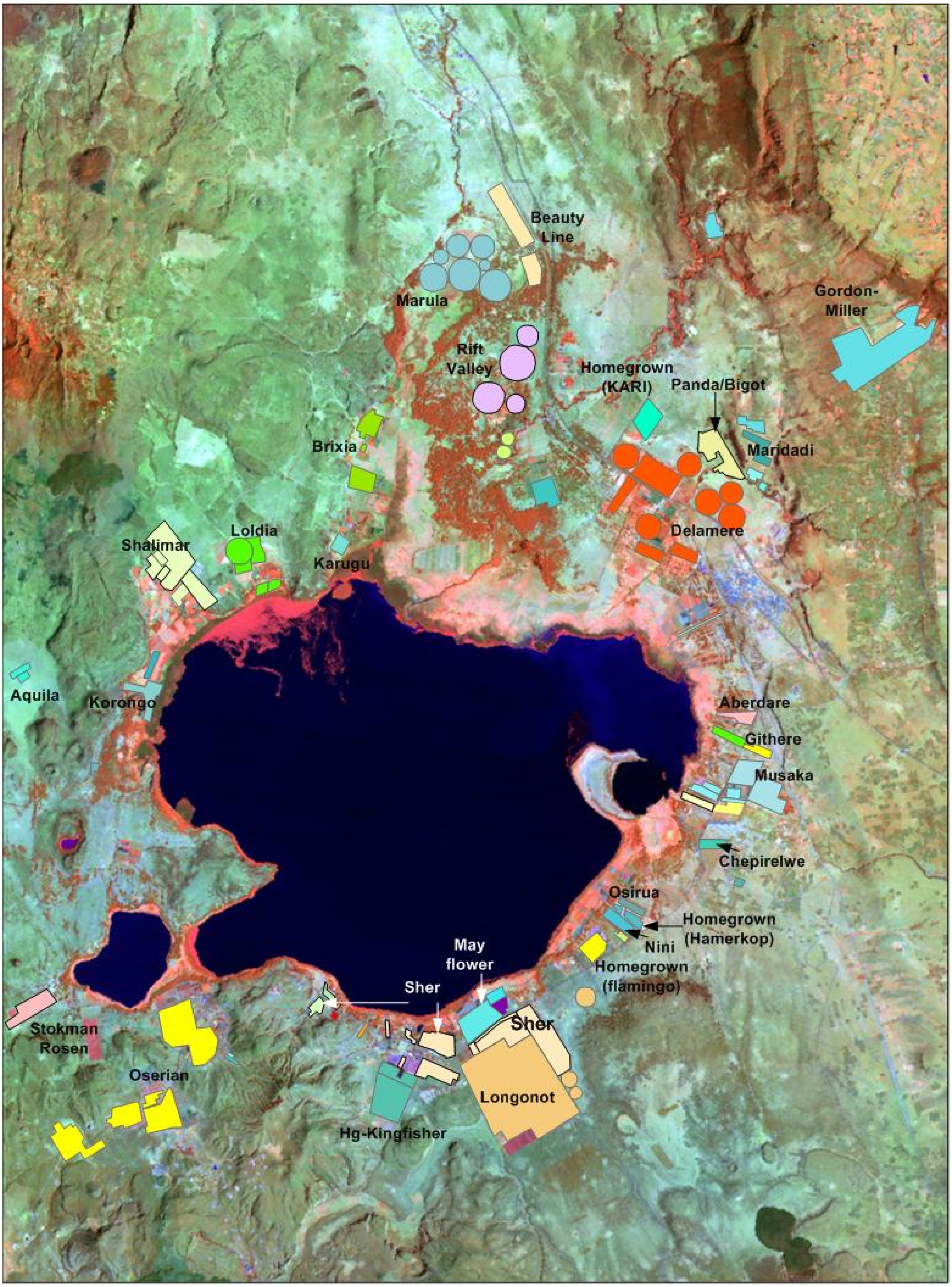
## Appendix I: Water footprint related to crop production in the upper catchment

