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Confronting climate variability and change in Djibouti through risk management

R.L. Wilby
Department of Geography, Loughborough University, UK

S. Mora
Engineering Geologist, Consultant to the World Bank, Costa Rica

A.O. Abdallah
Ministère de l'habitat, de l'urbanisme, de l'environnement et de l'aménagement du territoire, Djibouti,

A. Ortiz
Sr. Urban Economist, The World Bank

ABSTRACT: The observed annual mean temperature range, maximum relative humidity, atmospheric pressure and sea level have all increased in Djibouti, a coastal country in north-east Africa; projected precipitations show a tendency for more frequent and heavier rainfall. Even in the absence of climate change Djibouti faces water scarcity as a consequence of rising demand and falling supply. Djibouti-ville is vulnerable to periodic drought, fluvial-flooding and coastal inundation. Without appropriate management, exposure is expected to increase under climate change. Therefore, it makes sense to identify robust strategies that address the vulnerability now and in the future while at the same time contributing to the reduction of poverty. Given the dependency on service industries and natural resources, the livelihoods and the economy of Djibouti are highly vulnerable to climate variability; climate change is expected to exacerbate this situation through incremental rises in temperature, sea level and eventually by more frequent extreme weather events. This could mean that new infra-structure and development efforts might fail to achieve their intended benefits. Improved integration of climate hazards information within planning process will yield more reliable decision-making. Institutional and sectoral structures should be put in place to deliver "low-regret" risk management programmes and projects through measures that address the needs of present vulnerability and build resilience for the future.

1 INTRODUCTION

The scientific consensus voiced through Working Group I of the Fourth Assessment Report (FAR) of the Intergovernmental Panel on Climate Change (IPCC) asserts that "…*warming of the climate system is unequivocal*…". Evidence of human influence is beginning to be discernible at continental scales in some temperature and wind records. Even if emissions of greenhouse gases were kept constant at year 2000 levels, the slow response of the oceans will result in further warming of ~0.1°C per decade over the next few decades. Furthermore, climate model projections indicate that decadal-average warming by 2030 is insensitive to the choice of emission pathway and is very likely to exceed natural variability's extremes. Precipitation is projected to increase at high-latitudes and decrease over most subtropical land regions. However, there is less certainty about regional precipitation because of a lack of both reliable baseline data and climate model consensus for large parts of Africa, Asia and South America. Overall, climate models suggest that East Africa could become wetter during the boreal winter (December–February) and autumn (September–November).

The economies and livelihoods of peoples in Djibouti are already vulnerable to climate variability because of their high dependency on water resources and exposure to hydro-meteorological hazards. Climate change is expected to exacerbate this situation through incremental rises in temperature and sea level, as well as by more extreme weather events such as droughts and floods (Fig. 1). An intensification of climate hazards could mean that new infrastructure or development programmes might fail to realise their intended benefits (Wilby 2009). Therefore, improved integration of hazards information within development programmes will depend on greater access to and uptake of high-quality data characterising climate variability and change. Credible scenarios are needed at the spatial and temporal scales relevant to decision-making (Wilby et al. 2009) as well as technical capacity to undertake vulnerability assessments. Institutional and sectoral structures must also be in place to deliver "low-regret" development programmes and projects; that is, measures addressing the needs of the vulnerable now, and making them resilient to the uncertainty inherent to projections of future climate hazards.

2 CLIMATE HAZARDS IN DJIBOUTI

2.1 *Hydro-climatologic features in Djibouti*

Climate in Djibouti is largely controlled by migrations of the Inter-Tropical Convergence Zone (ITCZ) and the Arabia and Libya anticyclones. These result in two distinct seasons: a relatively cool period between October and April and a hot dry period between June and September (Fig. 2, left). Rainfall is concentrated in two seasons, with maxima around October–November and March-April, but only exceeding 200 mm/yr in the mountains of Tadjourah. The seasonal pattern of rainfall has remained relatively stable between successive 30-year periods (Fig. 2, right).

