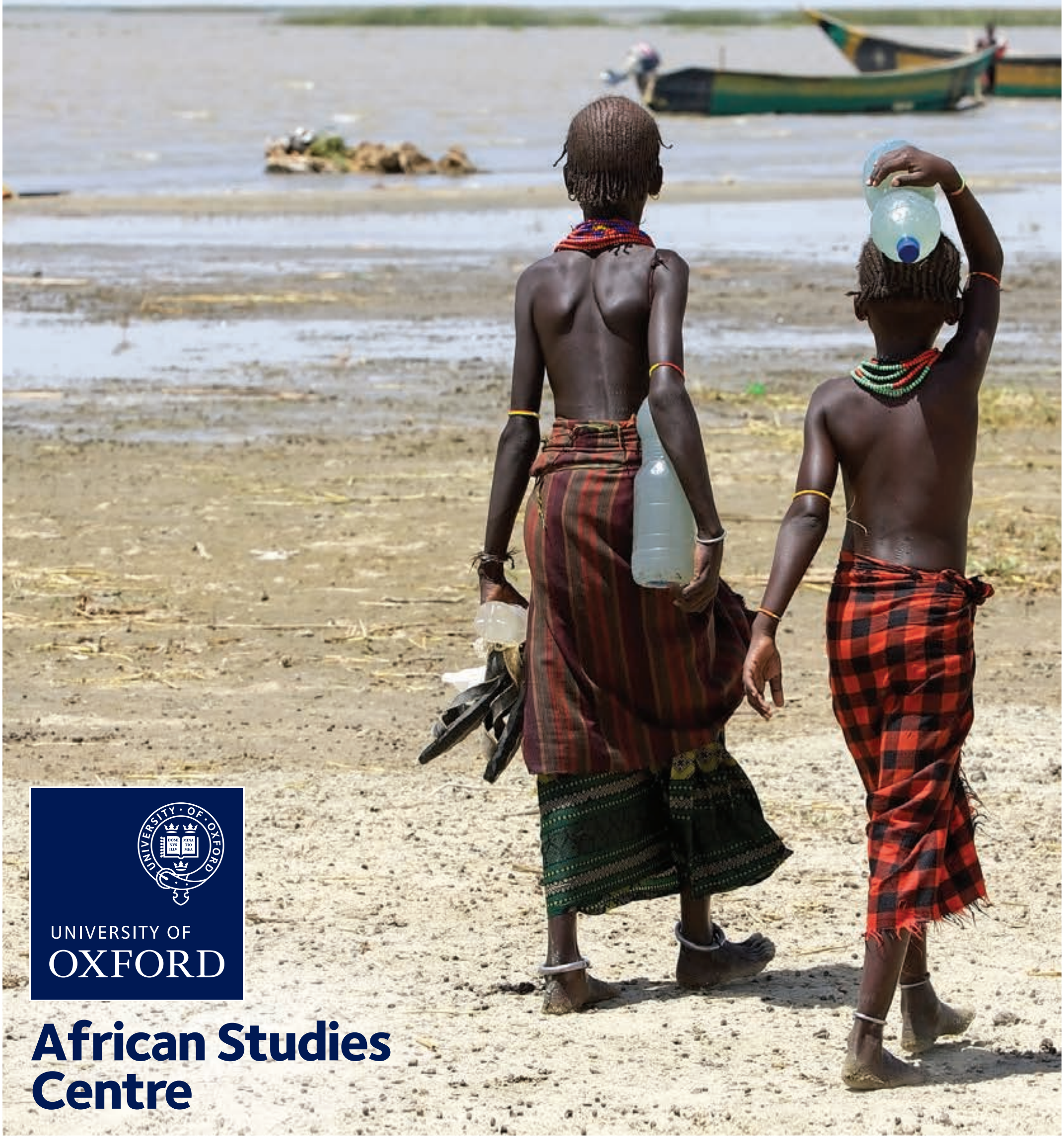
The impact of hydropower and irrigation development on the world's largest desert lake

What Future for Lake Turkana?

Sean Avery



UNIVERSITY OF OXFORD

African Studies Centre

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The landscape of the Lower Omo and Lake Turkana basin will soon undergo one of the biggest transformations in its history, thanks to the Gibe III hydropower dam which is now under construction, 600 kilometres upstream from the lake. Due for completion in 2014, Gibe III will permanently alter the natural hydrological cycles upon which the flood plains ecology, the productivity of Lake Turkana's fisheries and the livelihoods of the local population have always depended.

By regulating the flow of the river, the dam will also make possible large-scale commercial irrigation schemes in the Lower Omo which is set to become the largest irrigation complex in Ethiopia. One of the schemes now being implemented will almost equal in extent the entire current irrigated area of Kenya. Irrigation development on this scale will require a huge rate of water abstraction from the Omo, which is a trans-boundary river and the source of 90 per cent of Lake Turkana's freshwater and accompanying nutrient inflow.

The result could be another Aral Sea disaster in the making, with up to 50 per cent of the lake's Omo inflow being abstracted for irrigation alone. In this case the lake will drop by more than 20 metres (its average depth is roughly 30 metres) and its biomass volume will reduce drastically, as will its dependent fisheries. Ultimately, the lake could reduce to two small lakes, the northern one fed by the Omo and the southern one by the Kerio and Turkwel rivers.

NE shores near Alia Bay, Sibiloi National Park

Small lake near the south end of Lake Turkana

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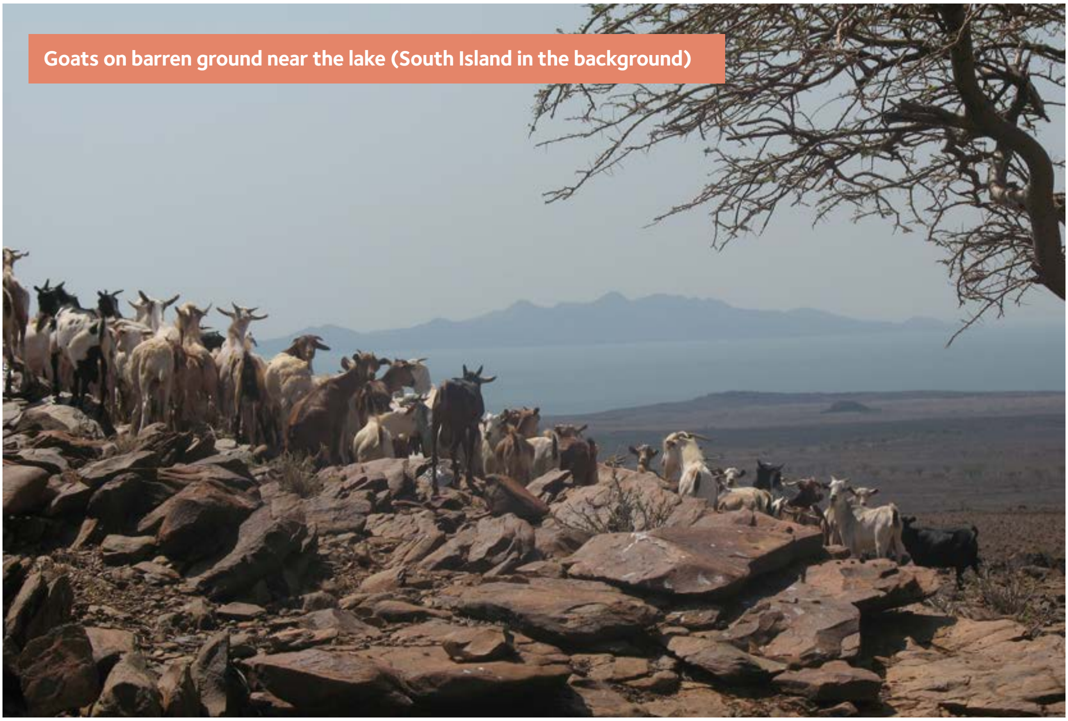
South Island, Lake Turkana



Goats on barren ground near the lake (South Island in the background)

Acronyms

AFDB	African Development Bank
AFD	Agence Française de Development (French Development Agency)
ADF	African Development Fund
ALRMP	Arid Lands Resource Management Project, Kenya
ASAL	Arid and Semi-Arid Lands
ARWG	Africa Resources Working Group
EEPCo	Ethiopian Electric Power Company
EIB	European Investment Bank
EPA	Environmental Protection Authority, Ethiopia
EVDSA	Ethiopian Valleys Development Studies Authority
EWCA	Ethiopian Wildlife Conservation Authority
EWRA	Ethiopian Water Resources Authority
FoLT	Friends of Lake Turkana, Kenya
ILRI	International Livestock Research Institute
IUCN	International Union for Conservation of Nature
JICA	Japan International Cooperation Agency
KETRACO	Kenya Electricity Transmission Co. Ltd.
KFS	Kenya Forest Service
KMD	Kenya Meteorological Department
KMFRI	Kenya Marine & Fisheries Research Institute
KNBS	Kenya National Bureau of Statistics
KPLC	Kenya Power & Lighting Co. Ltd
KWS	Kenya Wildlife Service
MALDM	Ministry of Agriculture, Livestock Development and Marketing
MoA	Ministry of Agriculture, Kenya
MoE	Ministry of Energy, Kenya
MoFD	Ministry of Fisheries Development, Kenya
MoLD	Ministry of Livestock Development, Kenya
MoLD&F	Ministry of Livestock Development and Fisheries, Kenya
MoWD	Ministry of Water Development, Kenya
MoWI	Ministry of Water & Irrigation, Kenya
MoWR	Ministry of Water Resources, Ethiopia
MoWRD	Ministry of Water Resources Development, Kenya
NEMA	National Environment Management Authority, Kenya
NIB	National Irrigation Board of Kenya
NIVA	Norwegian Institute for Water Research
NK	Nippon Koei, Consultants, Japan
NMA	National Meteorological Agency, Ethiopia
REGLAP	Regional Learning & Advocacy Programme for Vulnerable Dryland Communities
UNEP	United Nations Environment Programme
WDD	Water Development Department, Kenya
WHC	World Heritage Centre (UNESCO)
WRMA	Water Resources Management Authority, Kenya

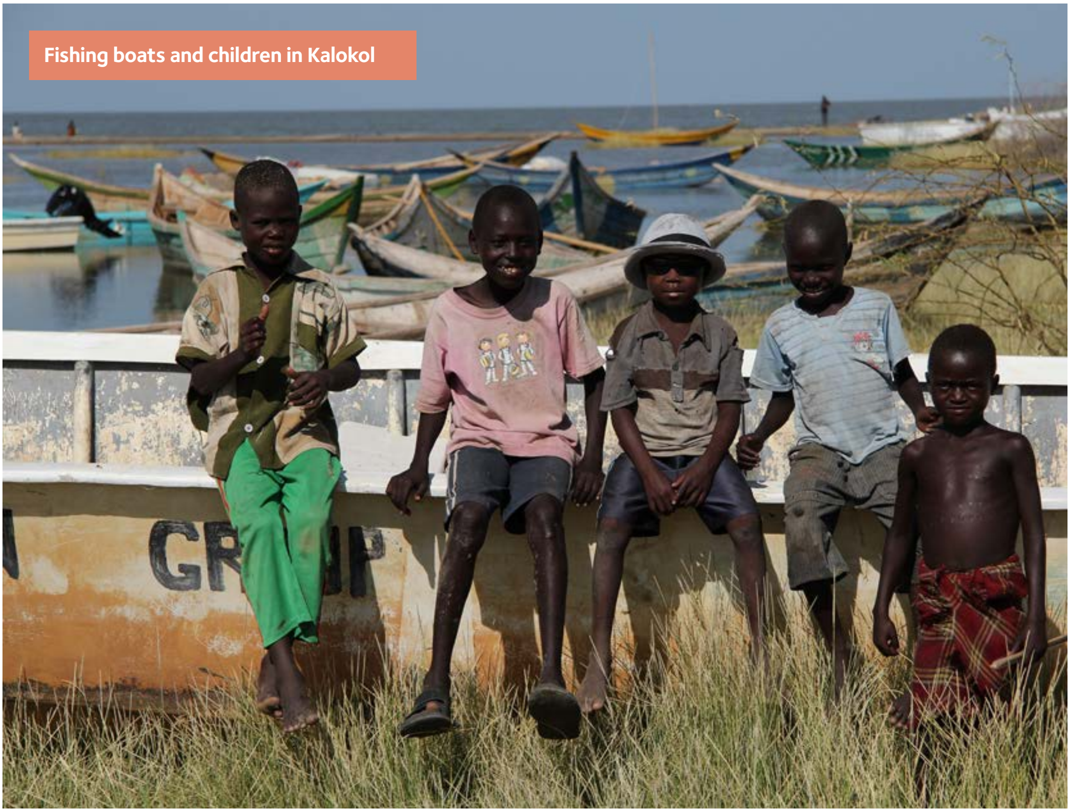
Acknowledgements

This paper, and the report on which it is based, were commissioned by the African Studies Centre of the University of Oxford. I am grateful to Professor David Anderson and Dr David Turton for this opportunity and to Dr Turton for sharing his intimate knowledge of the Lower Omo and for his consistent support throughout. My hydrological studies of Lake Turkana began in 2009, with a commission from the African Development Bank (AFDB) to report on the potential impact on the lake of the Gibe III hydroelectric dam. I was very grateful to the Bank for the chance to undertake this work, since a consolidated hydrological study of this type had not previously been done.

I am grateful also to the many scientists, professional colleagues and friends whose names are included in my full report, and would mention in particular Ikal Ang'elei, the youthful champion of the NGO Friends of Lake Turkana, and also Dr Jeppe Kolding of the University of Bergen, Elina Rautalahti of UNEP, and Dr William Ojwang of KMFRI, for their encouragement.

It has been a privilege to have visited Turkana on many occasions over the past 34 years, and this would not have been possible without the enthusiastic participation of my family - my patient wife Carol, my fishermen sons Patrick and Kieran, and my feisty daughter Kuki. We shared many weeks on safari together exploring these harsh but fascinating areas.

Lake Turkana - the 'Jade Sea' - south of Loiyangalani



Fishing boats and children in Kalokol

Photo: Kieran Avery

South end of Lake Turkana

About the author

Sean T. Avery (BSc., PhD., C.Eng., C. Env.) is a consulting civil engineer and hydrologist specialising in African water resources, particularly in Kenya and East Africa. He was born in Tanzania and has lived in Kenya since 1979. He has led many professional consultancies in the water, wastewater, irrigation, drainage, and environmental sectors over the past thirty years and more, working with many African governments and international donors. His specialist interests are in engineering hydrology and arid zones, and his developing interests include water resource conflict resolution. He has written reports on the impact of river basin development on the hydrology of Lake Turkana for the African Development Bank and the African Studies Centre of the University of Oxford. He has developed a strong working relationship with this university, and is a member of Water Resources Associates (www.watres.com), a network of international specialist consultants based nearby in Wallingford. He is also an Associate of the Department of Geography at the University of Leicester, UK.

A CD containing the report on which this paper is based can be found inside the back cover.

One of many reed fringed channels in the Omo Delta

Photo: Kieran Avery

Small lake amidst barren volcanic terrain at the south end of Lake Turkana

Introduction

The Omo River drains south from Ethiopia's humid highlands to the semi-arid lowlands of the Lower Omo where the river finally terminates in Kenya's Lake Turkana. The lake is a closed basin located north of the Equator within Kenya's Rift Valley, and in a climatically challenged area of extreme aridity. The Omo delta, an ever-changing wetland with a multiplicity of channels and rich in biodiversity, alters in response to varying lake level. Sediments are deposited, forming banks to channels reaching sinuously out into the lake. At times of lake recession, wetlands become 'stranded', lake margins recede, the river downcuts, and the delta retreats south into Kenya. At times of lake rise, the northern lake margins inundate and the delta advances north into Ethiopia.