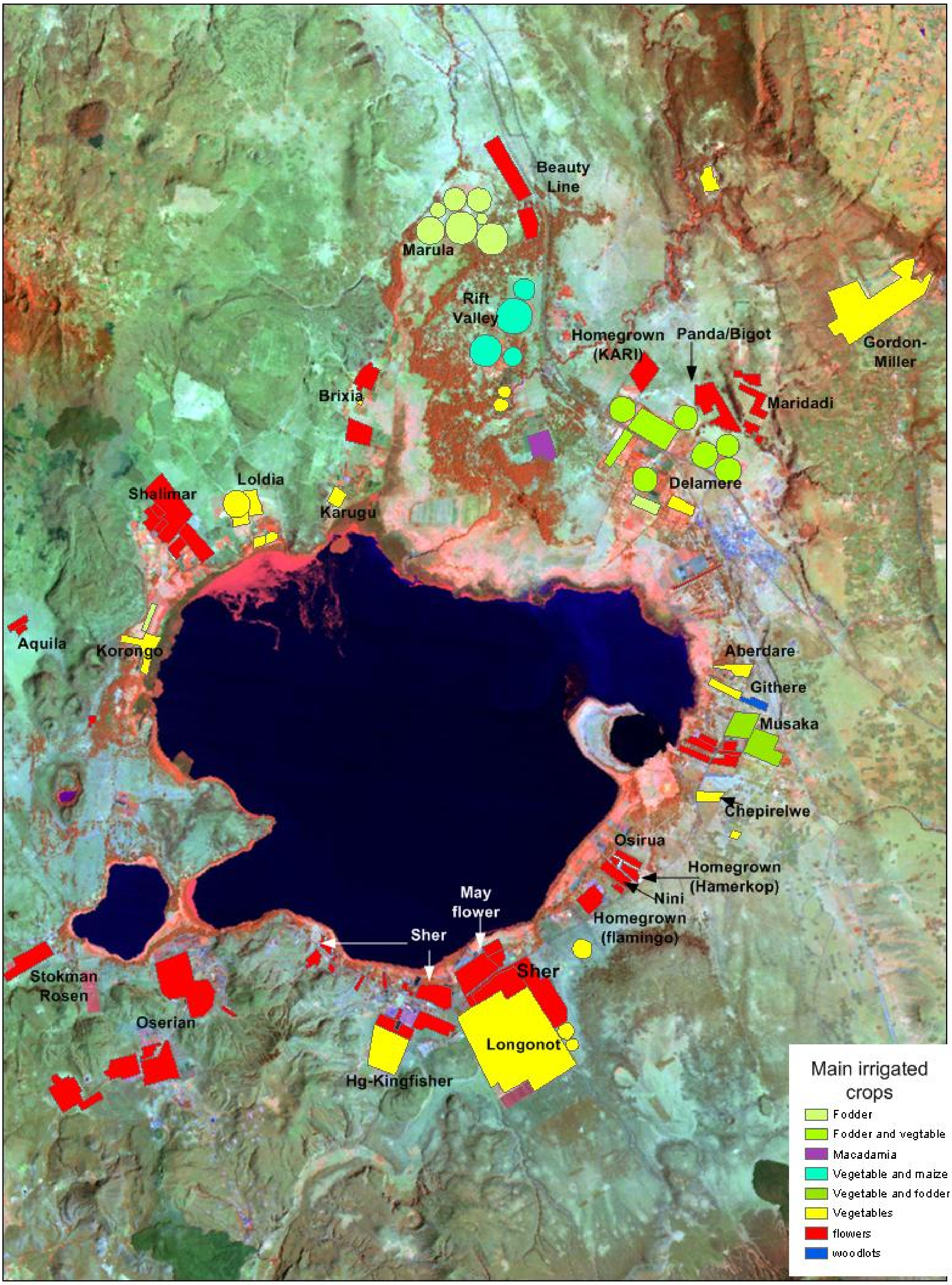
| Crops | Area cultivated | | Total water footprint (1000 $m^3$/yr) | | | | Water footprint per unit of crop ($m^3$/ton) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Area (ha) | Irrigated (%) | Green | Blue | Grey | Total | Green | Blue | Grey | Total |
| Banana | 236 | 6.9 | 1798 | 56 | 33 | 1888 | 284 | 9 | 5 | 298 |
| Cassava | 392 | 0.0 | 1292 | 0 | 0 | 1292 | 220 | 0 | 0 | 220 |
| Castor oilseed | 19 | 0.0 | 119 | 0 | 0 | 119 | 20087 | 0 | 0 | 20087 |
| Citrus not elsewhere specified | 90 | 4.3 | 549 | 7 | 10 | 567 | 633 | 8 | 12 | 653 |
| Coconut | 67 | 0.0 | 466 | 0 | 0 | 466 | 1513 | 0 | 0 | 1513 |
| Cotton | 266 | 17.3 | 953 | 74 | 0 | 1027 | 4612 | 358 | 0 | 4970 |
| Cowpea | 711 | 0.0 | 1321 | 0 | 43 | 1365 | 2690 | 0 | 88 | 2778 |
| Maize | 9747 | 0.8 | 28534 | 14 | 1193 | 29742 | 786 | 0 | 33 | 819 |
| Mango | 86 | 0.0 | 487 | 0 | 32 | 519 | 510 | 0 | 33 | 544 |
| Millet | 593 | 0.0 | 1362 | 0 | 0 | 1362 | 3001 | 0 | 0 | 3001 |