Mean annual rainfall in the vicinity of Djibouti-ville is ~150 mm/yr. Observed monthly precipitation totals at Djibouti airport show an October–November maximum and June minimum (Fig. 3, left). Annual precipitation totals exhibit large inter-annual variability, compared with a modest increase of just ~20 mm over the period 1901–2000 (Fig. 3, right) mainly due to higher totals in April–May. However, there is statistically significant evidence of a change in precipitation seasonality: the wettest month shifted from November to October between the first and second halves of the 20th century. July-September (JAS) precipitation totals at Djibouti airport fell by 20 mm during 1950–1999. However, October–December (OND) (wet season) precipitation totals increased by 30 mm during the same period and overall annual totals increased by less than 10 mm. Corresponding changes in the Tyndall

Figure 1. Flooding of Djibouti-ville by Oued d'Ambouli in April 1994. This event claimed the lives of 200 people and caused significant damage to infrastructure and agriculture. Photo by Mohamed Jalludin.

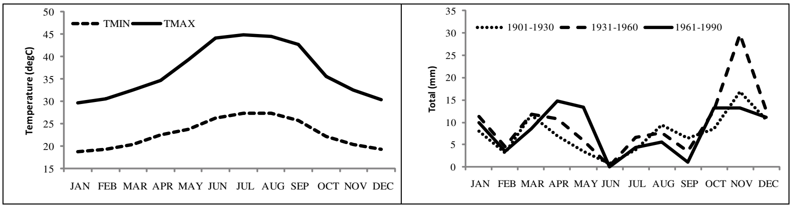

Figure 2. Left: Monthly mean daily minimum (TMIN) and daily maximum (TMAX) temperatures at Djibouti airport 1961–1990. Right: Mean monthly precipitation totals estimated for the same site using 30-year periods: 1901–1930, 1931–1960, and 1961–1990 (Wilby 2009).

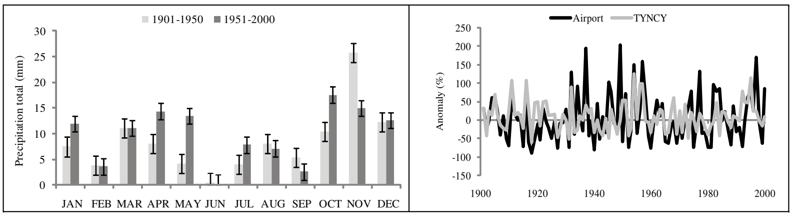

Figure 3. Left: Monthly precipitation totals. Right: annual precipitation anomalies. Djibouti airport, 1901–2000. Data: KNMI Climate Explorer and TYNCY country summary (Wilby 2009).

Centre country average (TYNCY) were –90 mm (JAS), –90 mm (OND) and –10 mm (ANN). These variations serve as a cautionary reminder of the fallibility of trend analysis based on a single station.

2.2 *Climate hazards*

2.2.1 *Climate variability*

Global, regional and local processes are influenced by El Niño/La Niña-ENOS, the Inter-Tropical Convergence Zone, polar thrusts and tropical cyclones. They all produce space-time variations of rain and wind intensities (e.g. *khamsim*) and seasons. Djibouti is exposed to: i) multi-year droughts that compound the effects of the natural aridity of the climate, exacerbating water scarcity; ii) flash floods with attendant loss of life, impacts on livelihoods and damage to infrastructure; and iii) fires fuelled by the extended dry periods. There are very little data for long-term trend analysis, even of annual precipitation totals, for much of the Middle East and North Africa (MENA) region, including Djibouti. Observed monthly climate data for Djibouti were obtained from three main sources: 1) meteorological observations for 1961–2007 by Djibouti's Service de la Météorologie's station at the airport (Fig. 4); 2) a country summary for 1901–2000 based on the Climatic Research Unit's 0.5° global gridded data set (TYNCY) (http://www.cru.uea.ac.uk/~timm/cty/obs/TYN_CY_1_1.html) and; 3) a few pre-1960 meteorological records (for Djibouti airport and Aden, Yemen) distributed by the KNMI Climate Explorer of the Royal Netherlands Meteorological Institute (http://climexp.knmi.nl/getstations.cgi).