The Omo carries 14 per cent of Ethiopia's entire annual runoff and provides about 90 per cent of the lake's annual inflow. It thereby acts as an 'umbilical cord', supporting the ecology of the semi-arid and arid Lower Omo and arid Lake Turkana. The richness of the river's ecology has attracted, over the centuries, people with a remarkable diversity of cultures and languages. Seasonal floods have inundated pastures adjoining the river, sustaining both livestock and wildlife populations and making flood-retreat agriculture[1] possible along the riverbanks. The river's flood pulses trigger fisheries breeding and dilute the lake's semi-saline waters. The annual floods raise the lake level, and the inundated lake margins provide a flourishing habitat for breeding fish.

But the Omo Basin is undergoing dramatic man-made changes due to hydropower and irrigation development, with oil exploration also in progress. The filling of dam reservoirs will cause temporary drops in the water level of Lake Turkana and, once in operation, the dams will permanently regulate river flows, changing the hydrological cycle. The abstraction of water from the Omo for irrigation, downstream from the dams, will cause a permanent reduction in lake level. The change in water level, combined with alteration of the hydrological cycle by the dams, will lead to the destruction of the lake's flood plains fisheries. The impact on the human population will also be dramatic, with residents of the Lower Omo being evicted from their land and resettled elsewhere, to make way for commercial agriculture.

1 Also known as flood recession agriculture.

In 1996, a Master Plan was presented for the 'integrated development' of the Omo-Gibe[2] River Basin (Woodroofe et al. 1996). Major hydropower and irrigated agriculture potential was identified in the Omo Basin, but the impacts of these developments on Lake Turkana were not studied. In 2006, construction of the massive 243 metre high Gibe III dam began on the Omo, some 600 km upstream from the lake.[3] The project will generate 1,870 MW of electricity, equivalent to the entire power generating capacity of Kenya. An environmental and social impact assessment (Agriconsulting, 2009) was belatedly approved by the Ethiopian Government's Environmental Protection Agency, three years after construction had begun. Like the Master Plan, this did not consider impacts on Lake Turkana or Kenya.

In 2009, the African Development Bank (AFDB), which was considering financing the Gibe III power station, commissioned hydrological and socio-economic studies to assess the impact of the project on Lake Turkana. The hydrological studies (carried out by the present author) revealed major hydrological and ecological impacts on Lake Turkana arising from Gibe III and irrigation developments downstream (Avery, S.T., 2009 and 2010). The AFDB's interest in the project ceased, however, when Chinese donors stepped in to finance the power station in 2010. Completion of the dam is long overdue but it was reportedly 71 per cent complete in May 2013 and could be operational by 2014. The total cost is put at 1.47 billion Euros (Tegegne, 2013). Two further hydropower dams downstream, Gibe IV and V, are at the planning stage, Gibe IV comprising a major reservoir the size of Gibe III.

In 2011, large-scale irrigation development by the state-owned Ethiopian Sugar Corporation began in the Lower Omo, covering a huge area never envisaged in the Master Plan. This included the flood-retreat cultivation and grazing areas of thousands of resident agro-pastoralists, and vast areas taken from two national parks and a wildlife reserve. The local administraton has begun a programme of what it describes as 'voluntary villagisation' for traditional landowners, but there have been ongoing reports of forced evictions and other human rights abuses (e.g., Human Rights Watch, 2012; Oakland Institute, 2013).

Once the extent of planned irrigation had become known, I was commissioned by the African Studies Centre of the University of Oxford to update my AFDB study for a project focusing on environmental change in the Lower Omo.[4] My terms of reference

2 The Omo is named 'Gibe' in its upper and middle basins.

3 Gibe I, with a planned generating capacity of 184 MW, began operating in 2004. Gibe II is a power house which draws its water through a 25 km tunnel from the Gibe I reservoir and has a generating capacity of 420 MW. It was inaugurated in January 2010 but had to shut down almost immediately because of a tunnel collapse and did not resume operation until December of the same year.

4 This project, 'Landscape people and parks: environmental change in the Lower Omo Valley', was run by Professor David Anderson and Dr David Turton and funded by the UK Arts and Humanities Research Council, under its 'Landscape and Environment Programme'.

were to consolidate and expand my earlier findings, in the light of new information about the future extent of planned commercial irrigation development in the Lower Omo. This paper, also commissioned by the African Studies Centre, is a condensed version of the resulting report, the full version of which is included with the hard copy of this paper on a CD.

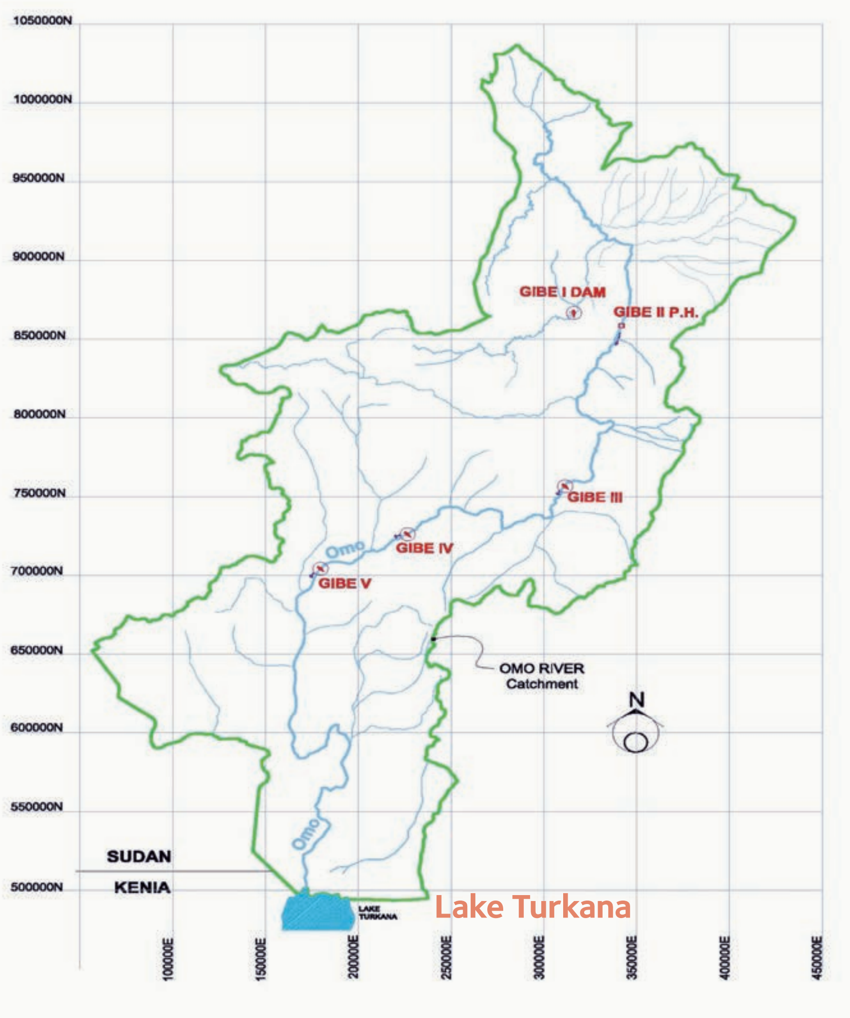


Figure 1: The Omo-Gibe hydropower cascade.

(From CESI & Mid-day International, 2009, p. 46)

Dried fish being stored near the lake

Photo: Kieran Avery


Spring water source near Loiyangalani

The Lake - its people, history and ecology

Human occupation

The Lake Turkana area has a fascinating human evolutionary history, and is often referred to as the 'Cradle of Mankind'. The oldest known fossil remains of our anatomical ancestor, Homo sapiens, dating back nearly 200,000 years, were discovered in the Lower Omo in 1968 (MacDougall et al., 2005), making this the oldest landscape in the world known to have been inhabited by modern humans.[5] Today there are around 52 different linguistic groups living in the Omo and Turkana Basins, the majority of them within Ethiopia. Population densities vary according to climate, which governs livelihood opportunities. The moist fertile highlands of the upper Omo Basin support 500-2,500[6] persons per square kilometre, whereas in stark contrast, the deserts east of Lake Turkana sustain less than 5 persons per square kilometre (Avery, S.T., 2012, p.83). These deserts are the least densely populated area in the whole of Kenya (ibid., p.81).

The distribution of ethnic groups in the Lower Omo and around the lake is shown in Figure 2. Not only is this an area with many different languages, but the languages represented fall into two of the four major African language families, Nilo-Saharan and Afro-Asiatic. The Nilo-Saharan speakers fall into three sub-families, Surmic (Bodi, Kwegu, Mursi and Suri), Eastern Nilotic (Nyangatom, Turkana and Samburu), and Southern Nilotic (Pokot). The Afro-Asiatic speakers fall into two sub-families, Omotic (Hamar and Kara) and Cushitic (Dassanech, Gabbra, Elmolo and Rendille). The Nilo-Saharan speakers extend from South Sudan and Uganda, whilst the Cushitic speakers extend from southern Ethiopia and Somalia. The lake forms a natural north/south physical divide between these groups. Cushitic communities on the eastern shores still regard the lake as a physical barrier that "protects them from rustlers" (Kaijage and Nyagah, 2010).

The predominantly agro-pastoral population of the the Lower Omo depends heavily on flood-retreat cultivation along the banks of the Omo. Planting begins as the

5 The "fundamental importance" of this area in the study of human evolution was recognised by the designation of the "Lower Valley of the Omo" as a UNESCO World Heritage Site in 1980.

6 Data extracted from population mapping produced by Thomas Ballatore, Natasha Gownas, and Alfred Burian from LandScan 2008 (ORNL).

Figure 2: Peoples of the Lower Omo and Lake Turkana

(Base map from Carr, 2012)

flood retreats in September/October, with the harvest coming in December/January. Rainfall increases northwards from the lake and this allows the Bodi, Mursi, Kwegu and Nyangatom to practise some rain-fed cultivation, though with limited reliability. The Kwegu, who live in very small groups along the banks of the Omo, and are acknowledged to have pre-dated their current neighbours in the area, are traditionally hunters and fishermen.[7] Immediately north of the lake, in Dassanech territory, the annual flood inundates large areas of grassland, away from the river, thereby rejuvenating dry season pastures and making large areas available for cultivation.[8]

Although traditionally the Turkana occupied the western side of the lake, some have crossed at its narrowest point to occupy the eastern shore between El Molo Bay and Moite and north to Sibiloi National Park. The Turkana are Kenya's third largest pastoral group and they also cultivate along the Kerio and Turkwel Rivers. They are the lake's dominant fishing community today and Turkana fishermen are active on all the lake's shores.

The Pokot occupy lands south-west of the lake within the Kerio Valley and have occasionally raided into Turkana occupied lands near the south-western lake shore. The Cushitic-speaking Dassanech live in the Omo delta, extending south into the Ileret area of Kenya, and into the northern parts of Sibiloi National Park. The El Molo, who live on El Molo Bay, north of Loiyangalani, are the lake's only 'hunters' who traditionally fished and hunted crocodile and hippo. Although Cushitic, they have integrated over the years with the Nilo-Saharan speaking Samburu.

The Gabbra are Oromo-speaking camel pastoralists who range over the northern areas of Kenya between the lake, the Ethiopian border, and Marsabit in the east. The Rendille are camel nomads who range the Kaisut desert south-east of the lake, south of the Gabbra traditional range, extending south towards Isiolo.

Livestock in the dry lands include cattle, sheep, goats, camels and donkeys, with cattle restricted to areas with freshwater sources, and with camels ranging into the most arid areas.

According to the Omo-Gibe Master Plan, the Omo Basin's Ethiopian population numbered 8.78m. in 1994 and was forecast to more than double to over 19m.by 2024 (Woodroofe et al., 1996).[9] The Lower Omo population was reported to number 173,542 people in 2010, of whom 82,000 (roughly half) are directly dependent on the Omo River (SOGREAH, 2010, p.65).

7 Information from David Turton, African Studies Centre, University of Oxford.

8 For more detailed information on recent changes in the livelihood strategies of the Dassanech and others living in the Lower Omo and Omo delta area, see Claudia Carr, 2012.

9 Population data are tabulated in Avery, S.T., 2012 – Table 15, p.79.

According to Kenya's 2009 population census, around 1m. people were then living within Kenya's Turkana, Samburu and Marsabit Administrative Districts surrounding the lake (Avery, S.T., 2012, Table 17, p.80). The western lakeshore population density is six-times that of the eastern shores (ibid., Figure 21, p.83). Roughly 200,000 people live "within reach of" the eastern and western shores of the lake, of which about 90,000 are "along or close to" the shore (estimates based on Kenya's 2009 population census (Avery, S.T., 2012, p.81). The lakeshore population is small, with 56,000 estimated to be living on or close to the western shore, and 35,000 on or close to the eastern shore (ibid.).

The published livestock population of Turkana District has fluctuated widely since the late 1970s, but it has not increased overall, being limited by forage availability (Avery, 2012, Figure 27, p.101). The human population, on the other hand, has increased dramatically, resulting in a steep decline in per-capita livestock wealth and a growing dependence on food aid. Food aid can account for up to 75 per cent of average household food intake around the lake (Brewin, 2009), and up to 50 per cent in the Lower Omo (SOGREAH, 2010, p.46).

The lake's reducing drainage area

Lake Turkana was formed within the East African Rift System that extends over 3,000 kilometres from the Red Sea and Gulf of Aden, through Ethiopia, Kenya and Tanzania, to Southern Mozambique (Dunkley et al., 1993). The Rift Valley formed 20m. years ago, and Lake Turkana was in existence 4.2m. years ago. A major lacustrine phase at that time was followed by regression, and 3.9m. years ago the Omo River flowed through to the Indian Ocean, until further rifting led to the formation of a closed lake basin (Ochieng et al., 1988).

With a surface area of 7,000 square kilometres, today's Lake Turkana is Kenya's largest lake, Africa's fourth largest, and the world's largest desert lake. Its length is 257 kilometres, its average width 31 kilometres and its average depth 31 metres. It reaches its maximum depth of 114 metres near its southern end. But 10,000 years ago there was a more humid climate and a "mega" lake existed, with a water level almost 100 metres higher than it is today (Avery, S.T., 2012, p.72-73). Its surface area was five-times larger and the shore extended 100 kilometres north into what is now Ethiopia (ibid., Figure 16, p.75). About 150 kilometres northwest of the present delta, the lake was able to relieve pressure by spilling over a sill into the drainage basin of the Nile, thus preventing the lake from rising any higher.

The lake's ancient shoreline is clearly visible today in the form of conspicuous wave-cut platforms (Figure 3), and remnant beaches are found at the former

Nile spill elevation. Remnant freshwater mollusc beds can still be found at this elevation. In the south, the ancient shoreline is 80 metres above the present-day water level, 20 metres lower than in the north, this difference being attributable to subsequent tilting of the land surface (Garcin et al., 2012).