| Oilseed not elsewhere specified | 444 | 0.0 | 1228 | 0 | 0 | 1228 | 4269 | 0 | 0 | 4269 |
| Pigeon pea | 1029 | 0.0 | 1824 | 0 | 2601 | 4426 | 2192 | 0 | 3126 | 5318 |
| Plantains | 227 | 0.0 | 1704 | 0 | 22 | 1726 | 293 | 0 | 4 | 297 |
| Potatoes | 743 | 0.0 | 1326 | 0 | 428 | 1754 | 144 | 0 | 46 | 190 |
| Pulses not elsewhere specified | 459 | 0.0 | 812 | 0 | 29 | 841 | 4403 | 0 | 155 | 4557 |
| Rice | 25 | 93.6 | 83 | 68 | 0 | 151 | 827 | 679 | 0 | 1507 |
| Sisal | 174 | 0.0 | 992 | 0 | 5 | 997 | 4419 | 0 | 22 | 4440 |
| Sorghum | 855 | 0.0 | 2321 | 0 | 219 | 2539 | 2235 | 0 | 211 | 2446 |
| Sugar cane | 344 | 1.5 | 2495 | 10 | 118 | 2623 | 43 | 0 | 2 | 45 |
| Sweet potatoes | 304 | 0.0 | 1222 | 0 | 0 | 1222 | 251 | 0 | 0 | 251 |
| Vegetable not elsewhere specified | 423 | 42.6 | 1243 | 235 | 162 | 1640 | 168 | 32 | 22 | 222 |
| Wheat | 905 | 0.0 | 2476 | 0 | 243 | 2719 | 605 | 0 | 59 | 665 |
| Total | 18137 | 2.0 | 54609 | 465 | 5137 | 60211 | | | | |