Records of flood duration and volume were provided by the Centre d'Études et Recherches de Djibouti (CERD) for Oueds d'Ambouli (1980–1987) and Ouéah (1980–1990). Floods were matched to indices of atmospheric circulation, humidity and stability obtained from the National Centre for Environmental Prediction (NCEP) re-analysis via the Canadian Climate Impacts Scenarios (CCIS) portal: http://www.cics.uvic.ca/scenarios/sdsm/select.cgi. Although the flood events coincide with higher than average specific and relative humidity, the atmospheric anomalies were not statistically significant. This suggests limited predictability from atmospheric state alone. The flood series of Oueds d'Ambouli and Ouéah were used to estimate return periods using the Generalised Extreme Value (GEV), Gumbel and

Log-normal distributions (Fig. 5). Peak discharges (m³/s) were derived from the flood volume and duration assuming a triangular hydrograph. With less than 10 years of data, estimation of longer return period events is highly problematic. Anecdotal evidence suggests that an event of the magnitude experienced on 12–13 April 2004 last occurred at Oued d'Ambouli in 1927, implying a return period of at least 70 years. A Log-normal estimate for an event of this return period is ~270 m³/s (Fig. 5).

The largest discharge at Oued d'Ambouli during 1980–1987 was associated with a rainfall of ~100 mm at the airport, corresponding to a ~10 year event (STDE, 2007). Flood peaks simulated by the model HEC-HMS are much larger than those estimated by the statistical method (Table 1). This may be an artefact of the method itself, period used for the hydrograph simulations (1994–2006), or a difference in the location used for the discharge estimate.

Monthly data are also available for sunshine, temperature range (derived from maxima and minima), relative humidity (maximum and minimum), mean sea level pressure and maximum wind speed at Djibouti airport since 1961 (Fig. 6). Trend analyses suggest that the temperature range, maximum relative humidity and pressure show statistically significant ($p < 0.05$) increases since 1961. Although the trend in temperature range is relatively weak, the finding is consistent with analyses elsewhere (Dai et al. 2006) and, in the case of Djibouti, primarily driven by increasing day-time (maximum) temperatures.

Figure 4. Meteorological station, Djibouti-ville's airport, 2008.

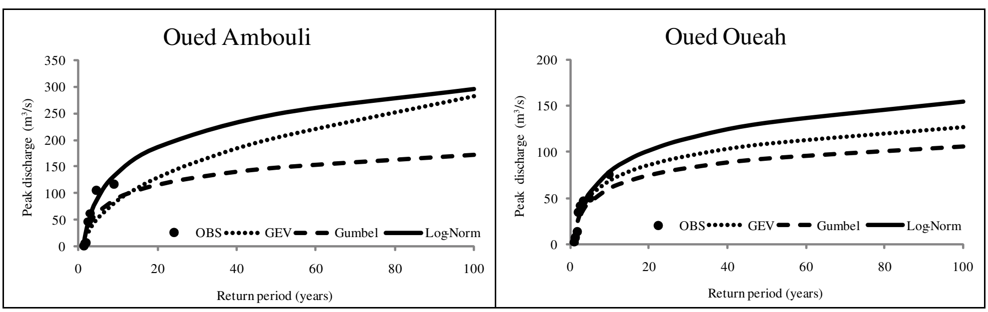

Figure 5. Frequency analysis of estimated peak discharges for Oueds d'Ambouli (Left) and Ouéah (Right), using data for the 1980s. Log-normal distributions best describe the data.

Table 1. Comparison of flood peak estimates from different models.

	Return period (years)			
	2	10	100	1000
Precipitation (airport) (mm)	36	111	204	296
Precipitation (basin) (mm)	14	44	82	118
HEC-HMS peak (Djibouti) (m³/s)	170	1010	1600	2710
Log-Normal peak (Ambouli?) (m³/s)	31	140	295	451