Figure 3: South Island, showing the ancient shoreline

The last time there was fluvial connection between Lake Turkana and the Nile basin was about 6,500 years ago. It is probable that there then occurred a "major climatic transition" (Garcin et al. 2012), as a result of which the region became more arid, a period during which all regional lake levels dropped. In response to the declining rainfall, crop agricultural activity declined and pastoralism emerged as the most successful arid-zone livelihood, an adjustment that occurred throughout East Africa. In recent years, the pastoral livelihood balance has been upset by human-induced changes. These include a burgeoning population, sustained by external support mechanisms in health and food, constraints on mobility imposed by international borders, and contraints due to resource competition and the conversion of pastoral rangelands to other purposes.

Contemporary lake water levels were first compiled by the geomorphologist Karl Butzer (1971). Butzer's observations were updated by Hopson et al. (1982) and Kallqvist et al. (1988). In my African Studies Centre report (2012), I extended these observations with data from the Kenyan Marine and Fisheries Research Institute for 1988-2008, and satellite radar altimeter data from the US Department of Agriculture's Foreign Agricultural Service for 1992 to the present (Avery, S.T, 2012, p.152 and p.156). Since its contemporary 'high' water level in 1896, the lake declined 20 metres to its lowest levels in the 1940s and 1950s, before rising sharply in the 1961 floods, then dropping to its lowest levels again in 1988. The lake level rose to a high in 1999, and today is still above the lowest level (ibid., Figure 57, p.152).

The "mega" Turkana catchment area once covered 203,080 square kilometres and incorporated many lake basins that have since disconnected fluvially, becoming themselves closed basins (ibid., p.106). These include the Ethiopian Rift Valley lake chain and Kenya's Suguta Valley, Lake Baringo, and Lake Bogoria. Even in contemporary times (between 1908 and 1920) Sanderson's Gulf, now a large clay mudflat at the northwestern end of Lake Turkana, disconnected from the main lake (Hopson et al., 1982), and the lake's direct drainage area thereby reduced from 148,000 to 130,860 square kilometres (Avery, S.T., 2012, p.106). Today's catchment remains a major trans-boundary basin, split roughly equally between Ethiopia and Kenya, but also encroaching into South Sudan from southern Ethiopia, and beyond Mount Elgon in western Kenya into Uganda (ibid., Figure 31, p.109).

Water quality and health

Lake Turkana, which lies within Kenya's most arid zone, receives roughly 10 times less annual rainfall, as recorded at Lodwar[10] on the Turkwel River, than the highland catchment area of the Omo.[11] This contrast can be described in terms of annual 'net evaporation' (the balance between potential evaporation and rainfall). The Ethiopian highlands experience a negative net evaporation of up to 2,000 mm (i.e. after evaporation, there is a net 2,000 mm of water available annually through rainfall) while Lake Turkana experiences a positive net evaporation of roughly the same amount, which means it has the potential to lose 2,000 mm more surface water through evaporation than it gains through rainfall. In terms of water balance (the balance between inputs into, and outputs from, a drainage system), therefore, there is a potential difference of up to 4,000 mm between the moist upper highlands and the arid lowlands.

Since the lake is a closed basin, its water level represents the balance between inflow and evaporation. Every year it loses over 10 times more surface water through evaporation than it receives through rainfall, a volume equivalent to the entire annual Omo River inflow. Water is retained in the lake for only about 11.5 years, leaving behind minerals carried into the lake by rivers. Hence the lake is semi-saline, but with a salinity level much less than it might be. The present salinity level is equivalent to a lake only 600 years old, whereas the lake has been 'closed' for more than ten-times that period. This means that salts are being

10 The Lodwar rainfall chart dates from 1921 and, since that time, the average annual rainfall has increased overall, with the driest periods recorded in the 1930s and 1990s – see Avery, S.T., 2012, Figure 42, p.128

11 There is also less variation in rainfall, from year to year, in the highlands – see Avery, S.T., 2012, Figure 33, p.119

removed at a considerable rate through deposition and chemical processes (Hopson et al., 1982; and references in Avery, S.T., 2012, p.162).

Ever since the lake became a closed basin, its waters have become progressively more saline through the relentless evaporation. Although people and livestock drink the lake water today, they do so only in the absence of alternative potable sources. Around the lake, there are many scattered springs, and numerous wells, many being dug in seasonal watercourses which are replenished by periodic rainfall (Avery, S.T., 2012, Section 16, p.177-188). People will use these in preference to lake water, when they can. In addition, the freshwater inflow from the Omo dilutes the lake's northern waters, thereby improving quality locally, but lake salinity increases southwards.

Water chemistry data for Lake Turkana show this is a sodium carbonate lake with a high pH level, high in dissolved salts (total dissolved solids) and with an ionic composition typical of East African saline lakes.[12] Total ion levels in the lake are far in excess of the limits set by the WHO's potable water quality standards (WHO, 1984). The individual ion levels are also high, with the exception of calcium, magnesium, iron, nitrate, and phosphate. This is attributable to salt losses occurring through "sediment / water interactions" (Hopson et al, 1982). Notably, the calcium concentration has halved in the lake through its use as an essential skeletal nutrient, and its subsequent deposition to the lake bed as calcite.[13] Other nutrients commonly used by plankton include iron, silica, phosphorus and nitrogen, with nitrogen being this lake's limiting nutrient insofar as 'productivity' is concerned. Ion concentrations in the Omo, however, are well within the WHO limits (ibid., Hopson et al. 1982). If we compare the lake's water chemistry with Kenya's quality standards for community water supply, we find that the total dissolved solids concentration (salinity) is double the 'guide value' (MoWD, 1992a; Avery, S.T., 2012, Table 44, p.172). For livestock, the lake's salinity level is just within the allowable limit but its fluoride concentration is more than double the limit (ibid., Table 46, p.174). Camels and small stock are watered from the lake on a permanent basis, but "cattle are known to take ill effect" (MoLD, 1991; Avery, S.T., 2012, p.174).

The lake's fluoride concentration far exceeds acceptable health limits for both humans and livestock (Avery, S.T., 2012, p.172-174). Varying degrees of fluorosis occur. Mottling of teeth due to fluoride in water is not unusual in Kenya, but

12 See Walsh and Dodson, 1969; Hopson et al, 1982; Avery, S.T., 2012, p.171. An ion is an atom or molecule "in which the total number of electrons is not equal to the total number of protons, giving the atom a net positive or negative electrical discharge" (Wikipedia).

13 See Avery, S.T., 2012, Table 42, p.171 for tabulated calcium levels. Note that calcite (calcium carbonate, $CaCO_3$) is the primary constituent of the skeletal structures, scales and teeth of aquatic organisms and animals (Wikipedia) such as plankton, algae, fish, crocodiles, etc. Upon death, the calcite sinks to the lakebed.

around Lake Turkana there are people suffering from crippling skeletal fluorosis. One old man interviewed in January 2012 denied that dependance on lake water caused his disease. Instead, he regarded his skeletal deformation as a "curse" and said that he preferred to drink lake water because "it tasted better" and because "one does not need to add salt to food" (ibid, p.173). Even though international NGOs were installing a new water supply nearby from a potable protected spring, this old man claimed he was ignorant of the consequences of high fluoride in his drinking water.

Long-term reductions in Omo River inflow into the lake will exacerbate the already significant health risks associated with the drinking of lake water by lakeside communities. Added to these risks will be the potential for chemical pollution stemming from commercial agricultural activity in the Lower Omo, and the water quality effects of algal blooms (a consequence of excess nutrients coming from agricultural run-off). Algal blooms are an explosive growth that can 'clog' the water with dense toxic algae harmful to fish. The blooms block light penetration and, on die-off, exert a biological oxygen demand, thereby depleting oxygen resources.

Finally, and according to Kenya's 'Standards for Irrigation Water' (EMCA, 2006), the lake's salinity level is already double the limit suitable for irrigation (Avery, S.T., 2012, Table 48, p.175).

Fisheries

Lake Turkana was the last of the world's large lakes to have its underwater topography ('bathymetry') mapped in detail. This was undertaken by the 'Lake Turkana Project' (1972-75), a major three-year scientific expedition run and funded by the Fisheries Department of Kenya and the UK Ministry of Overseas Development (Hopson et al., 1982). The aims of the project were to complete a fisheries inventory, to study fisheries ecology and numbers and the prospects for commercial fisheries, and to prepare a bathymetric chart. Sixteen scientists were mobilised and a 50 ft research vessel was built and imported from Scotland, an extraordinary logistical undertaking. The expedition's work established a fisheries ecology baseline. Forty eight species of fish were identified, 12 of which were riverine and confined to the Omo delta. Further studies were undertaken from 1985-88 by the Norwegian Institute for Water Research and the Kenya Marine and Fisheries Research Institute (Kallqvist et al., 1988). In recent years, the list has grown to include 60 fish species (Ojwang et al., 2007).

The lake's aquatic ecology has evolved directly from its former Nile fluvial connection. The lake's fisheries are thus mainly Nilotic, but with some endemic species. Interestingly, similar fish species occur right across northern Africa to the Gambia (Hopson et al.,1982). Hopson reported that the fish population was "well adapted to the environmental conditions", hydrology being all-important, and that "Breeding activity…reached a peak during the Omo flood season in nearly all species".

In a classic paper, Talling and Talling (1965), classified African lakes into three classes according to their ionic content: 'low' (Class I), 'higher' (Class II) and 'saline' (Class III).[14] Lake Turkana is amongst the most saline in Class II, but still hosting varied fish resources, although with less diversity than other African Great Lakes (Muska et al., 2012). With the exception of Mormyrids (electro-sensory fish), the fish were "apparently unaffected" by the transition from fresh to semi-saline conditions (Hopson et al., 1982). Crocodile Lake on Central Island falls within Class III (saline), but in spite of this, there are still populations of four fish species also found within the adjacent open lake. With 2,440 parts per million (ppm) of dissolved salts, Lake Turkana is not yet 'truly saline' but it is not far off.[15]

Photo: Patrick Avery

Figure 4: Fishing community on North Island

14 See Avery, S.T., 2012, Table 40, p.168.

15 A truly saline lake contains 3,000 ppm of dissolved salts (Kolding, 1992, p.27, citing Williams, 1981). See Avery, S.T., 2012, Table 43, p.172 for the USGS 'salinity' classifications.

As this lake hosts Africa's highest salinity fisheries, it is worth noting some of the key ecological findings on the distribution of the food chain through the lake, as reported by Hopson et al. (1982). The phytoplankton (plankton which are photosynthetic) "were dominated by blue-green algae and were characterised by a low species diversity" with "marked differences in species composition between the north and south". The primary productivity and algal biomass is high in the north of the lake, and very low in the south. On sub-littoral[16] fringes of the lake, there were "rich communities of attached algae". "The open water phytoplankton of Lake Turkana was almost entirely uncropped by either fish or crustacea". This prompted the Hopson team to contemplate the intoduction of an alien fish species to graze the under-utilised phytoplankton (a suggestion fortunately never tested). The proportion of fish feeding on zooplankton (plankton which are not photosynthetic) in Lake Turkana was "unusually high" and production rates of zooplankton in the north of the lake were 10 times those in the south. In general, inshore areas of the lake, like Ferguson's Gulf, were found to have an algal flora quite different from that of the open lake and production rates were as high here as in the northern areas of the lake. Fish yields in Ferguson's Gulf were described as "phenomenally high".

Apart from salinity, a number of other environmental factors affect fisheries production in Lake Turkana. These include wind, temperature, incoming river floods, lake levels, and invasive species.

Wind

The prevailing strong south-easterly winds are a major factor in the lake environment, for a number of reasons. First, the winds cause surface currents in the upper layers and reverse currents occur in the lower layers, which means that the water column is well mixed and well oxygenated. There is, however, some stratification of oxygen and temperature - i.e., oxygen levels diminish at depth, as does water temperature. The wind-induced surface currents transport zooplankton, which thus concentrate on the northwest shores, leading to unusual concentrations of small pelagic[17] fish and their predators (Hopson et al., 1982).[18] The prevailing winds also affect the distribution of littoral zone fish, which prefer the sheltered eastern shores. As a consequence of all this, the southern end of the lake tends to hold less fish, and has a fisheries environment more akin to a lake, in contrast to the NW shore which is more akin to a river or flood plain (Kolding, 1992, p.31). And finally, the mixing induced by the south-easterly winds ensures that the lake waters remain turbid, and this limits the penetration of light for photosynthetic activity to the top six metres of water (Hopson et al., 1982). [19]

16 'Sub-littoral' refers to the bed of the littoral (inshore) zone of the lake.

17 Pelagic fish are those which inhabit offshore water, away from the lake bed.

18 The lake's surface current of about 7-9 cm/s from the southeast is compensated by an opposite deepwater return current (Kolding, 1992, p.23).

19 Winds are fierce at the southern end of the lake, diminishing to the west and north, and can cause hazardous rough boating conditions.

Water temperature

Water temperature remains constantly warm throughout the year in the open lake, with slightly cooler waters at depth. The lake's warmth is one of the main drivers of its high productivity (Kolding, 1992, p.31). In the shallow enclosed 'flood plains' areas such as Ferguson's Gulf, heating up of the waters will occur. There is also slight warming of the shallower northern waters, with a consequent small temperature gradient along the length of the lake.[20]

Incoming river floods

The most profound seasonal changes in the lake arise during the annual flooding, which peaks in the period August to October and the principal source of which is the Omo. The upstream flooding of the Omo, the seasonal inundation of offstream areas and the runoff therefrom capture valuable organic matter and nutrients, which are carried into the lake. Nitrogen, one of the two most important factors limiting fisheries production (the other being light), is also transported into the lake through the Omo waters (Hopson et al., 1982). The flood influxes also stimulate the migration of spawning fish into the Omo.

Within the main lake, fish breeding tends to be greatest during flood periods. This is due to the sediment-rich waters, which extend south right through the central sector of the lake. The floods dilute the lake water and lower the salinity levels in northern parts in particular. The sediment plume reduces visibility and fish tend to move to the lake surface and to the shore, and the reduced light penetration affects production of organisms that depend on photosynthesis. The influx of nutrients during the flood season initiates changes in the algal population, and the margins of the lake inundate (ibid.).

Lake levels

The lake level rises are typically up to 300 mm/month, starting from July, and in flat areas of the lake, the inundated margins such as at Ferguson's Gulf (on the western shore near Kalokol) can extend many hundreds of metres. When inundated, the shoreline terrestrial vegetation provides a refuge habitat for young, recently hatched fish. If the shoreline areas were previously heavily grazed, this will reduce the potential refuge habitat and thus affects potential breeding success. On the other hand, the presence of livestock adds nutrients. The effect of nutrient load on chlorophyll production is very pronounced in northern parts of the lake (Hopson et al, 1982). Chlorophyll levels are indicative of the abundance of phytoplankton.

20 This amounted to 3.5° Centigrade in January 2012, from 26° in the south to 29.5° in the north (Avery, S.T., 2012, p.165, Fig 69, p.166). Since records began in 1960, the lake water temperature has warmed slightly, though not noticeably since 1990 (Avery, S.T., 2012, Fig 39, p. 125).

The inundation of littoral zones through floods in various African lakes has been shown to result in a boom in fish populations, often short-lived (Kolding, 1992, p.32). Falling lake levels between 1972 and the late 1980s reduced biomass and resulted in a 70 per cent reduction in the endemic zooplankton-based open-water pelagic fish communities in the lake. These fish communities are shorter-lived and unstable. Kolding reported that the fish population had "undergone unpredictable and drastic transformation in the past decade" (ibid.).