**Appendix II : Irrigated farms around Lake Naivasha**



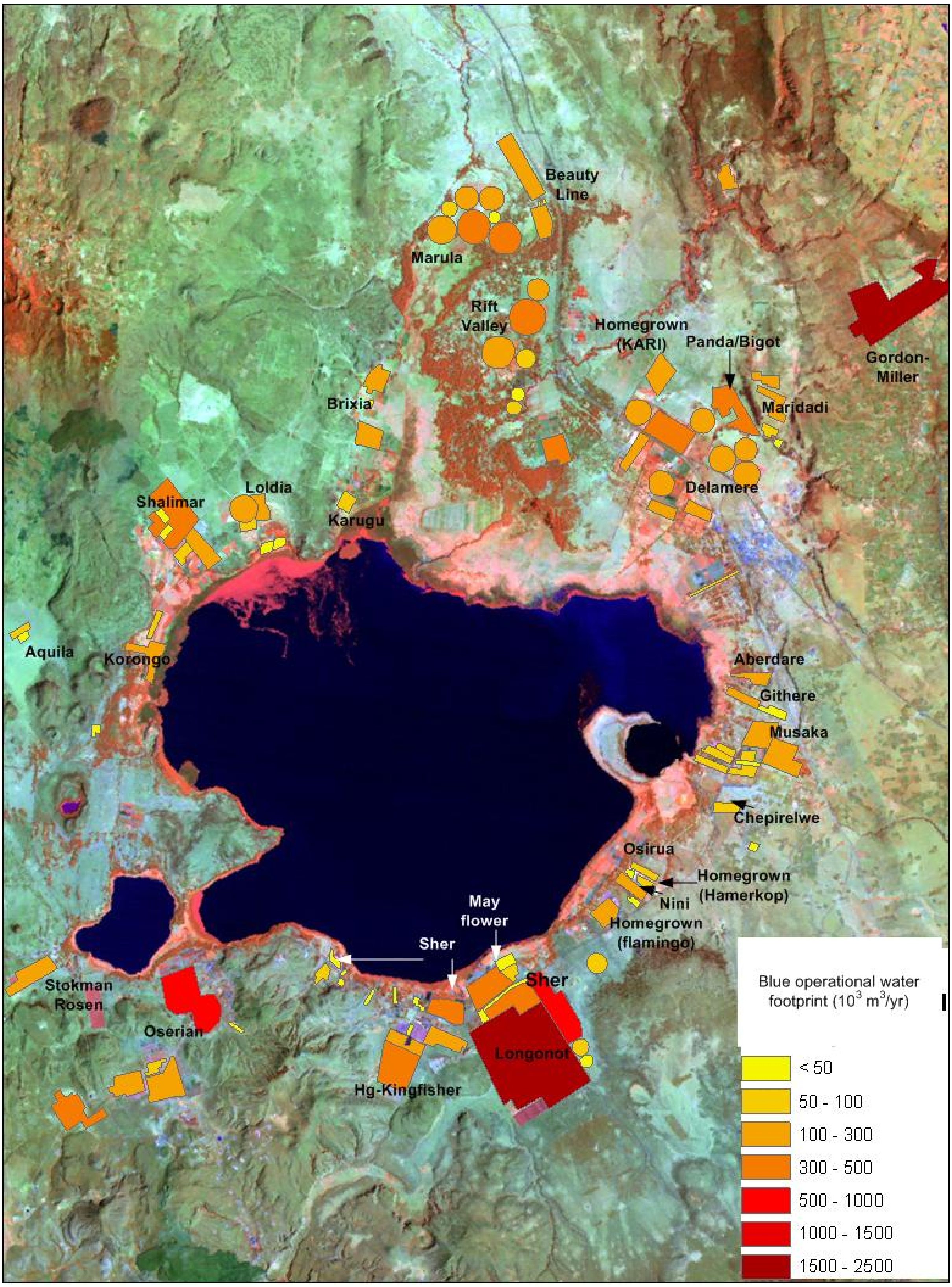

Source: ITC Naivasha database (Becht, 2007). Data for 2006.