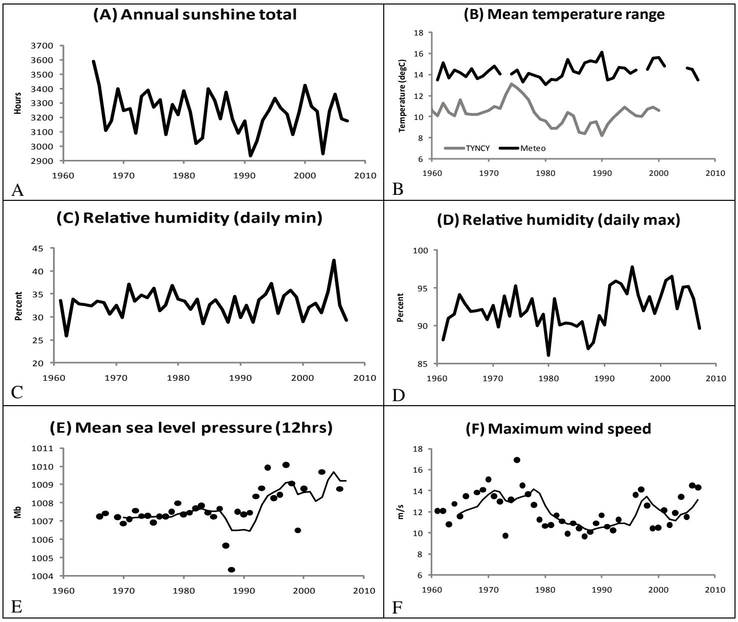

Figure 6. Annual mean sunshine (A), temperature range (B), relative humidity (C,D), sea level pressure (E) and maximum wind speed (F) at Djibouti airport 1961–2007 (Source: Service de la Météorologie).

2.2.2 *Climate change*

Observed changes in annual mean temperature in Djibouti are broadly within the envelope predicted by IPCC multi model data (MMD) set; that is, an average regional warming of 0.2 to 0.5°C since 1901, increasing to 0.1 to 0.3°C per decade since 1979 (Trenberth et al. 2007). Africa is expected to warm by between 3°C and 4°C by the 2080s under the SRES A1B emissions scenario, roughly 1.5 times the global mean response. However, the most rapid warming projections are for North Africa and the Middle East in summer. The interquartile range of the ensemble projections for summer temperature changes over East Africa is 2.7 to 3.6°C by the 2080s. Ensemble average annual rainfall is projected to decrease over the eastern Mediterranean, but a small increase is expected for East Africa and the southern half of the Arabian Peninsula. Annual data for Aden were used to extend the length of temperature records and reconstruct values in Djibouti since 1881, via linear regressions based on overlapping series for 1951–1967 (Fig. 7, left panel). Overall, temperatures at Aden capture about half of the annual variability in those at Djibouti. The resulting "bridged" record suggests warming of 2.2°C during the period 1881–2007 and warming of 1.7°C since 1950 (Fig. 7, right panel). In comparison, the TYNCY annual temperature series shows warming of 0.2°C throughout the 20th century.

Djibouti lies at the margin of a region of consensus amongst the 21 GCMs where December–February and annual rainfall totals are expected to increase. However, the exact position of the transition between rainfall increase and decrease is sensitive to the future behaviour of the ITCZ. Westphal (2007) reports an 80% consensus in winter rainfall projected by an unweighted sub-sample of 11 GCMs (Table 2), yielding an average increase of 19–26% in winter precipitation by 2030–2050. However, the outlook for Djibouti is uncertain as it lies within a transition zone between drier conditions to the north and wetter to the west. Although these scenarios imply a benign climate outlook, recall that the total area of Djibouti (23,200 km^2) equates to just half the area of a typical GCM grid box. Furthermore, the most important rainfall periods in Djibouti are in the transition seasons of February to April and October to December. Nonetheless, a decline in precipitation across a swathe of the Sahel extending into East Africa is conspicuous in the period 1961

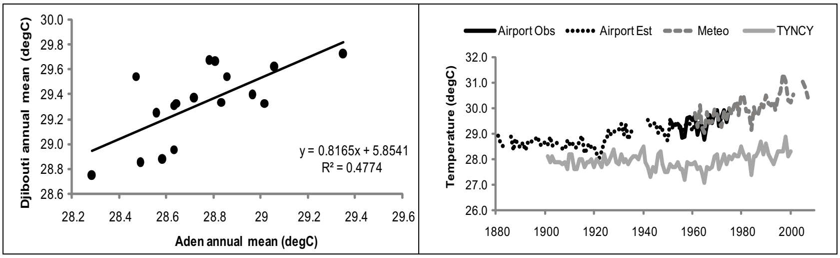

Figure 7. Left: Linear regression equation used to reconstruct temperatures at Djibouti airport since 1881. Right: temperature data at Djibouti Airport. Overlapping observations from Service de la Météorologie and KNMI are also shown. The TYNCY country-level temperature series for Djibouti is provided for comparison.

Table 2. Country-level summaries of IPCC AR4 GCM projections under A1B emissions by 2030–2050 compared with 1980–1999 (Westphal 2007).