Invasive species

Prosopis juliflora, an aggressive invasive plant species which over-runs pastures, was introduced to the Lodwar area west of Lake Turkana by an NGO to 'green the desert' (Avery, S.T., 2012, p.96). Indigenous to Mexico, it was introduced to the Afar region of Ethiopia in the 1970s, and reached Kenya in the 1980s. It is choking Ferguson's Gulf and obstructing access to the lake by fishermen. It is displacing indigenous vegetation from the banks of the Turkwel River and delta, as noticed between 2001 and 2008 (ibid.). It thrives in arid areas and is almost impossible to eradicate. In view of this, efforts are being made to utilise it as a resource - for example as fuel.

In summary, the production potential of the lake's fisheries is significantly affected by fluctuations in river discharge. Shallow littoral areas, inundated during seasonal rises in lake level, are likely to be particularly important (Kallqvist et al., 1988; Kolding, 1992). There is exceptionally high photosynthetic activity in this lake and the effect of the nutrient load from the Omo on chlorophyll production is very pronounced in its northern areas. Primary production rates for algae in Lake Turkana were lower than in Lake Victoria, but higher than Lake Tanganyika, and production rates in Ferguson's Gulf were some of the highest recorded (Kallqvist et al., 1988). Because of the importance of fluctuation in river discharge and lake level on the ecology of the lake, continuous monitoring should be undertaken (ibid.; Kolding, 1992). Finally, developments in the catchment area affecting discharge of water to the lake, are likely to have serious effects on the lake ecosystem (Kallqvist et al., 1988).

Lake Turkana was once unique amongst African lakes in lacking a substantial indigenous fishery (Bayley, 1982). Commercial fishing commenced around 1950 (Kolding, 1992, p.28). Since the 1960s, however, increasing numbers of pastoralists living around the lake and in its delta area have taken to fishing to alleviate famine and destitution. Amongst pastoralists, fisherfolk are seen as 'poor' – people without livestock. In 2010, an AFDB study (Mbogo, 2010) reported 8,160 fishermen, with numbers increasing. Fishing practices were described as 'artisanal', with 60 per cent of the 6,900 boats being traditional raft boats ('ngatedie'). The marketing of fish is hampered by poor or absent transport infrastructure, the long distance to markets, and the absence of storage facilities - local people rely on sun-drying and salting of fish for storage. In the 1980s a fish processing plant was built at Kalokol in an illresearched albeit well-intentioned donor initiative. The plant never opened and was described as a "welcome object for ridicule from aid sceptics ever since" (NORAD, 2008).

Annual total fish catch records have reached 9,500 tonnes/year, in recent years (Avery, S.T., 2012, Fig.84, p.200), well below the estimated sustainable production of 15,000 to 30,000 tonnes/year (Kallqvist et al., 1988). Whilst Lake Turkana's annual fish catch is the second highest in Kenya (after Lake Victoria), in proportion to lake area the catch is tiny. The area of Lake Victoria fished by Kenyan fishermen is only 4,260 square kilometres, slightly more than half the 7,000 square kilometres of Lake Turkana, yet the fish catch is typically 12-times, and up to 50-times higher.[21] Nonetheless, even at present production levels, Lake Turkana's fisheries provide a valuable protein source and an alternative livelihood in a vulnerable area with food security challenges. The destruction of the Turkana fisheries would therefore have very serious socio-economic consequences.

National parks

In 1997, the 'Lake Turkana National Parks' were added to UNESCO's World Heritage List as a site of 'outstanding universal value'. This World Heritage site comprises Sibiloi National Park and the two island national parks, Central Island and South Island (Figure 2). Sibiloi National Park is the only Kenyan national park created for archaeological reasons. The lake's third island, North Island, is not a national park, and hence is not within the protected area. Figure 5 shows South Island from south of Loiyangalani and the distinct colouration of the lake, caused by its dominant blue-green algae, which has earned it the popular name 'the Jade Sea'.

The crater lakes of Central Island were formerly submerged and have progressively emerged as the main lake level declined (Hopson et al., 1982). Flamingo Lake became isolated in the late 1890s, followed by Crocodile and Tilapia Lakes in 1902 and 1972 respectively. Lake Turkana once boasted the highest concentration of crocodiles in the world and Crocodile Lake was a world renowned breeding place.[22] Although 'isolated', the lakes are replenished mainly through underground percolation from the main lake, and thus their individual lake levels 'follow' the main lake level. However, their salinity levels do differ, being mainly a function

21 Based on data from 2003-2004, see Avery, S.T., 2012, Table 56, p.199. The Lake Victoria fish catch in Kenyan waters is over 100,000 tonnes annually.

22 A field expedition in early 2012 reported very few crocodiles. Nests were witnessed being raided for eggs by fishermen and crocodiles were noted being ensnared and drowning in nets. It was also suspected that they were being shot, as large animals pose a threat to fishermen (Avery, Patrick, 2012; Avery S.T. 2012).

Figure 5: The 'Jade Sea', with South Island in the background

of the time elapsed since they separated from the main lake, and also a function of exposure to winds. Thus Flamingo Lake, the longest isolated, is the most saline, with an electrical conductivity reading over 10-times that of the open lake (Avery, S.T., 2012, Table 39 and Fig.71, p.165-166). If the open lake level drops significantly, these crater lakes could dry up altogether.

In 2011, the UNESCO World Heritage Committee expressed concerns about the cumulative impacts of hydropower dams and large-scale irrigation in the Omo Valley on the Lake Turkana National Parks. The Committee urged the Ethiopian government to halt construction of the Gibe III dam, pending reports from both Ethiopia and Kenya (WHC, 2011). The Ethiopian response dismissed the Committee's concerns out of hand, describing them as "one-sided and highly biased" (Turton, 2012c). In March 2012, a joint monitoring mission from the World Heritage Centre and the IUCN visited the Lake Turkana World Heritage Site at the invitation of the Kenyan Government (WHC, 2012a; Avery, S.T., 2012, p.44).[23] In its report to the World Heritage Committee, the WHC / IUCN team recommended that Lake Turkana National Parks be added to the 'List of World Heritage in Danger'. But at its two subsequent meetings the Committee has failed to act on this recommendation (WHC, 2012b and 2013a and 2013b).

23 The Committee had requested a similar invitation from Ethiopia but none had been forthcoming.

Irrigation water demand in the Omo Basin

In 1996, a development 'Master Plan' was produced for the Omo-Gibe Basin (Woodroofe et al., 1996). The Terms of Reference were prepared by the Ethiopian Development Studies Authority (EVDSA, 1991) and approved by the African Development Bank (AFDB). The aim was to plan the basin's multi-sectoral development strategy, and prepare implementable sustainable projects, mainly agricultural, to exploit the basin's natural resources (ibid.). This included exploiting the hydropower and irrigation potential of the basin, and identifying schemes that would depend on major dams to control the Omo river water. These dams would raise the river water level to create a head of water needed for hydropower generation. The dams would impound sufficient water to thereafter enable reliable controlled releases through the turbines throughout the year. In so doing, the dams would alter the entire river hydrology. The dams would control floods, and uplift the river's low flows, thereby reversing the declining low flows that are a consequence of increasing smallholder irrigation abstraction. The uplifted low flows, and the increased low flow reliability, would also enable year-round commercial irrigated agriculture downstream from the dams.

A major failing of the Master Plan was the omission of any study of the transboundary impacts of the proposed basin developments, particularly on Lake Turkana. This was in spite of its prediction that 32 per cent of the Omo waters would be abstracted by the year 2024. The consultants acknowledged there would be detrimental effects on Lake Turkana's fisheries, but they appeared to diminish the significance of these effects by stating that the fisheries were declining anyway due to over-exploitation (Avery, S.T., 2012, p.25). The Master Plan did however recommend a bilateral agreement between Ethiopia and Kenya "before either country changes the natural flow of the river" through hydropower or large-scale irrigation development (ibid.). This recommendation was unfortunately disregarded.

The World Bank has also long been encouraging Ethiopia to reduce its food security challenges by utilising the country's abundant water resources for irrigated agriculture in its semi-arid lowlands. In a 'Concept Paper' published in 2004, the Bank justified development impacts on Lake Turkana on the grounds that "there is no significant use of Lake Turkana's waters" and that the Kenya Government can "benefit" from Ethiopia's projects. The paper concluded that, whilst the Omo Basin was "an early candidate for development", there was also a need for research into the social problems that might arise as a result of population displacement (World Bank 2004a; Avery, S.T., 2012, p.26-27). Whereas no such social studies have materialised, ecological consequences did not even warrant a research recommendation.

Potential irrigated area

The Master Plan estimated that 31,780 hectares in the Lower Omo were suitable for small-scale irrigation and 54,670 hectares for large to medium-scale irrigation,[24] making a total irrigable area of 86,450 hectares.[25] Much bigger estimates have been made by other organisations, including 348,000 hectares (World Bank, 2004a) and 445,000 hectares (FAO, 1997). The hydrological impact of potential irrigation development on anything like this scale is nowhere considered in the impact assessments for the Gibe III hydropower dam. This is surprising since, as pointed out in the Master Plan, it was precisely the regulated river flow created by hydropower dams that would make large-scale, year round commercial irrigation schemes possible in the Lower Omo. And yet, in the few sentences devoted to commercial plantations in the Gibe III project documents, it is assumed, "for the sake of argument", that these will cover no more than 5,000 hectares and that they will "almost certainly" be confined to the delta plain. Cotton was described as the most likely crop and sugar the least likely because of its high infrastructural costs (Agriconsulting et al., 2009, p.83-84).

Nevertheless, it was announced in January 2011 that the Ethiopian Sugar Corporation was in the process of implementing a plan to create 150,000 hectares of irrigated plantations in the Lower Omo, a figure that was later increased to 175,000 hectares.[26] The greater part of this area (135,285 hectares) was to be excised from the Omo National Park, the Mago National Park and the Tama Wildlife Reserve (EWCA, 2011)[27] – something that had not been envisaged in the Master Plan. This scheme, known as the 'Omo-Kuraz Sugar Development Project', will create a huge potential water demand from the Omo River. The three 'sugar blocks' making up Kuraz are shown in Figure 6, along with the proposed irrigation conveyance canals

24 The Master Plan adopted the criteria used by the Ethiopian Government to classify irrigation schemes, according to area cultivated, as follows: small-scale: < 200 ha; medium-scale: 200-3,000 ha; and large-scale: >3,000 ha (Woodroofe et al., 1996; Avery, S.T., 2012, Section 4.12, p.54).

25 The Master Plan's small-scale irrigation areas are listed in Avery, S.T., 2012, Table 7, p.56. The Master Plan's medium and large-scale areas are located as shown in Avery, S.T., 2012, Fig.8, p.55 with scheme details tabulated in Tables 8 and 9, p.58.

26 According to local press reports, the total area allocated to the Sugar Corporation in the lower Omo was 245,000 hectares, but not all of this was considered suitable for sugar production.

27 The EWCA excised areas and maps are included in Avery, S.T., 2012, p.37-39.

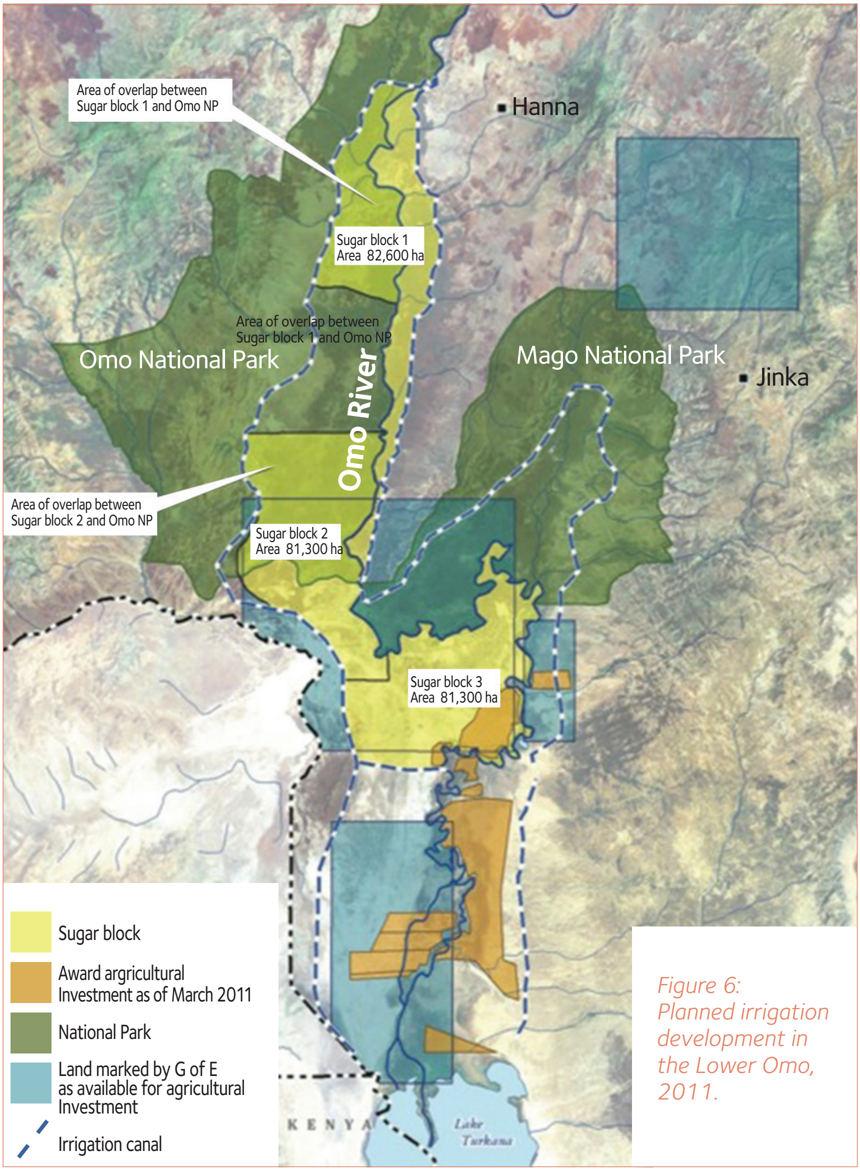


Figure 6: Planned irrigation development in the Lower Omo, 2011.

(Source: Human Rights Watch, 2012)

leading to the lake (shown as dashed blue lines). The Omo and Mago National Parks are shown shaded green, and the Tama Wildlife Reserve is the area between the two parks.