**Appendix III Land use type around Lake Naivasha**

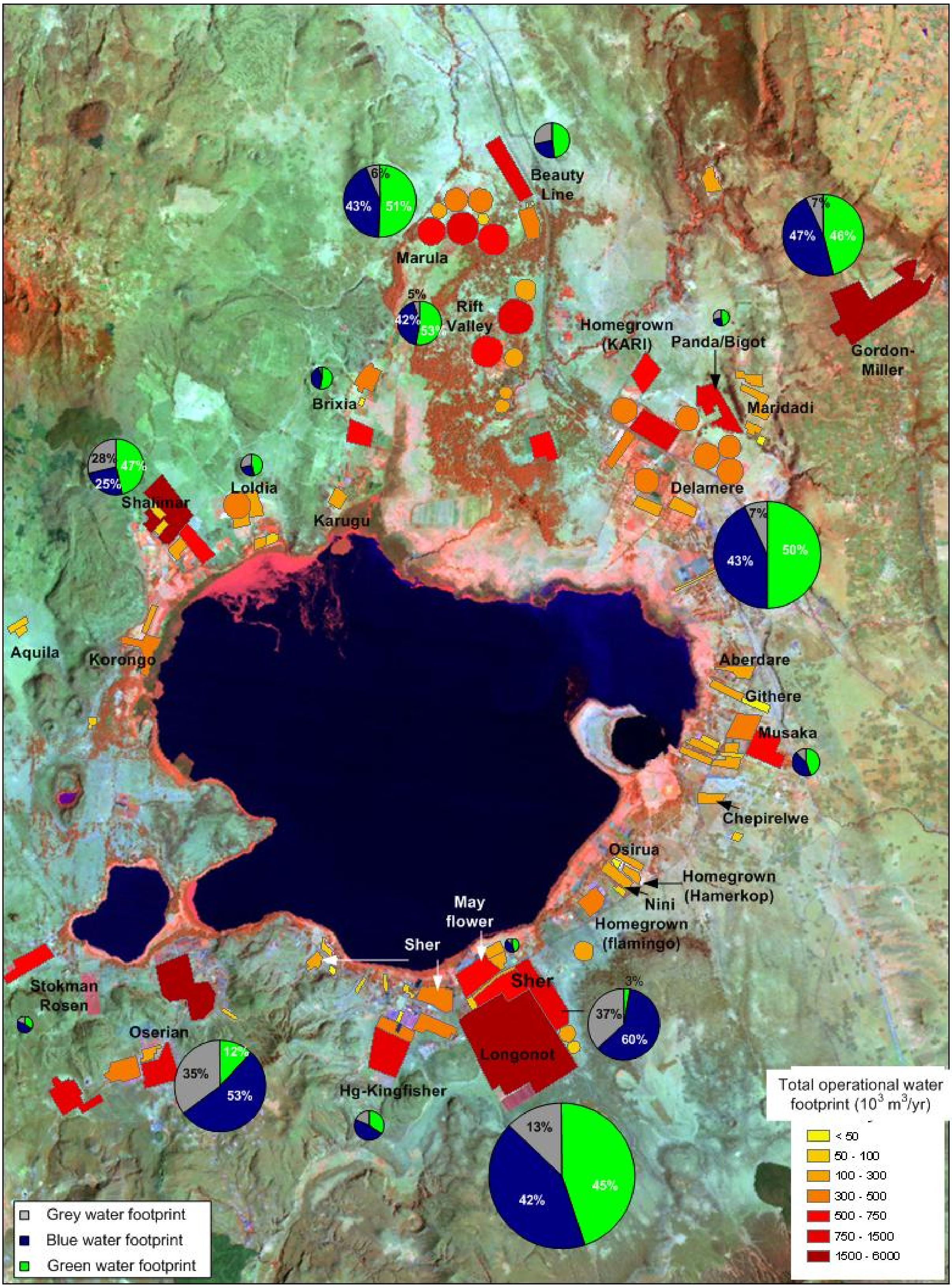



Source: ITC Naivasha database (Becht, 2007). Data for 2006.