Variable	Oman	Saudi Arabia	Yemen	Somalia	Djibouti
DJF temp mean change (°C) (8 GCMs)	1.51	1.48	1.51	1.24	1.50
JJA temp mean change (°C) (8 GCMs)	1.49	2.14	1.63	1.31	1.53
DJF precip mean change (%) (11 GCMs)	9.35	4.53	14.56	37.01	25.78
Min across country (%)	–5.68	–23.42	8.26	22.85	19.01
Max across country (%)	35.41	35.41	35.41	52.25	26.40
% models that agree with sign of change	58	66	64	91	80
JJA precip mean change (%) (11 GCMs)	20.05	73.57	42.00	18.49	22.02
Min across country (%)	9.58	–259.71	23.45	1.46	16.34
Max across country (%)	36.12	1958.26	77.00	40.06	23.45
% models that agree with sign of change	64	60	79	68	64
Change in (Max) consecutive dry days	–1	–3	–4	–4	–4
% models that agree with sign of change	58	64	61	79	85
% change in r5d (max. rain over 5 days)	18.53	17.75	23.86	18.12	16.82
% models that agree with sign of change	89	85	97	99	100
Mean runoff change (%) (2041–2060; 1900–1970; A1B) (Milly et al. 2005)	20 to 30	2 to 5	10 to 20	20 to 30	10 to 20
Pairs of model runs (out of 24) agreeing with sign of change (Milly et al. 2005)	3 to 9	3 to 9	3 to 9	15 to 21	3 to 9

through 1990 (Hulme 1992; Rowell et al. 1995; Dai et al. 2004). Experiments with coupled ocean-atmosphere general circulation models (OAGCMs) suggest that drying since the 1970s is partly explained by natural climate variability and partly by anthropogenic emissions of greenhouse gases and aerosols, as well as by vegetation changes (Held et al. 2005; Biasutti and Giannini 2006).

Another ensemble of 9 GCMs is available from the IPCC Third Assessment Report experiments under SRES A2 and B2 emissions scenarios (Table 3). As with the Westphal (2007) ensemble all GCMs show warming. However, in this case five out of the nine GCMs project drier conditions in winter under A2 emissions, yet the ensemble mean suggests an overall increase in precipitation. This highlights the distorting influence of outlier projections (such as MRI2 and CCSR/NIES2) when there is limited consensus about the sign of the change. Note also that dust aerosol feedbacks were not included in the IPCC experiments. However, shifts in large scale wind patterns could affect dust deflation power across a zone to the north of 15°N latitude and hence offset some regional warming; likewise, some known vegetation-climate interactions are not incorporated in the ensemble (Wilby 2008).

There has been relatively little research on changing climate extremes for Africa. Nonetheless, high-intensity precipitation events are expected to become heavier, in line with recent

Table 3. Changes in mean winter (DJF) and summer (JJA) temperature and precipitation totals by the 2080s, under SRES A2 and B2 projected by nine GCMs, reviewed by the IPCC Third Assessment Report (2001; adapted from Mitchell et al. 2002).

	Temperature				Precipitation			
GCM	A2-DJF	A2-JJA	B2-DJF	B2-JJA	A2-DJF	A2-JJA	B2-DJF	B2-JJA
CGCM2	4.43	4.15	2.93	2.71	25.91	13.28	16.63	38.07
CSIRO mk2	4.16	4.76	3.47	3.51	−37.35	−39.28	−23.07	5.82
CSM 1.3	3.28	2.76	2.22	2.01	−7.76	25.97	−8.01	22.48
ECHAM4	4.23	3.92	3.18	2.97	14.98	22.08	14.98	17.55
GFDL R15b	2.94	3.69	2.29	2.55	−21.81	−2.11	55.97	1.71
MRI2	2.04	0.6	1.32	0.72	64.24	22.71	24.17	5.22
CCSR/NIES2	4.35	1.51	3.29	0.96	114	169.9	225.4	106
DOE PCM	2.89	2.29	2.38	1.77	−5.4	19.85	27.88	14.81
HadCM3	4.03	4.84	3.03	3.37	−9.26	3.54	−9.02	9.51
Mean	3.59	3.17	2.68	2.29	15.28	26.22	36.10	24.57

observations (Alexander et al. 2007; Groisman et al. 2005; Zhang et al. 2005). This view is supported by analyses of downscaled heavy rainfall events over South Africa (Hewitson and Crane 2006; Tadros et al. 2005). A global analysis of temperature and precipitation extremes based on nine GCMs showed increased frequency of days with precipitation exceeding 10 mm and a higher fraction of total precipitation contributed by heavy events in the vicinity of Djibouti (Tebaldi et al. 2006). Precipitation totals from consecutive rain-days are also expected to increase, implying increased flood hazard driven by single and multi-day precipitation amounts.