Photo: Kieran Avery

Also shown on this map are areas south of the sugar blocks which were known to have been leased to private investors and land that had been identified by the Ethiopian Government as available for agricultural investment. Putting together both government and private land investment plans in the Lower Omo, the Oakland Institute (2011) reported that the area potentially totalled 445,501 hectares, including the 245,000 hectares allocated to the Sugar Corporation.[28] Flintan (2011) presented a map and table of agricultural investment areas in the Lower Omo totalling 180,675 hectares.[29] These data, which came from the Ethiopian Embassy in Stockholm and did not include the sugar plantation areas, were consistent with the Oakland Institute data. Finally, in 2012, the Kenya Government announced 10,000 hectares of irrigation development near the northwestern shore of Lake Turkana, at Todenyang (Figure 2). The water source and water demand have not been reported but the Omo is an obvious potential source. In addition, massive underground aquifer finds were recently announced in Turkana, which have raised expectations about the possible future use of this water for irrigation (Radar Technologies International, 2013).[30]

Table 1 represents a conservative estimate of the potential extent of medium and large-scale irrigation in the Lower Omo, based principally on the Master Plan predictions and known plans for the Kuraz Sugar project. The Kuraz plantation potential totalled 161,285 hectares,[31] and the total lower basin potential irrigation (including 10,000 hectares at Todenyang) amounted to 208,655

28 The tabulation of agricultural area allocations is reproduced in Avery, S.T., 2012, p.52.

29 The map of South Omo agricultural investment areas is reproduced in Avery, S.T., 2012, p.60.

30 The resulting media euphoria needs to be put into perspective, as explained in the final section of this paper.

31 This figure is the summation of 135,285 ha excised from national parks/reserves and 26,000 ha south of the Omo National Park (Avery, S.T., 2012, p.58). The figures are based on reported soil studies of suitability for irrigation (ibid.). Note that there are unusual characteristics associated with the lower Omo soils. In the case of the abandoned Ethio-Korean scheme near Omerate, sink holes developed with irrigation or heavy rainfall (SOGREAH, 2010, p.31). These are young soils, as this area was formerly the lake bed (ibid.). The author has frequently encountered these 'dispersive' soils in the Rift Valley, on one occasion losing an entire Land Rover in a large sink hole. The Sugar Corporation has mentioned the potential sugar plantation area being as much as 175,000 ha, but as supporting soil studies have not been released, I did not adopt this figure for these calculations.

Table 1: Potential medium and large-scale irrigation areas in the Omo Basin

Name of Farm Area [5]	Existing Irrigated Area (Ethio-Korean Farm)[3]	Potential Before Soil Survey (M.Plan)	Potential After Soil Survey (M.Plan)	Excised Area [2] (EWCA)	Kuraz Sugar Potential [4] (ESDC)	2012 Potential Irrigable Area[5]
	ha	ha	ha	ha	ha	ha
Upper Omo (M.Plan) [1]						
Bako-Gibe	-	-	400	-	-	400
Kulit-Darge	-	-	1,600	-	-	1,600
Walga-Kulit	-	-	5,300	-	-	5,300
Lower Omo Excision [2]						
NP / Tama Excisions	-	-	-	135,285	135,285	135,285
Lower Omo (M.Plan)						
Omo Higher Farm	-	10,000	8,700	-	-	8,700
Dip'a Hayk	-	5,000	5,880	-	-	5,880
Omo Rate (Ethio-Korean) [3]	1,400	-	-	-	-	1,400
Omo Rate West	-	10,000	4,020	-	-	4,020
South of Mago	-	8,000	8,000	-	-	8,000
South of Omo NP (Kuraz)	-	26,000	26,000	-	26,000	26,000
Nargi Ridge	-	8,000	2,070	-	-	2,070
Kenya Basin	**-**	**-**	**-**	**-**	**-**	**-**
Todenyang	-	-	-	-	-	10,000
Total	**1,400**	**67,000**	**54,670**	**135,285**	**161,285**	**208,655**

Note [1]: Woodroofe et al, Vol. XI, F2, p53, 1996
Note [2]: EWCA (2011) – Section 3.10, p58 (Note: NP=National Park).
Note [3]: Woodroofe et al (1996) (Ethio-Korean Scheme reported "abandoned" in 1991).
Note [4]: ESDC = Ethiopia Sugar Development Corporation.
Note [5]: Location of Schemes – see Avery, S.T., 2012, Fig.9, p55, and Fig.10, p59

hectares.[32] To put the Lower Omo project scale into a regional perspective, the Kuraz sugar scheme alone covers an area almost equivalent to the entire irrigated area of Kenya, estimated to be 165,800 hectares in 2011 (JICA/NK, 2012).

32 When viewing published data on agricultural development areas, a distinction needs to be made between irrigated agriculture, and land used for rain-fed or other non-water consumptive agricultural purposes. This distinction is not always made clear in publications.

Available information on the actual and potential extent of small-scale irrigation in the Omo Basin is sketchy and contradictory. In 1996, the Master Plan estimated that 8,751 hectares were under small-holder irrigation, with the potential for this to increase to 31,782 hectares.[33] In 2009, the Gibe III Economic and Social Impact Assessment (ESIA) reported that existing and potential small-scale irrigation areas amounted to 667 hectares, and 10,100 hectares, respectively (CESI and Mid-Day, 2009). The 'existing' figure seems low, and the 'potential' is a fraction compared to the Master Plan estimate. In 2010, the consultants SOGREAH used satellite imagery to assess the area of flood-retreat agriculture in four weredas (districts) in the Lower Omo (SOGREAH, 2010). They estimated about 4,000 to 5,000 hectares under flood-retreat cultivation in the Dassanech wereda, with "small-scale cropping" limited to riverbanks elsewhere (ibid., p.37), and with 82,000 people depending directly on the river (47 per cent of the area's population) (ibid., p.34 and 65). They also estimated that an additional 15,000 people benefitted from the seasonal inundation and rejuvenation of dry-season grazing lands (ibid., p.34).[34] A total population of 100,000 could thus be affected (ibid., p.37). It is essential to consolidate these estimates and verify the total area under small-scale irrigation today, in order accurately to assess both irrigation water demand and the potential impacts of irrigation abstraction on available water downstream.

The Gibe III project documents predicted that the people of the Lower Omo would experience enhanced food security as a result of Gibe III's regulated flow sequence, with people downstream being encouraged to move away from "risky rain-fed agriculture" to "more secure irrigated agriculture" (Agriconsulting, 2009). It was also suggested that "…major benefits would be induced by the regulation of river flow in the downstream Lower Omo valley in terms of…permanent availability of water with stable water levels allowing for development of commercial irrigated agriculture" (Salini Costruttori et al., 2009b). The amount of water that would have to be abstracted from the Omo to provide these benefits was described as "negligible", compared to the annual flows. My own study on behalf of the AFDB, however, did not confirm this prediction and instead raised the spectre of Lake Turkana reduced to two small disconnected lakes – a potential African 'Aral Sea' in the making.[35]

33 The Master Plan tabulation of small-scale irrigation areas is reproduced in Avery, S.T., 2012 – see Table 7, p.56.

34 A tabulation of the SOGREAH flood-recession agriculture data is included in Avery, S.T., 2012 - Table 3, p.51.

35 See Avery, S.T, 2012, p.33; Avery, Patrick, 2012. The Aral Sea, Central Asia's most infamous man-made environmental disaster, was once one of the four largest lakes in the world. It steadily shrunk after rivers feeding it were diverted in the 1960s by Soviet irrigation projects (Wikipedia). By 2007, the lake was 10 per cent its original size (ibid.). Salinity levels rose, fishing ceased altogether, and salts blown by winds from the dried lake bed are destroying pastures (UNEP, 2008).

Irrigation system efficiencies

The overall efficiency of an irrigation scheme determines the gross water abstraction required from the river. It is dependant not only on the irrigation methodology adopted, but also on competent scheme design and construction, and the efficiency of operation and maintenance. As far as Lake Turkana is concerned, the less efficient the irrigation scheme, the more fresh water the lake will be deprived of, although some of the water will return to the river, either through percolation, or through drainage canals. In any event, substantial water losses are inevitable and irrigation methodology will be a critical factor in minimising impacts on Lake Turkana. Unfortunately, however, we do not know what irrigation methodologies will be used in the Lower Omo because feasibility studies have not been released. In what follows, therefore, typical schemes and efficiency values are outlined, using indicative figures published in FAO documents (FAO, 2000; and 2009).

Irrigation water is abstracted from the river and conveyed to the scheme, either by open canal, or by pipeline. Pipelines are used for pumped water or where topography is not suited to gravity canals. 'Earthen' canals are suitable in impermeable soils, but canals passing through permeable soils should be lined. According to FAO's 'indicative values', the 'conveyance efficiency' of a scheme can vary hugely, from 60 per cent for a long canal in sandy soil to 95 per cent for a lined canal.

Once the water has reached the crop area, one or more of the following water 'application methods' may be used. In surface irrigation, the water is 'applied' through simple gravity 'flooding' of the crop area through furrows, with irrigation water soaking into the crop root zone. In sprinkler irrigation, the water is mechanically sprayed onto the crop as a jet or spray, using pressure fed sprinklers or centre pivot[36] systems. This is more sophisticated, as it requires hydromechanical systems to pressurise and convey the water, but high evaporation losses can result during this application process. In smaller intensive cultivation systems, and where water is scarce, water can be fed directly to the root system. This 'drip' system is more intricate and well suited to intensive horticulture, and nutrients are often blended with the applied water. Surface irrigation is the more traditional system and hence more common. According to FAO's 'indicative values', the 'application efficiency' (i.e., excluding losses due to the conveyance system) of a surface irrigation system is 'typically' 50 per cent. For sprinkler irrigation the figure is 55-75 per cent and for drip irrigation 80-90 per cent.

36 In 'centre-pivot' systems, water is sprayed from a perforated pipe at the centre of a circular field.

Considering the overall efficiency of a scheme,[37] FAO categorizes 50-60 per cent overall efficiency as 'good', 40 per cent as 'reasonable' and 20-30 per cent as 'poor'. The Master Plan adopted 45 per cent overall efficiency for assessing irrigation water demands in the Omo Basin (Woodroofe et al., 1996), while Kenya's National Irrigation Board adopted 40 per cent overall irrigation efficiency for its Hola scheme on the Tana River (NIB, 2004). The rainfall and climate conditions for the Omo and Tana schemes are comparable, and both are on flood plain soils adjacent to a major lowland river.

Irrigation water demand as a percentage of Omo flow

The Lower Omo is hot, dry and windy throughout the year.[38] Irrigation design aims to avoid crop stress by ensuring that crop water evapotranspiration[39] needs are met. As evapotranspiration in the Lower Omo is on average almost 8-times the rainfall, the water deficit to be met by irrigation is huge. To estimate this demand, it is necessary to consider the water needs of different crops and cropping patterns. For this study, two crop scenarios were chosen, both at 60 per cent[40] overall irrigation efficiency: a mixed crop scenario, requiring 0.712 litres per second per hectare (SOGREAH, 2010) and sugar cane plantations, requiring 1.115 litres per second per hectare (FAO, 2009; 2000).[41]

In Table 2, the potential irrigation water requirement from the Omo is shown, first, for the Kuraz sugar scheme alone (161,285 hectares), second for the remaining area that previous studies have identified as suitable for irrigation (47,370 hectares) and third for the two combined. The water requirements are huge, as is the water saving through increasing the irrigation efficiency from 45 to 90 per cent. The figures do not include canal conveyance water losses. These canals are assumed lined, with losses 'returnable' to the river system, although a portion will be evaporated. The 'field efficiency' in the table, therefore, refers only to losses associated with the irrigation application methods. In the case of sprinklers, the water is sprayed through the air, with resulting airborne evaporation losses. There

37 Scheme Irrigation Efficiency (overall efficiency) = Conveyance Efficiency x Field Application Efficiency (see Avery, S.T., 2012, p.62-63).

38 Typical Lower Omo climate data near the lake are as follows: Annual average temperature, 29.8°C; Average wind speed 1.9 m/s; Annual average rainfall 335 mm per year; Evapotranspiration, 2,293 mm per year (Avery, S.T., 2012, p.114-120).

39 Evapotranspiration is the loss of water vapour to the air through both evaporation and plant transpiration.

40 This is a relatively optimistic assumption, given that the Master Plan assumed an overall irrigation efficiency of only 45 per cent – see other comparisons in Avery, S.T., 2012, p.62.

41 For more details on crop water requirements see Avery, S.T., 2012, Section 4.16.3, p.63-64, also Section 4.16.1, p.61.

Table 2: Lower Omo irrigation – potential annual water usage

Lower Omo: Kuraz annual irrigation @ 161,285 hectares

Percent Field Efficiency	Irrigation Category Method	Total Net Irrigation	Total Gross Irrigation	Gross Irrigation Water for 161,285 ha		Irrigation Demand % Omo
%		mm/yr	mm/yr	MCM/yr	m3/s	%
45%	Poor	2,110	4,689	7,562	240	43.9%
60%	Furrow	2,110	3,517	5,672	180	32.9%
70%	Sprinkler	2,110	3,014	4,862	154	28.2%
90%	Drip	2,110	2,344	3,781	120	22.0%

Lower Omo: Remaining "suitable" area, mixed cropping @ 47,370 hectares

Percent Field Efficiency	Irrigation Category Method	Total Net Irrigation	Total Gross Irrigation	Gross Irrigation Water for 47,370 ha		Irrigation Demand % Omo
%		mm/yr	mm/yr	MCM/yr	m3/s	%
45%	Poor	1,347	2,992	1,418	45	8.2%
60%	Furrow	1,347	2,244	1,063	34	6.2%
70%	Sprinkler	1,347	1,924	911	29	5.3%
90%	Drip	1,347	1,496	709	22	4.1%

Lower Omo: Combined 208,655 hectares (161,285 ha sugar + 47,370 ha mixed crop)

Percent Field Efficiency	Irrigation Category Method	Gross Irrigation Water 161,285 ha	Total Irrigation Water 47,370 ha	Combined Irrigation Water 208,655 ha	Irrigation Demand % Omo
%		m3/s	m3/s	m3/s	%
45%	Poor	240	45	285	52.2%
60%	Furrow	180	34	214	39.1%
70%	Sprinkler	154	29	183	33.5%
90%	Drip	120	22	142	26.1%

will be a small 'returnable' component of the losses, through drainage from the fields back into the river. This is not quantified here, since it is not critical in terms of this water balance. But it could be critical in terms of its potential to carry chemical pollutants back into the river or into the underlying groundwater table, both of which lead to the lake. The sugar factories will also require water, as will the thousands of migrant workers imported to run the schemes. But, these water demands pale into insignificance compared to the huge irrigation crop demand.

Note that the Kuraz scheme alone will require over 30 per cent of the Omo flow as a minimum and this rises to nearer 40 per cent when the 'remaining' area is included. The total requirement could easily reach over 50 per cent, which in magnitude is equivalent to almost half of the renewable surface water resource in the whole of Kenya.[42] The potential reduction of inflow to Lake Turkana is therefore huge, and far greater than previously reported. It should also be borne in mind that any increases in temperature with ongoing climate change will raise evaporation rates, and hence increase crop water requirements. Climate change models forecast increases in rainfall in these arid zones, but rainfall is very low anyway, and the increased rainfall volume is very small. Hence the long-term irrigation water demand is likely to increase, as will evaporation losses from the lake itself (Avery, S.T., 2012, p.66). The high evaporation associated with arid and semi-arid areas creates other challenges. It leads naturally to much more saline soils than in humid moist areas. Soil salinisation is exacerbated by ill-designed irrigation schemes (FAO, 1976). FAO has stated: "The introduction of irrigation is often considered a solution to the pressing problems of the arid and semi-arid regions. However, there are numerous examples of soils degraded and lost to production due to ill-conceived or poorly implemented irrigation schemes…". Soil salination is an escalating global problem associated with irrigation schemes in semi-arid areas but, without access to the Lower Omo scheme studies and designs, it is not possible to comment further on this.