**Appendix IV : Operational blue water footprint of irrigated farms around Lake Naivasha**



**Appendix V : Total operational water footprint of irrigated farms around Lake Naivasha**



## Appendix VI: Operational water footprint of the commercial farms

| Farms | Operational water footprint ($m^3$/yr) | | | |
|---|---|---|---|---|
| | Green | Blue | Grey | Total |
| Longonot Hort. | 2812661 | 2667963 | 800846 | 6281470 |
| Delamere | 2302822 | 1989145 | 318251 | 4610217 |
| Oserian | 420519 | 1848422 | 1237448 | 3506389 |
| Gordon-miller | 1480133 | 1520118 | 220340 | 3220590 |
| Marula Estate | 1598270 | 1373583 | 194559 | 3166411 |
| Sher Agencies | 86432 | 1627690 | 1007473 | 2721594 |
| Shalimar | 996263 | 527965 | 607169 | 2131397 |
| Rift Valley Veg. | 985663 | 789269 | 83659 | 1858591 |
| Beautyline | 658018 | 328370 | 388748 | 1375136 |
| Hg-Kingfisher | 455286 | 606947 | 233064 | 1295297 |
| Musaka | 522378 | 498153 | 147758 | 1168289 |
| Loldia | 474747 | 406309 | 145246 | 1026302 |
| Brixia farm | 430951 | 215294 | 246937 | 893182 |
| Panda/Bigot | 0 | 434858 | 262473 | 697331 |
| StokmanRozen (prop) | 324982 | 158061 | 189511 | 672554 |
| Mayflower | 0 | 392700 | 237026 | 629726 |
| Kenya Nut | 278032 | 303047 | 33845 | 614924 |
| Hg-Kari farm | 270063 | 131350 | 157485 | 558898 |
| Korongo farm | 219622 | 182756 | 71969 | 474347 |
| Maridadi | 0 | 273380 | 165007 | 438387 |
| Ol Njorowa farm | 93604 | 195340 | 145009 | 433952 |
| Hg-Flamingo | 0 | 188131 | 113552 | 301683 |
| Quality farm | 123737 | 127080 | 18420 | 269238 |
| Aberdare farm | 114975 | 103248 | 30728 | 248951 |
| Blue sky farm | 113564 | 101981 | 30351 | 245896 |
| Nini ltd | 0 | 139673 | 84304 | 223976 |
| Githere Lake Veg | 102023 | 104779 | 15188 | 221989 |
| Wildfire flowers | 105144 | 51139 | 61314 | 217596 |
| Chepirelwe | 93299 | 88748 | 34295 | 216342 |
| Bilashaka | 0 | 133619 | 80650 | 214269 |
| Shantara | 99452 | 48370 | 57995 | 205817 |
| Karugu | 89299 | 80191 | 23866 | 193356 |
| Sher D Safari Hort | 85135 | 41407 | 49646 | 176189 |
| Aquila farm | 33001 | 72412 | 53263 | 158675 |
| Ol Suswa | 75616 | 64986 | 9205 | 149806 |
| Hg-Hamerkop | 0 | 91734 | 55369 | 147104 |
| Osirua ltd | 0 | 78563 | 47419 | 125982 |

| Farms | Operational water footprint ($m^3$/yr) | | | |
|---|---|---|---|---|
| | Green | Blue | Grey | Total |
| Sher -Rift farm | 0 | 74197 | 44784 | 118981 |
| Hammer Florensis | 0 | 72809 | 43946 | 116756 |
| Linsen Kreative | 0 | 58947 | 35579 | 94526 |
| Lake Flowers | 0 | 51916 | 31335 | 83251 |
| Plant factory | 0 | 41528 | 25066 | 66594 |
| Near Kiu-Karagita | 25425 | 24197 | 9355 | 58977 |
| Double Dutch | 25692 | 12496 | 14982 | 53169 |
| Indu farm | 0 | 31699 | 19133 | 50832 |
| Goldsmith | 24235 | 11787 | 14132 | 50155 |
| Lormona ltd | 0 | 29654 | 17898 | 47552 |
| Star Flowers | 0 | 23876 | 14411 | 38287 |
| Florema Prop | 0 | 18300 | 11046 | 29346 |
| Plantations plant | 0 | 9653 | 5826 | 15480 |
| Grand Total | 15521042 | 18447839 | 7946881 | 41915763 |