Regional climate models (RCMs) provide information on the local climate response to large-scale atmospheric conditions projected by GCMs. However, few RCM experiments have been undertaken for Africa and the Middle East (Evans et al. 2004) and these have focused on validating model skill at reproducing present climatology, such as the West African monsoon (Pal et al. 2007). For example, experiments with RegCM3 show good agreement in simulated temperature patterns over Africa. However, the RCM shows large wet biases, particularly in regions of high terrain under present climate. Statistically downscaled regional precipitations and temperatures under future greenhouse gas emissions are available for Djibouti via the University of Cape Town (UCT) portal (http://data.csag.uct.ac.za/). These techniques involve deriving physically-sensible empirical relationships between local variables (e.g. daily precipitation) and large-scale atmospheric predictors (sea level pressure, humidity) supplied by GCMs. The UCT model has been extensively tested using sites across Africa and against other downscaling methods (Hewitson and Wilby 2008). The UCT portal currently provides precipitation and maximum daily temperatures at Djibouti airport downscaled from seven GCMs under SRES A2 emissions for the 2050s. Ensemble mean changes in annual precipitation (PRCP) and daily maximum temperature (TMAX) are +10% and +2.4°C respectively. However, individual members show wide variance in precipitation (spanning +54% to −32%), consistent with previous studies reporting low agreement between precipitation scenarios for regions bordering the Indian Ocean (Conway et al. 2007).

There are very little data on mean sea level for Djibouti. The Proudman Oceanographic Laboratory (POL) holds data only for 1970–1972, the CERD archive for 1992 and 2004, and the Global Sea Level Observing System (GLOSS) for 2007–2008. However, a longer record is available for Aden in Yemen (Fig. 8). During the period 1881 to 1969 the Revised Local Reference (RLR*) sea level at Aden rose by ~3.3 mm/year. This compares with a global average rate of sea level rise of 1.8 (1.3 to 2.3) mm/yr since 1961 and 3.1 (2.4 to 3.8) mm/yr since 1993. Global mean sea level is projected to rise by 0.18 to 0.59 m compared with 1980–1999, based on the 5 to 95% range of a spread of GCMs and emissions scenarios. Thermal expansion is by far the largest component, but glacier, ice cap and Greenland ice melt are all expected to contribute positively to sea level. Conversely, increased snow-

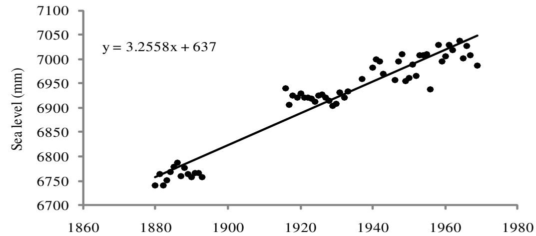

Figure 8. Sea level rise at Aden, Yemen, 1881–1969. Source: Proudman Oceanographic Laboratory; http://www.pol.ac.uk/psmsl/psmsl_individual_stations.html. * The RLR datum at each station is defined as ~7000 mm below mean sea level. This arbitrary choice was made to avoid negative numbers in the RLR monthly and annual mean values.

fall over the Antarctic Ice Sheet contributes negatively to sea level. Spatial variations in modelled sea level rise are 0.08 m (one standard deviation) under A1B emissions. However, parts of the Indian Ocean are expected to have significantly higher sea level rise due to local changes in ocean circulation and density.