We also need to consider the impact of land use changes on hydrology. The Omo Basin's Ethiopian population is forecast to reach 19m. people in the year 2024 (Woodroofe et al. 1996).[43] In the 30-year period since 1994, the population will more than double. Increasing population and associated agricultural needs have resulted in dramatic land use changes throughout Ethiopia, and in the upper and middle Omo Basin. People have migrated from the degraded highlands into the lowlands, a process actively promoted by the World Bank (2004a). Vegetation is being cleared with increasing use of river water for irrigation. The catchment

42 Kenya's average annual renewable surface water runoff is 654 m^3/s (JICA/NK, 2012 April). The Omo's average annual inflow to Lake Turkana from 1993–2011 was estimated to be 555 m^3/s (Avery, S.T., 2012, Table 59, p.213).

43 The population growth is tabulated in Avery, S.T., 2012, Table 15, p.79.

Figure 7: Cultivation with terraces to control runoff and erosion, Ethiopian highlands

Photo: Marco Bassi

Figure 8: Flood retreat agriculture in Kara territory, Lower Omo

Figure 9: Omorate, not far from the Omo delta

rainfall / runoff response is becoming faster. This means increased erosion risk, larger flood magnitudes, and declining low flows, resulting in an altogether less predictable hydrology, particularly affecting people in the lower basin (Avery, S.T., 2012, p.141).

The only way to reverse this process is through catchment management, the restoration of vegetation cover, and the complete protection of all riparian[44] zones, including prohibition of human activity within these zones. The laws of Kenya actually forbid any cultivation of riparian zones, but enforcement is well nigh impossible. Such areas are often utilised by people who have no other options. Thus flood retreat agriculture is practised in the Lower Omo and in the lower reaches of Kenya's Tana River. In the past, when population numbers were insignificant, the catchment degradation resulting from traditional riverbank agricultural practices was insignificant, but this has ceased to be the case in recent years. Ironically, the construction of storage dams provides the opportunity to

44 'Riparian', from the Latin *ripa,* meaning 'bank', refers to the edge or margins of a river or stream, or lake or ocean.

control the extremes of flow that are a consequence of careless anthropogenic activity, including riparian disturbance by commercial irrigation schemes.

This could be a short-term measure however, as without the enforcement of proper catchment protection, dam reservoirs rapidly fill with sediment, becoming progressively less effective, and thus can be relatively short-lived and costly investments. The construction of storage dams is a top priority in Kenya today. The country's ambitious goal is to increase total irrigated area 600 per cent by 2030 (NK/JICA, 2012). Climate change models predict a 20 per cent increase in Kenya's river flows in the same period (ibid.). The extent to which this extra water can be effectively harnessed is another matter, as extreme flood runoff will often occur when reservoirs are already full and spilling. It does, however, mean that greater volumes of water will reach the many regional lake sumps, offsetting (to an extent) losses through abstraction for irrigation.

Failure to learn from experience

It is remarkable that feasibility studies, impact assessments and resettlement plans for the Kuraz Sugar project and other irrigation schemes in the Lower Omo have not yet been released for public discussion and scrutiny. Countless studies of river-basin development – not least in Ethiopia itself – have shown that projects implemented in this way are likely to have tragic unintended consequences for people and the environment. Furthermore, it is contrary to the recommendations of the basin's Master Plan.

The main contractor, Salini Costruttori of Italy, was appointed without competitive bidding in a process described by the World Bank as lacking transparency (Mitchell, 2009). There was no detailed consideration of the impacts on Lake Turkana, and no consultation with potentially affected communities in Kenya. The so-called "Additional study on downstream impacts" (Agriconsulting et al., 2009) was initiated long after dam construction had started. Dam construction itself began without the prior approval of the Ethiopian Government's own Environmental Protection Authority (a requirement in Ethiopian law). In short, the project has been mired in controversy since it began. The World Bank, the African Development Bank and the European Investment Bank all declined to give it direct financial support, but in July 2010 the Industrial and Commercial Bank of China came forward with a loan of $450 million to cover the cost of the dam's turbines, to be supplied by a Chinese company, the Dongfung Electric Corporation.

The hydropower and irrigation schemes will drastically alter river hydrology, making dramatic changes in local livelihood practices inevitable. The terms of reference for the Master Plan included provision to "…plan and implement the essential transformation of the socio-economic system" of the local population, although what exactly was meant by "essential transformation" was not explained (EVDSA, 1991). The Master Plan included a raft of recommendations and a 'social study' which cited conflicts over the implementation of the Ethio-Korean Joint Venture farm in the Lower Omo (Woodroofe et al., 1996). It noted that "… there were major disturbances…people were not consulted…people were not compensated when land they viewed as theirs was annexed…" (Avery, S.T., 2012, p.22). The Ethio-Korean scheme was abandoned in 1991 (SOGREAH, 2010, p.39).

The above statements in the Master Plan are mirrored by complaints being made today. Over the past two years there have been persistent accusations, coming from campaigning organisations and others, of human rights abuses in the Lower Omo - essentially the forced eviction of people from their land without consultation or compensation (e.g., Human Rights Watch, 2012; Oakland Institute 2013; Turton, 2012(a) and 2012 (b)). If these reports are correct, the lessons of past experience – some of them documented in the Master Plan itself - are being systematically ignored in the implementation of river-basin development in the Omo Valley.

Sunset over Lake Turkana from North Island

Photo: Kieran Avery

The impact on Lake Turkana of regulated and reduced Omo flows

Water balance and flow duration curves

To assess the impact of future developments in the Omo Basin on Lake Turkana, one needs to know the current rate of lake inflows from the Omo. Records exist for the Omo's daily discharge (rate of flow) at Omorate, not far from the Omo delta, but only from 1977 to 1980. In the absence of continuous river inflow records, the 1996 Master Plan study developed a rainfall/runoff model, which simulated river discharges using available rainfall data from 1956 to 1994. In 2006, the Gibe III dam design team also used a rainfall/runoff model to derive flow sequences at the dam site. In my reports for the African Development Bank and the African Studies Centre at Oxford, I developed a water balance model using an entirely different approach. Since 1992, lake levels have been monitored using satellite radar altimeters traversing the middle of the lake at 10-day intervals. These data make it possible to generate lake inflow discharges directly from changes in the lake level.

The lake water level is the outcome of a water balance between additions to the lake and losses, as depicted in Figure 10 and in the following simple equations:[45]

Volume Change = Omo Flow + Rain + Other River Flow – Evaporation – Seepage Loss

∴ Omo Flow = [Volume Change] – [Rain + Other River Flow – Evaporation – Seepage Loss]

It follows that:

If [All River Inflows + Rain] > [Evaporation + Seepage Loss], the lake level **RISES**

If [All River Inflows + Rain] < [Evaporation + Seepage Loss], the lake level **FALLS**

The water 'addition' is the sum of river inflows and direct rainfall on the lake surface. The Omo alone provides over 90 per cent of the addition. The 'other rivers' add about 1.6 per cent.

45 Note that, in the equations, rain refers to 'lake rain', this being the rainfall on the actual lake water surface, not the land catchment. Similarly for evaporation.

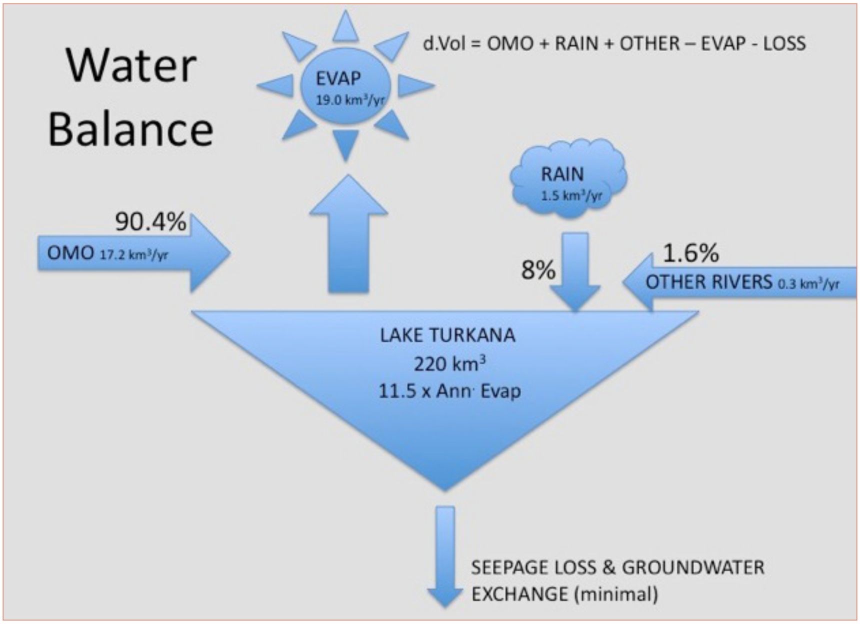


Figure 10: Lake Turkana water balance model

(Avery, S.T., 2012, p.208)

Since the lake is a closed basin with no outflow, the water 'subtraction' is the relentless surface evaporation loss, with the entire lake volume evaporating in 11.5 years. There will be some groundwater movement into and out of the lake, but the quantity is unknown, and by default, this factor is integrated within the computed daily evaporation loss. In any case, scientific studies have determined seepage losses to be minimal (Yuretich and Cerling, 1983). The daily evaporation loss from the lake surface was assessed by various methods, including measuring the daily drop in lake level at times when there are no known water additions - i.e., when Omo River inflow is negligible or zero (Avery, 2012, p.129-133; Hopson et al., 1982). The lake surface rainfall was estimated using data from the Meteorological Station at Lodwar, west of the lake. This input accounts for 8 per cent of the lake water addition.

The simplest form of river flow analysis is the 'flow duration curve', which shows the relationship between any given flow and the percentage of time the flow is exceeded (Institute of Hydrology, 1980). In Kenya, for example, the river flow that is exceeded 95 per cent of the time is often adopted as the flow that must be left untouched in any river to meet downstream river needs, which include 'basic human needs' defined in Kenyan legislation as 25 litre/capita/day (WRMA, 2012). Analysis of flow duration curves for the Omo River at Omorate confirms that, as predicted in the Master Plan, the Omo's 'natural' low flows are insufficient to sustain large-scale commercial agriculture (Avery, S.T., 2012, p.218-219). These flows are even more critical today, due to changes in the Omo catchment and abstractions to meet water demands along the river. Without Gibe III, then, the irrigation schemes now being implemented in the Lower Omo would, as expected, not be feasible (ibid.).

Gibe III's dampening effects and the potential destruction of fisheries

About 67 per cent of Lake Turkana's inflow will pass through Gibe III. Hence this portion of the flow will no longer follow natural hydrological cycles, but will instead be a controlled flow, released through turbines. The remaining 33 per cent of the flow will be contributed by the residual catchment, downstream of Gibe III between the dam and the lake. This 'residual' will preserve a degree of natural flow variability, but only until the downstream Gibe IV and Gibe V schemes are implemented. Gibe IV is planned to entail a huge reservoir, similar to Gibe III. Hence, when all three dams are in operation, virtually the entire inflow to Lake Turkana will be regulated and will thereby lose altogether its natural variability.

Figure 11 shows the average monthly rate of flow for inflows to the lake, before Gibe III ('natural hydrograph') and after Gibe III ('regulated hydrograph'), as presented by the project consultants (Agriconsulting and Mid-Day, 2009).[46] The average monthly rate of flow is dampened to the extent that for 10 months of the year, there is little change in monthly discharge. The high inflow months (July-September) will have diminished flows, whereas the average low flow of less than 200 m^3/s will be raised to a minimum of 500 m^3/s minimum. In the 'before Gibe III' scenario, the average peak monthly flow is over 8-times the lowest monthly flow, whereas in the 'after Gibe III' scenario, the ratio falls to just over twice the lowest monthly flow, a quarter of what it was before. The consequent 'dampening' impact on the lake level of the proposed 'average year' regulation regime introduced by Gibe III is shown in Figure 12. Based on average monthly flows, the typical 1,100 millimetres lake-level rise and fall cycle is 'dampened' to 700 millimetres. This could have a potentially devastating effect on the lake's fisheries.

A belated assessment of the impact of Gibe III on Lake Turkana levels was produced by the dam builder (Salini, 2010). The methodology was similar to that of my draft

46 The key measure belatedly introduced in this document to mitigate the downstream impact of the dam was a 'controlled flood', to last ten days annually in September. This could only have been contemplated because the Gibe III project documents overlooked the likely scale of irrigation development in the Lower Omo. The proposed 'controlled flood' has since become redundant because it would be regulated by, and potentially damage, the extensive irrigation and associated infrastructure needed for the Kuraz and other irrigation schemes.

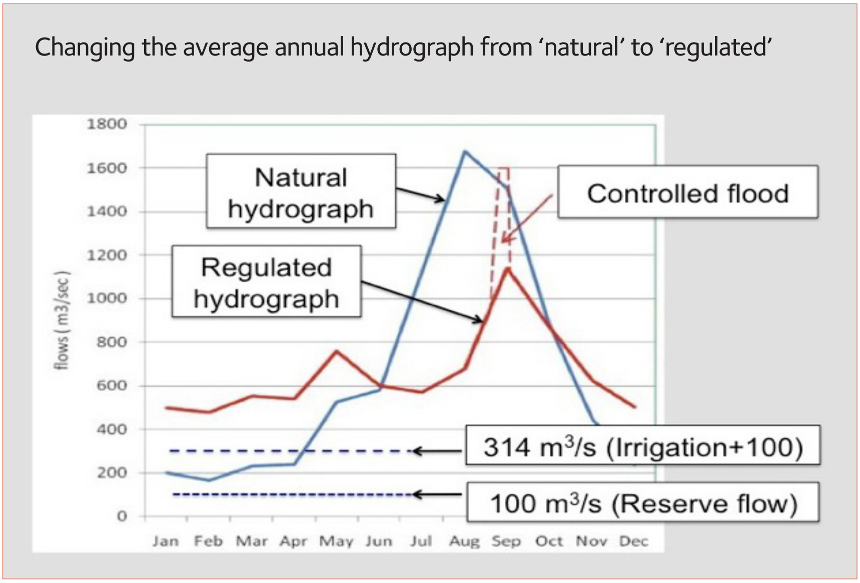


Figure 11: Proposed regulated flow sequence from the Gibe III dam

(Based on Agriconsulting and Mid-Day International, 2009)

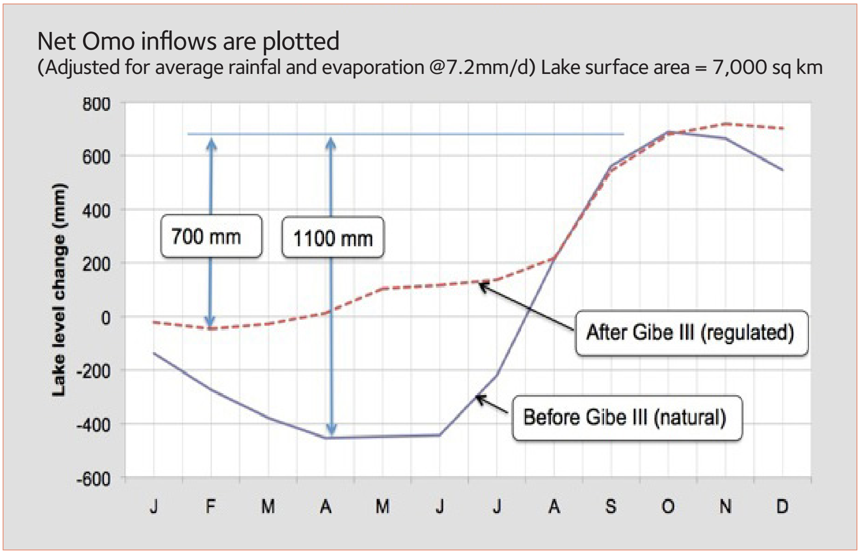


Figure 12: Dampening effect of Gibe III and lake level changes

(Avery, S.T., 2012)

AFDB report, and the timing pre-empted my final report.[47] This Salini report stated "…the lake area is barely inhabited" (ibid., p.2), which was presumably meant to imply that impacts will be of little consequence. The report concluded that "Gibe III will sensibly reduce the lake level fluctuations…" and "…may benefit the lacustrine environment" (ibid.). These statements are diametrically opposed to the views of fisheries experts, discussed below, and clearly demonstrate little understanding of the ecological driving forces of this particular lake.