## Appendix VII: Virtual water export related to export of cut flowers from Kenya

| Country | Virtual water export ($m^3$/yr) | | | |
|---|---|---|---|---|
| | Green | Blue | Grey | Total |
| Afghanistan | 29 | 60 | 44 | 133 |
| Algeria | 18 | 37 | 27 | 82 |
| Armenia | 35 | 73 | 54 | 162 |
| Australia | 4394 | 9144 | 6791 | 20329 |
| Austria | 1479 | 3078 | 2286 | 6844 |
| Bahrain | 1025 | 2132 | 1584 | 4740 |
| Belgium | 6286 | 13081 | 9715 | 29082 |
| Canada | 582 | 1210 | 899 | 2691 |
| China | 184 | 384 | 285 | 853 |
| Colombia | 9 | 19 | 14 | 41 |
| Congo, Dem Republic of | 34 | 71 | 53 | 158 |
| Croatia | 263 | 548 | 407 | 1218 |
| Cyprus | 158 | 328 | 243 | 729 |
| Czech Republic | 291 | 605 | 449 | 1344 |
| Denmark | 724 | 1507 | 1119 | 3350 |
| Djibouti | 45 | 93 | 69 | 207 |
| Equatorial Guinea | 189 | 392 | 291 | 872 |
| Estonia | 63 | 131 | 97 | 291 |
| Ethiopia | 276 | 573 | 426 | 1275 |
| Finland | 2150 | 4475 | 3323 | 9948 |
| France | 32877 | 68416 | 50815 | 152108 |
| French Polynesia | 65 | 135 | 100 | 300 |
| Georgia | 665 | 1384 | 1028 | 3077 |
| Germany | 229939 | 478494 | 355396 | 1063829 |
| Greece | 2340 | 4869 | 3617 | 10826 |
| Guinea | 18 | 37 | 27 | 82 |
| Hungary | 29 | 60 | 44 | 132 |
| Iceland | 6 | 12 | 9 | 26 |
| India | 205 | 426 | 317 | 948 |
| Ireland | 1049 | 2182 | 1621 | 4852 |
| Israel | 348 | 724 | 538 | 1609 |
| Italy | 9781 | 20354 | 15118 | 45252 |
| Japan | 5639 | 11735 | 8716 | 26091 |
| Jordan | 6 | 12 | 9 | 26 |
| Kuwait | 2164 | 4503 | 3345 | 10011 |
| Laos | 174 | 363 | 269 | 807 |
| Lebanon | 1550 | 3225 | 2395 | 7169 |
| Liberia | 190 | 395 | 294 | 879 |
| Lithuania | 0 | 0 | 0 | 0 |
| Luxembourg | 124 | 259 | 192 | 575 |
| Malawi | 248 | 515 | 383 | 1146 |
| Malaysia | 49 | 102 | 76 | 227 |

| Country | Virtual water export ($m^3$/yr) | | | |
|---|---|---|---|---|
| | Green | Blue | Grey | Total |
| Mauritius | 348 | 725 | 538 | 1612 |
| Namibia | 318 | 661 | 491 | 1470 |
| Netherlands | 2399204 | 4992664 | 3708245 | 11100113 |
| New Zealand | 107 | 223 | 166 | 497 |
| Nicaragua | 30 | 61 | 46 | 137 |
| Nigeria | 221 | 459 | 341 | 1021 |
| Norway | 1508 | 3139 | 2331 | 6979 |
| Oman | 29 | 60 | 44 | 132 |
| Pakistan | 90 | 188 | 140 | 419 |
| Papua New Guinea | 54 | 112 | 83 | 249 |
| Poland | 115 | 240 | 178 | 533 |
| Portugal | 124 | 257 | 191 | 572 |
| Qatar | 944 | 1965 | 1460 | 4370 |
| Romania | 17 | 36 | 27 | 79 |
| Russian Federation | 867 | 1803 | 1339 | 4009 |
| Saudi Arabia | 2097 | 4364 | 3241 | 9703 |
| Seychelles | 179 | 373 | 277 | 829 |
| Singapore | 286 | 596 | 443 | 1325 |
| Slovakia | 34 | 71 | 53 | 159 |
| Slovenia | 17 | 36 | 27 | 79 |
| Somalia | 9045 | 18823 | 13980 | 41848 |
| South Africa | 36937 | 76864 | 57090 | 170891 |
| Spain | 726 | 1512 | 1123 | 3361 |
| Sudan | 89 | 185 | 138 | 412 |
| Sweden | 1584 | 3297 | 2449 | 7330 |
| Switzerland | 58769 | 122296 | 90834 | 271898 |
| TAIWAN (POC) | 69 | 145 | 107 | 321 |
| Tanzania, United Rep of | 155 | 322 | 239 | 715 |
| Turkey | 6 | 12 | 9 | 26 |
| Uganda | 2261 | 4705 | 3495 | 10461 |
| Ukraine | 974 | 2027 | 1506 | 4507 |
| United Arab Emirates | 15988 | 33269 | 24711 | 73968 |
| United Kingdom | 611021 | 1271515 | 944403 | 2826939 |
| United States of America | 8204 | 17071 | 12680 | 37955 |
| Zambia | 35 | 73 | 54 | 161 |
| Zimbabwe | 82 | 170 | 126 | 378 |
| Total | 3,458,230 | 7,196,461 | 5,345,090 | 15,999,781 |

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