3 VULNERABILITY IN DJIBOUTI

3.1 *Vulnerability drivers and aggravating factors*

Djibouti has limited arable land (0.1% by area), rainfall and groundwater reserves. The hinterland, an extension of the deserts of Ethiopia and Somalia, is sparsely occupied by a pastoral and nomadic population. About 40% of Djibouti's population are under age 15 and only 15% over age 40. Life expectancy at birth is 45 years. Vulnerability to natural hazards is enhanced by the lack of water resources management, land use planning, building codes, social-environmental and financial protection schemes, risk management public policies and by environmental degradation and/or contamination. Beyond the longer-term risk posed by climate change, groundwater availability is at the centre of most problems associated with vulnerability. Even without climate change, Djibouti is facing a water crisis due to the pressure placed on its limited renewable freshwater resources. With less than 400 m^3/yr/per capita (2005), it is classified as water scarce (i.e., after the World Health Organisation definition of <1000 m^3/yr/per capita).

3.2 *Anticipated climate hazard impacts*

According to Djibouti's Programme National d'Adaptation aux Changements Climatiques (PNACC), the most vulnerable sectors in Djibouti are agriculture and forestry, livestock, coastal zone and marine ecosystems. Table 4 provides a summary of climate drivers and associated impacts. In many cases, climate change will exacerbate existing hazards.

Once the population reaches 1 million and assuming water resources remain unchanged, per capita water availability will fall to 300 m^3/yr. Available supplies are placed under further duress by groundwater contamination, untreated wastewater, accidental spills and saline intrusion to aquifers. A vulnerability assessment focused on the groundwater resources of Djibouti-ville and rural districts of Mouloud and Ali-Sabieh highlighted the effects of reduced infiltration on groundwater levels and rising salinity of pumped water (Hussein and Jalludin 1995). Higher sea levels combined with rainfall deficit will further extend saline intrusion. Impacts on rural areas include loss of water storage, loss of pasture and land degradation. Projected increases in frequency, accumulated totals of the heaviest rains and increased vulnerability would signal a long-term rise in flood hazard and potential losses because of Djibouti-ville's exposure to flooding. A recent study stressed Djibouti's coastal zone vulnerability to a sea level rise of 80 to 390 mm by 2050, combined with a high

Table 4. Potential climate hazards impacts on Djibouti.

Sectors	Drivers	Example impacts
Water resources	Climate variability, flooding and drought	Lack of potable water; rising salt concentrations; falling water tables; contamination of wells by flood waters carrying suspended materials; increased grazing pressure around watering holes; reduced groundwater recharge
Agriculture, forestry and livestock	Climate variability, flooding and drought	Loss of yields due to water scarcity or destruction by flooding; disease or pest outbreaks; loss of soil fertility due to salination; soil erosion by wind and runoff; reduced area of pasture; increased mortality and morbidity of livestock; abandonment of terraces; increased reliance on emergency food aid and assistance
Human health	Climate variability, flooding and drought, rising temperatures	Loss of life due to flash floods; outbreaks of diarrhoea, cholera and malaria; heat stress; reduced food security
Built environment	Flooding	Damage to property and national infrastructure; increased surface and groundwater contamination; disruption of land transportation networks
Terrestrial ecosystems	Climate variability, flooding and drought	Loss or degradation of natural habitats; replacement of endemic tree and herbaceous invasive species by such as *Prosopis (Mesquite)*; loss of vegetation cover increases runoff and reduces recharge
Coastal zone	Sea level rise	Loss of coastal land due to inundation and erosion by the sea; loss of agricultural output; loss of mangroves and fish spawning habitat
Marine ecosystems	Rising ocean temperatures	Increased coral bleaching and disease; appearance of alien species; changing fish stocks in shallow waters

tide of 600 mm and a surge of 1.2–1.8 m (1:1000 year event; Hussein 2005). Two water level scenarios of 2 m and 3 m were applied to a map of Djibouti-ville: at 2 m high water level ~25% of the city would be inundated, affecting ~85,000 inhabitants. Under a 3 m high water level ~30% is flooded and ~149,000 inhabitants affected.

4 RISK MANAGEMENT OPTIONS

4.1 *The reduction of vulnerability*

Climate model projections of precipitation are highly uncertain across large parts of Africa. Over the next few decades, climate change signals are expected to remain a relatively small

Table 5. Examples of "low regret" adaptation measures for water resources management (Wilby 2009).