In the tropics, 'flood plain' fisheries are reportedly the most productive (Welcome, 1979 and Junk et al., 1989, both cited by Kolding & Zweiten, 2012). Studies have shown that productivity increases with instability, that lake level changes promote interaction between aquatic and terrestrial systems (Kolding, 1994) and that annual fluctuations in lake level are very much more significant than absolute lake levels (Karenge and Kolding, 1995). Lake Turkana's peak production rates have been associated with peak rises in lake level, with declining production rates associated with falling lake levels (Kolding, 1992). Lake Turkana "is seemingly in a perpetual state of change", with fish yields, species composition and main fishing grounds recurrently undergoing unpredictable and drastic transformations (Kolding, 1992, p.33). The lake is "an unstable ecological system with the biological processes highly geared to the hydrological regimes" (ibid., p.23). This makes it very different – indeed unique – when compared to other African Great Lakes (ibid.).

Ecologists recognise that diversity is a consequence of change and variability. Hence regulation of the Omo river flow, which dampens the natural river and lake level cycles, as well as the speed at which the changes would otherwise occur, could destroy the existing flood plains ecology and fisheries. This is the widely held view of fisheries experts such as Kolding, Ojwang et al., Mbogo, Muska and others. As far back as 1992, Kenya's National Water Master Plan warned that increasing abstractions from the Omo might reach the point where the fisheries will collapse (MoWD, 1992b). In 2009, a scientific team that undertook hydroacoustic surveys of the lake presented a paper depressingly entitled "A last snapshot of natural pelagic fish assemblage in L.Turkana" (Muska et al., 2012). None of the above experts would agree that reducing lake level fluctuations, given the unique ecology of this lake, is "sensible".

Gibe III filling period and losses during operation

The filling of the Gibe III reservoir will detain river flows that would otherwise have passed down river to the lake. Hence Lake Turkana's water level will be

47 A review is included in Avery, S.T., 2012, Section 3.7, p.34-35.

reduced during this filling period, the lake will be deprived of nutrient inflows, and the subsequent lake level cycle will be permanently altered. The reservoir's gross storage capacity will be 14.690 cubic kilometres (inclusive of dead storage[48]), and seepage into the banks during filling was estimated to be up to 1.568 cubic kilometres (Salini & Studio Pietrangeli, 2007). Hence the total water volume required to fill the reservoir is 16.26 cubic kilometres. This equates to about one year's inflow volume into Lake Turkana, and is equivalent to the volume stored in over two metres depth on the entire Lake Turkana surface (Avery, S.T., 2010, p.211).

It is planned to fill the Gibe III reservoir over a period of up to three years, depending on how wet it is, but at the same time to ensure an 'ecological flow' of 25 m^3/s and to release an 'artificial flood' of 1,000 m^3/s in September each year (see Figure 11 and Footnote 46). The impact on the lake of the specified filling rules is shown in Figure 13, superimposed on the natural lake levels between 1993 and 2012. It can be seen that the level would have dropped up to two metres below the natural lake level, and would then have recovered under regulated flow release conditions, being substantially restored after 16 years, but still rising until equilibrium is achieved. Hence, the filling of Gibe III alone will draw the lake level down and dampen the annual cyclical changes, albeit with the lake level ultimately being restored. Meanwhile, the 25 m^3/s flow release is pitifully small, and the distance to the lake so great that one wonders how far it will reach. As we shall see shortly, once irrigation abstractions are added to the water balance model, a much more dramatic picture emerges.

The Gibe III design team claimed that, as a consequence of the regulation of flows by the dam, Lake Turkana will enjoy a "positive" water balance (Agriconsulting S.p.A & Mid-Day, 2009). It is of course true that a hydroelectric power scheme does not 'consume' water but stores it within a reservoir impounded by a dam, and then releases controlled flows downstream through the dam's turbines and sluices. But merely by storing water, the probability of water losses and change in water quality is introduced - a large lake is created, nutrients are deposited and lost, there are seepage losses underground, and additional evaporation losses occur.

The dam will be 243 metres high and the reservoir will thus impose 243 metres hydraulic pressure. Apart from the real possibility this raises of seismic effects, it has been claimed that underground seepage losses of up to 75 per cent could

48 Dead storage is so called because this is the bottom portion of a dam's reservoir that is set aside for accumulating sediment deposits below the dam's lowest outlets. It is 'dead' because it is not otherwise utilised. The balance of the reservoir storage to the water surface is termed 'live storage'.

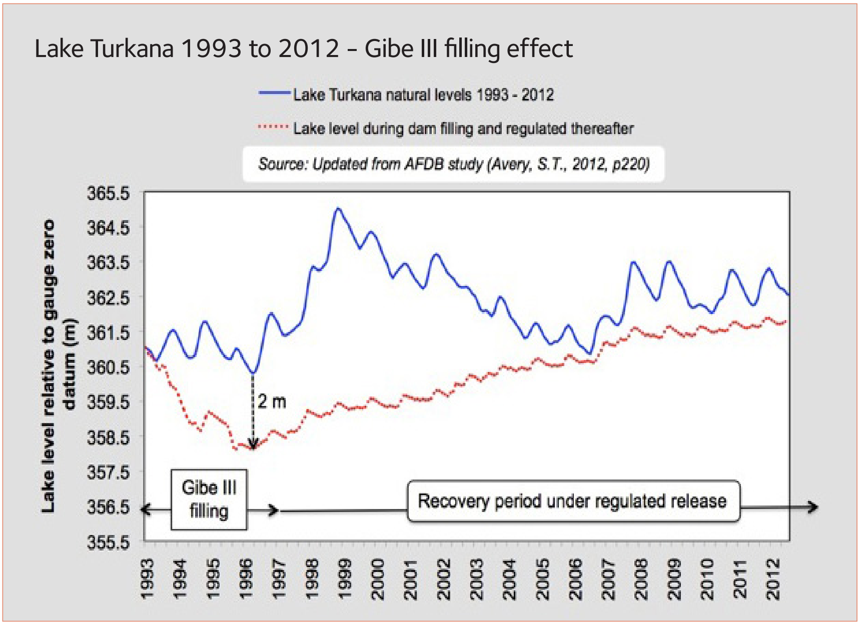


Figure 13: The effect of Gibe III filling

(Avery, S.T., 2012, p.220)

occur (African Resources Working Group, 2009). Although some seepage is inevitable, this is a very high figure which I have yet to see substantiated. For its part, the dam's design team undertook further geological site investigations of both the dam site and reservoir basin (Salini and Studio Pietrangeli, 2007), and remained of the view that no appreciable seepage losses would occur (Pers. Comm. Studio Pietrangeli, 2010). If such losses did occur, furthermore, it was argued that the topography would ensure that the water would feed back into the Omo River basin, and thus would not be 'lost'.

It has also been claimed by the dam builders that reservoir evaporation losses will be offset by reduced evaporative losses downstream. It is true that, if the regulation of the river flow eliminates inundation of the downstream flood plain and oxbow lakes, evaporation due to such flooding will also be reduced. The implementation of large-scale irrigation, however, will totally reverse the "positive" hydrological balance claimed by the dam builders.

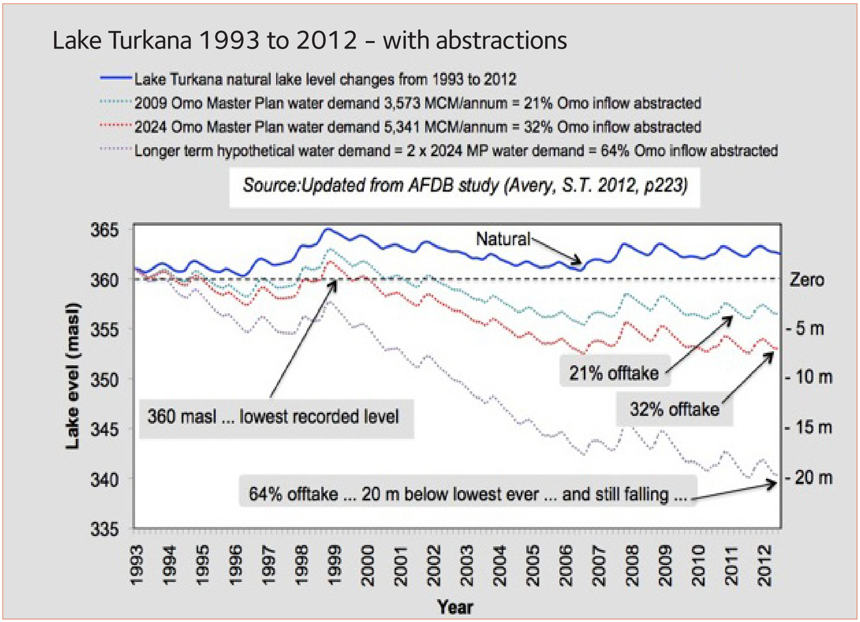


Figure 14: Lake level falls for various abstraction rates, 1993–2012 flows
(Avery, S.T., 2012)

Irrigation abstractions – a permanent lowering of the lake

There is no doubt that the main future water demand in the Omo basin is going to come from large-scale commercial irrigation development. The impact of various projected water demands on the natural lake level sequence since 1993 is shown in Figure 14. This is a monthly data series, covering the period for which satellite radar altimeter lake levels are available. The lake level rose slightly over this period, boosted by exceptional inflows during the 1997/98 El Nino floods. Three levels of demand are considered: (a) 21 per cent of Omo inflow (the Master Plan's projected demand for 2009); (b) 32 per cent of Omo inflow (the Master Plan's projected demand for 2024); and (c) 64 per cent of Omo inflow (double the Master Plan's projected demand for 2024). It can be seen that the 2009 and 2024 water demand abstractions would have both reduced the lake to well below its lowest recorded level of 360 metres above sea level. Note that the simulated falling lake levels do not reach equilibrium during the graph's time period, and are still falling in 2011.

Figure 15 shows the impact on lake level of two abstraction rates (32 per cent and 64 per cent of Omo inflow respectively) for the period 1888 to 2011. This is an average annual data series, so monthly fluctuations are smoothed. At the 32 per cent abstraction rate, the lake's simulated level falls up to 20 metres below the lowest recorded. (Note

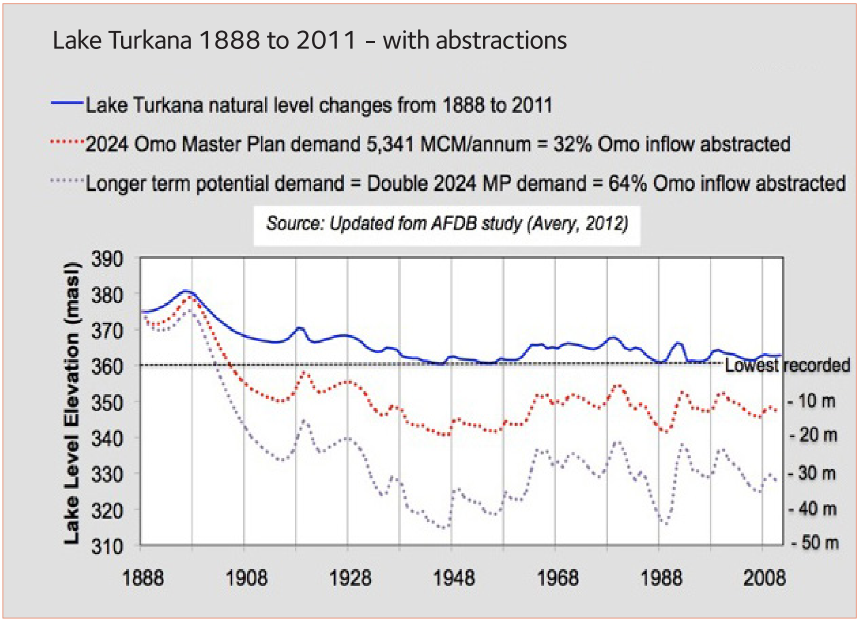


Figure 15: Lake level falls for two abstraction rates, 1888-2011 flows
(Avery, S.T., 2012, p.223)

that the 32 per cent abstraction is less than that which is likely to result from the Kuraz sugar project abstractions alone, as shown in Table 2 above.) Ferguson's Gulf would become permanently dry, the water table throughout the lake surrounds will be drawn down, and this will in turn draw down the levels in all the lake's hydraulically linked wetlands, such as the crater lakes on Central Island, and the crater lake and ponds at the southern end of Lake Turkana. At the 64 per cent abstraction rate, the lake's simulated level is up to 45 metres below its lowest ever. If we bear in mind that the lake's average depth is roughly 30 metres, this is clearly an alarming prospect.

Using a steady state water balance model, we can predict that, if 39.1 per cent of Omo water is removed for irrigation (at 60 per cent irrigation efficiency), (a) the lake level will fall 16 metres below its steady state equilibrium level of 363 metres above sea level; (b) its volume will reduce to 57 per cent of its sustainable equilibrium volume, thus losing 43 per cent of its biomass holding volume; and (c) its fisheries will be hugely reduced. If 52.2 per cent of the Omo flow is abstracted (at 45 per cent irrigation efficiency), the lake will fall 22 metres and its volume will be reduced to 41 per cent, thus losing 59 per cent of its biomass holding volume. The potential long term ecological changes resulting from irrigation abstractions are, to say the least, considerable.

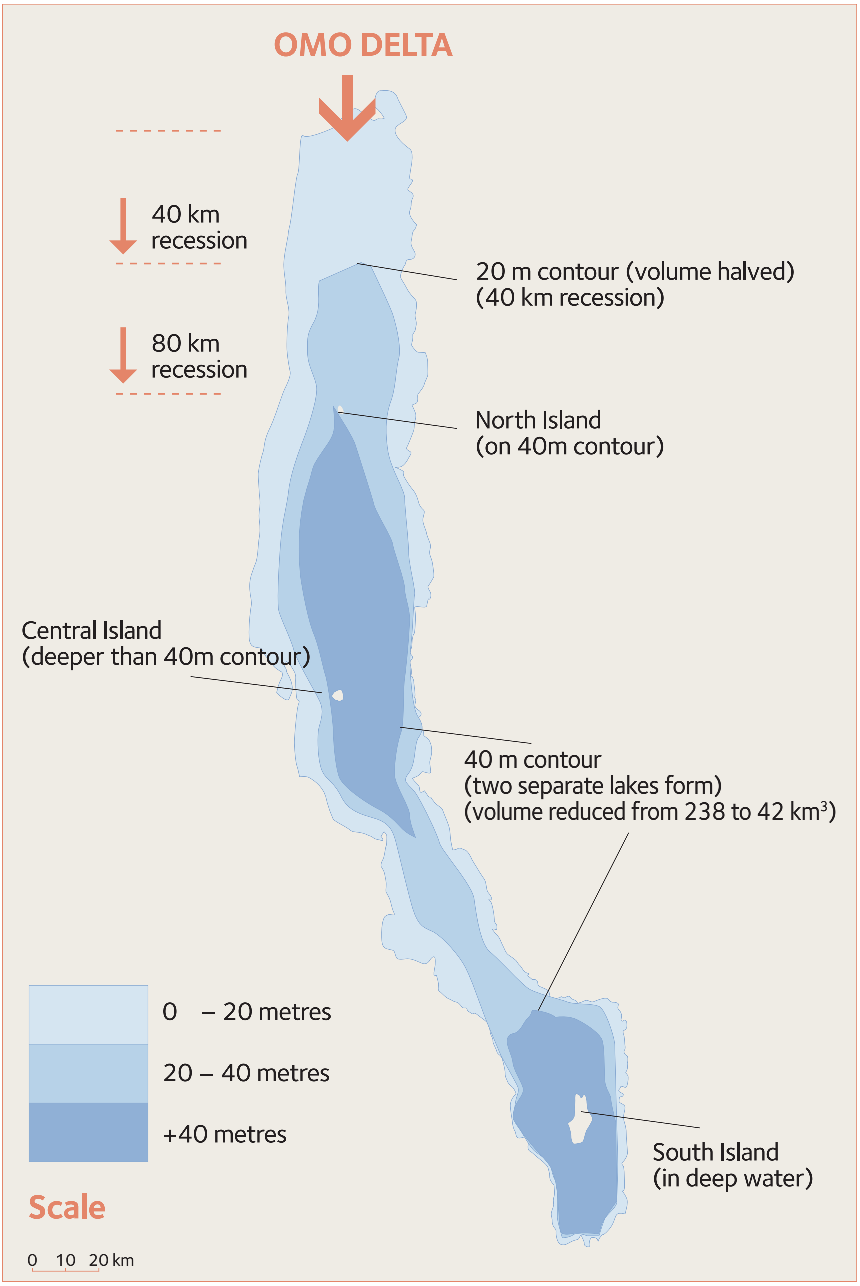


Figure 16 : Lake Turkana – an African 'Aral Sea' in the making?

(Avery, S.T, 2010, p. 2-37, based on hydrographic survey data from Hopson et al., 1982))

What future for Lake Turkana?

Gibe III and the two major reservoirs still to be built further downstream will intercept and store river flows, and will trap nutrients, altering water quality. The dams will thereafter release flows in a controlled manner,[49] changing forever the natural flood cycles upon which the ecology and the local population has always depended. The Omo provides over 90 per cent of Lake Turkana's freshwater input and nutrients. The fisheries breeding cycle is triggered by the Omo's seasonal floods. Although the Gibe III designers proposed an annual artificial flood release for ecological purposes, no adequate scientific basis for this was established in the project documentation. In any case, such measures will be made redundant by future downstream dams and by the need to protect all major capital irrigation investments from damage by floods. The regulation of the natural hydrological river flow cycle will permanently alter the present flood plains ecology, with catastrophic consequences. In addition, over 30 per cent of the lake's Omo inflow will be abstracted for irrigation alone, and the lake level will inevitably drop 20 metres or more. The lake biomass volume will reduce, as will the dependent fisheries. Ultimately, the lake could reduce to two small lakes, the northern one fed by the Omo, and the southern one by the Kerio and Turkwel rivers (Figure 16). Hence the fear that Lake Turkana could become Africa's Aral Sea (Avery, S.T., 2013).[50]

Does any of this matter? Some might consider the lake no more than a picturesque evaporation basin and that it is better to store the fresh waters in the cooler upper basin for alternative use. The international donor community appears to have taken this view. The Omo Basin Master Plan (financed by

49 These "controlled" releases can result in flow surges down the river as turbines are brought on line, and this raises public safety issues, especially for people crossing the river, by boat or on foot, and also potential riverbank erosion (Sogreah, 2010, p.76).

50 It is worth noting here UNEP's observations on the environmental consequences of the destruction of the Aral Sea in Central Asia, especially the impact on surrounding pastures and cultivated areas of wind-blown salts from the exposed lake bed (UNEP, 2008). Lake Turkana's lake bed holds salts deposited over thousands of years. What will be the consequence when these are exposed by the receding lake, and then blown onto pastures and farms by the lake's strong winds?

the African Development Bank) did not include consultations with Kenyan stakeholders and the threats to Lake Turkana's fisheries were dismissed in words which conveyed a depressingly defeatist attitude towards the lake's fisheries: "…the lake is already over-fished and reductions in [fish] yield are likely no matter what developments take place in the Omo-Gibe basin…" (Woodroofe et al, 1996, Vol XI, F1, p.84). The World Bank has been equally dismissive of the lake's importance to the regional economy, stating: "…While most of the lake lies within Kenyan territory, that is a sparsely inhabited semi-desert pastoralist region with no significant use of the lake's waters. It should therefore be relatively easy to negotiate 'no objection' from Kenya should that be required for multilateral/bilateral funding. Assuming a multi-purpose (hydroelectric / irrigation) dam / dams on the Omo, Kenya could also benefit from it..." (World Bank, 2004b, p.6, Para 3(i)). I am not aware of any ecological and socio-economic studies of the lake undertaken by the World Bank before it made these pronouncements.

Recent reports by UNESCO of vast underground aquifer finds west of Lake Turkana might be thought to diminish the importance of the potential demise of the lake. These aquifers are estimated to have a total storage capacity of 250 billion cubic metres - enough to support Kenya's present population of 41 million for seventy years before the resource is completely exhausted (Radar Technologies International, 2013, pp.60-61). One of these aquifers, the Lotikipi Basin Aquifer, is even said to offer the prospect of becoming the 'New Lake Turkana', since its storage volume is equal to that of Lake Turkana today and it offers fresh rather than saline water (ibid. p. 73). But, apart from being underground and therefore costly to exploit, these ancient aquifers have a recharge rate which is described as "considerably weak". For this reason, the "extraction of water from these structures should be done with great caution to prevent over-exploitation" (ibid., p.11).

In fact, the total renewable yield of the recently discovered aquifers amounts to 107 cubic metres per second, which equates to just 20 per cent of the Omo's annual runoff into Lake Turkana - enough to supply 69 per cent of the Kuraz sugar plantation's annual water requirements. These are sobering figures, particularly when we consider the vast irrigation water requirements needed to support crop agriculture in these arid areas where evaporative losses are so great that water is virtually 'hung out to dry'. It also needs to be remembered that the total Omo flow alone is equivalent to 85 per cent of Kenya's entire renewable surface water resource. The responsible utilisation of the Omo's transboundary water resources clearly remains a regional priority, and the recent aquifer finds will hopefully not distract attention from this priority. It is a matter of the utmost urgency, therefore, that the feasibility studies and impact assessments which have presumably been carried out for the Lower Omo agricultural developments – particularly for the Omo-Kuraz Sugar Development Project[51] - are shared and discussed with all stakeholders.

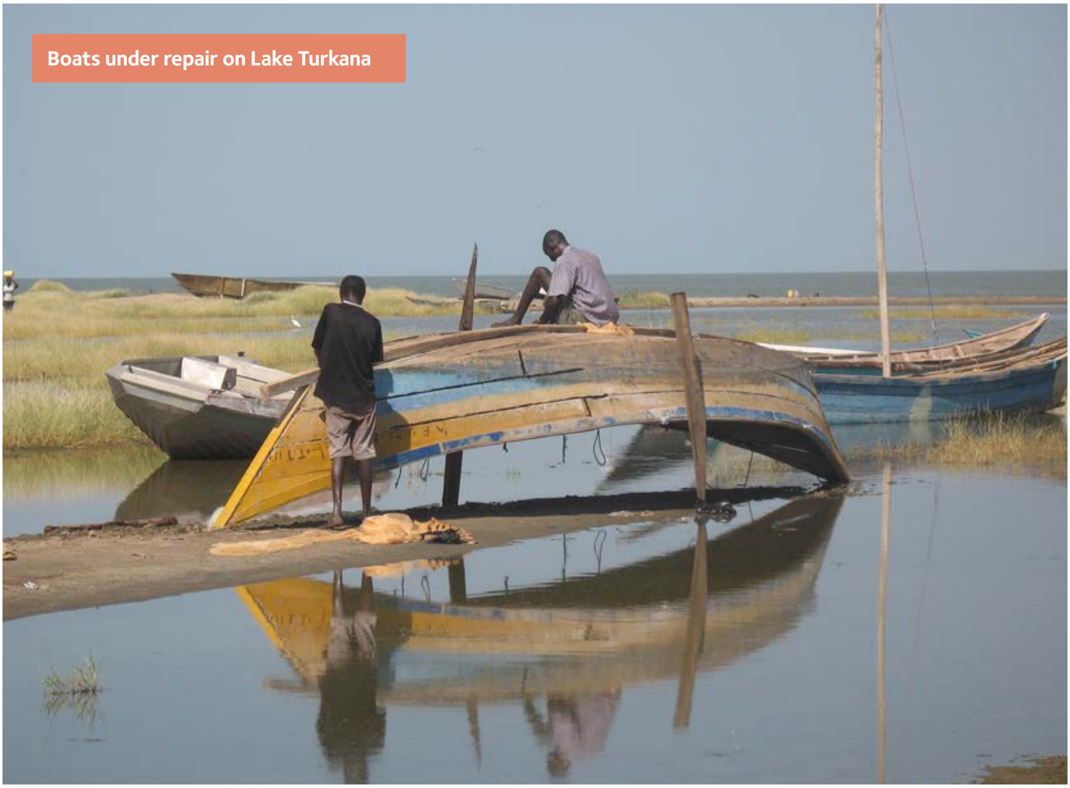
Many other questions, which are beyond the scope of this paper, remain to be answered. Will Ethiopia come to regret, for example, the destruction of its wildlife heritage in the Lower Omo? How will recent oil finds affect the socio-economic and environmental dynamics of the area? Will the contribution of sugar production to the Ethiopian economy justify the forced displacement of thousands of agro-pastoralists and the destruction of Lake Turkana's unique ecology and fisheries? Will the increased pressure on local livelihood systems in the Lower Omo and around Lake Turkana lead to new levels of intergroup violence, in an area already prone to conflict?[52] And how will the people of the Lower Omo be affected by the vast irrigation schemes that will take over their land? Will their socio-economic circumstances be transformed for the better, as the government predicts, or will they be locked into a life of grinding poverty, dependent on food aid and, if they are lucky, poorly paid seasonal work in the sugar plantations? In short, what specific steps will be taken to ensure that river-basin development in the Omo Valley does not become yet another "disgracing stain on development itself" (Cernea, 2008, p.1)?

There is no evidence that either the Ethiopian Government, or its advisers and donors, have seriously considered these questions. Until they do - and with full transboundary consultation - we are entitled to considerable misgivings about what the future holds for the people, ecology and environment of the Lower Omo Valley and Lake Turkana.[53]

51 As yet, no impact assessments, feasibility studies or resettlement plans for the Kuraz project have been released for public discussion.

52 The possible regional and international political consequences of river-basin development in the Omo Valley are discussed in an anonymously authored paper published by International Rivers (2013).

53 As this paper was being prepared for the printer, it was announced that trans-boundary consultations have been in progress, co-ordinated by UNEP, and that a consultation agreement between Ethiopia and Kenya could be signed in November 2013 (Voice of America http://www.voanews.com/content/kenya-ethiopia-mediating-omo-river-water-controversy/1770973.html). We can only hope that this process will involve all stakeholders, including the affected people, that it will draw on regional expertise and that it will be enacted swiftly.


Boats under repair on Lake Turkana


Lake Turkana's rugged south-western shore from South Island

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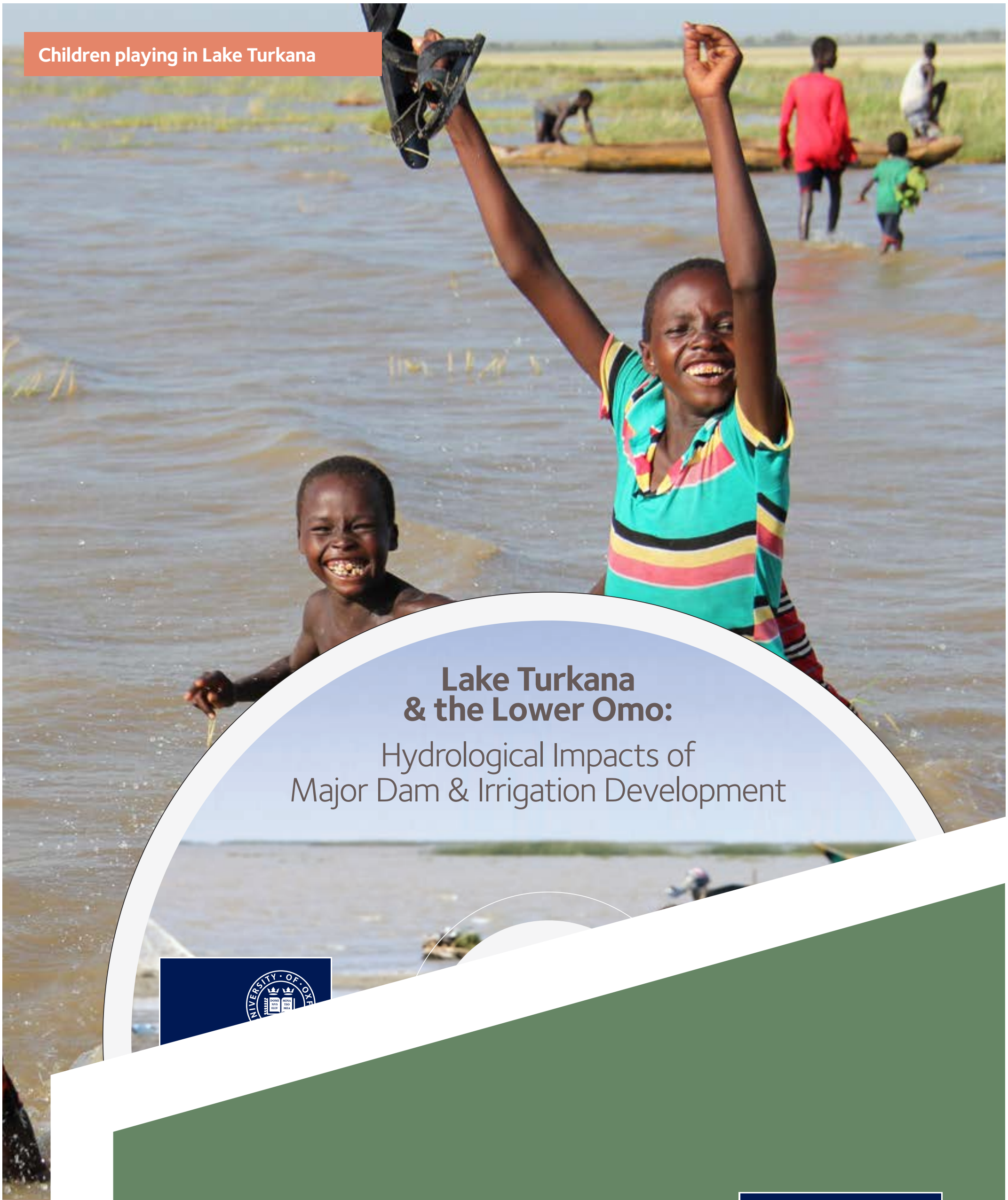

Children playing in Lake Turkana

Photo: Kieran Avery

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