Availability of information for hazard and vulnerability assessment

- Centralising meteorological data collection, quality control and dissemination
- Supporting meteorological data rescue and digitization
- Monitoring baseline and environmental change indicators
- Improving surface and groundwater resource models
- Improving understanding of regional climate controls and land surface feedbacks
- Developing real-time, seasonal and decadal forecasting capability
- Improving the dissemination and uptake of forecasts for emergency management
- Undertaking high resolution topographic surveys to identify flooding hazards

Water management practices

- Improving water governance and methods of allocation
- Undertaking resource protection from pollution and salination
- Increasing agricultural and urban drainage water re-use
- Managing artificial aquifer recharge
- Undertaking asset management and maintenance (leakage control)
- Improving water efficiency (domestic, agricultural, industrial sectors)
- Developing faster growing and/or more drought resistant crop cultivars
- Employing traditional water harvesting and retention techniques (such as terracing)
- Implementing risk management, contingency plans and post-disaster management

component when compared with the large inter-annual variability. It then makes sense to identify strategies that are robust to a wide range of conditions faced now and potentially in the future (Wilby and Dessai, 2010). "Low regret" measures should meet present needs, while remaining open to incorporating potential future scenarios. Building resilience to present climate variability is regarded as the first step towards addressing the challenges posed by climate change. Priorities include (PNACC 2006): 1) protecting life and livelihoods; 2) meeting adaptation needs of communities; 3) integrating measures with sectoral and national planning and; 4) raising awareness of risks and opportunities attached to climate variability and change. Activities planned under the Comprehensive Approach for Risk Assessments in Djibouti (CARAD; Mora et al. 2010) could also help reduce vulnerability when combined with land-use planning, improved hazard forecasting and building standards, regardless of the climate outlook (Table 5).

5 CONCLUSIONS

Long-term, systematic meteorological observations are scarce, and given the sparse observing network and highly variable climate, it is difficult to comment on long-term climate trends for Djibouti. However, composite temperature data show a warming of ~1.7°C since 1950. Precipitation totals exhibit considerable inter-annual variability and a modest increase in winter rainfall over the same period. The annual mean temperature range, maximum relative humidity, atmospheric pressure and sea level (at Aden) have all increased. Periodic extreme rainfall events have impacted Djibouti on several occasions since the 1970s, causing the floods of 1994 and 2004. The IPCC FAR climate model ensemble shows higher than global average warming and sea level rise in East Africa, although there is some variance in the sign of seasonal and annual precipitation change amongst the 21 models. This is also reflected in the smaller ensemble of GCMs (but different emission scenarios) of the IPCC's Third Assessment Report. Statistically downscaled precipitation scenarios for Djibouti show mixed results that are climate model dependent. Annual totals are projected to change by +54% to −32% under SRES A2 emissions by the 2050s, with a tendency for more frequent, heavier rainfall events. Uncertainty in regional precipitation scenarios translates into uncertainty in potential water resource and flood impacts. Therefore, it makes sense to identify robust vulnerability reduction strategies for the wide range of conditions experienced now and, potentially, in the future.

Even in the absence of climate change, Djibouti-ville is facing a water crisis as a consequence of rising demand and falling supply. Likewise, the city is already highly exposed to fluvial flooding and coastal zone inundation. Without appropriate vulnerability reduction measures, these risks are expected to increase under climate change. Djibouti's evolving legal and policy frameworks provide opportunities for harmonizing long-term vulnerability reduction and hazard management across sectors. Land use planning, expanded monitoring networks and new technologies for desalinization could also be trialled in rural communities. Changes in both the climate driver and exposure units will affect risk levels and cost-benefit of any intervention. Vulnerability increase will certainly be the parameter inducing higher risk levels. Metrics of exposure (e.g. percentage of the population living in oueds or low-lying coastal zones, rain-fed cropped-area, groundwater resource) will respond more directly to climate hazards. Migration to Djibouti-ville may increase because of salination of coastal aquifers due to rising sea level. Since patterns for each climatic hazard (and their joint occurrence) might evolve at different rates, so too will the distribution of hot spots and affected groups. Therefore, it is recommended to take actions to integrate climate hazards within the vulnerability context. Many options for reducing vulnerability may be regarded as "low regret" in the sense that they help build resilience and capacity that will remain effective regardless of the future climate. Furthermore, the imperative for adaptation to climate variability and change has been strengthened by the disappointing outcome of the COP15 negotiations in Copenhagen 2010.

DISCLAIMER

The findings, interpretations and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the views of the World Bank, its Executive Directors, or the countries they represent.

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