Strategic agenda for adaptation to urban water-mediated impacts of climate change in Addis Ababa, Ethiopia

URAdapt: Managing water in the urban-rural interface for climate change resilient cities

Foreword

Evidence shows that an increase in extreme rainfall events due to climate change is expected, accompanied by changes in other weather patterns. The impacts of these changes are expected across the country, but more notably in the urban areas which are home to large populations. Climate change adaptation measures in these areas are currently ad hoc, with no long-term plans and strategies in place.

From this background, a Strategic Agenda for Addis Ababa has been developed. This Strategic Agenda should play an important role in supporting informed decision-making for combatting climate change impacts. It was developed on the basis of an exhaustive dialogue over a three-year period in which all the pivotal stakeholders participated.

This Strategic Agenda reviews the findings of research and provides recommendations that can also be applied to other cities in Ethiopia. The research shows that if water resources are managed properly, Addis Ababa can become considerably more resilient to climate change even when faced with projected population increases and other compromising factors. This is a significant opportunity for innovative policy at the cutting edge of the climate change debate. We can create a country and people that are prepared for climate change impacts and not constantly responding to emergencies.

We invite all stakeholders and identified responsible organizations to support this endeavor.

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H. E. Ato Alemayehu Tegenu
Minister of Water and Energy
Federal Democratic Republic of Ethiopia
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Strategic agenda for adaptation in Addis Ababa

Cities are undergoing deep transformations throughout sub-Saharan Africa. Their populations are growing rapidly and their physical boundaries are expanding. Socioeconomic shifts – including the rise of an urban middle class – are leading to new patterns of production and consumption. Along with these shifts is a changing climate.

Addis Ababa is no exception. According to the 2007 census, the city had a population of about 2.74 million (CSA 2007) (excluding informal settlements in the 10 sub-cities within the administrative boundaries) and it was anticipated to grow to more than 3.1 million currently. Unofficial estimates suggest that more than 1 million people move in and out of Addis Ababa daily. The current area of Addis Ababa is approximately 518 km^2 (as per geographic information system (GIS) delineation). Land use has changed from being largely unbuilt areas (about 85% in 1984) to largely built-up areas (more than 57% of the area in 2002), with impervious areas increasing rapidly.

As Ethiopia continues on its development trajectory to reach middle income status in 2025, its key economic assets will be affected by climate change (FDRE 2011). There is a clear need for new resource management practices that can secure a sustainable, climate-compatible future for cities and their surroundings. This is where the URAdapt strategic agenda comes in. The strategic agenda provides direction for city managers on how Addis Ababa's water and wastewater systems can respond to the impacts of climate change. It is intended for national, regional and municipal decision-makers as well as private sector and non-governmental actors.

The strategic agenda sets out key recommendations as the basis for more detailed action plans by different stakeholder groups. The recommendations are contextualized in terms of current practices and policies, as well as the measures needed to build the climate change resilience of urban water and wastewater systems.

The recommendations were developed on the basis of a science-based dialogue among representatives of research institutes, public authorities, industry groups and non-governmental organizations. Collectively, they identified topics for research, which were carried out by a team of biophysical and social scientists. The results of these studies are available in the section, *Case studies and findings.*

The agenda describes three strategic objectives of major and immediate relevance when addressing climate change adaptation options for Addis Ababa. It outlines the pertinent issues and concerns, and presents the strategic recommendations for each objective, in addition to describing the enabling conditions and designating the responsible organizations. The document conforms to the urban water and climate change governance contexts of Ethiopia and Addis Ababa, and refers to the national development priorities as described in the Growth and Transformation Plan for Ethiopia.

STRATEGIC OBJECTIVE 1: ADOPTING REGIONAL INTEGRATED WATER SUPPLY AND DEMAND MANAGEMENT.

Sub-issues	Concerns	Strategic recommendations/actions	Enabling environment	Responsible organizations
Water supply development.	• Likely increase of water availability due to climate change, but this cannot offset the future water needs of Addis Ababa because of its location at the head of the basin. • Future planned water supply development is insufficient to meet the current and future water supply-demand gap. • Increasing population and urbanization in the upstream side of the sources of water supply may threaten the water supply to the city. • Sedimentation of storage reservoirs as a result of land-use change threatens water availability.	• Build distributed water conservation system in the city as part of a short-term/medium-term plan. • Focus on developing distance water supply options in response to long-term needs. • Secure finance for implementation of new water supply development projects/programs. • Widen revenue base and improve revenue collection by city council. • Include land conservation as an integral part of Integrated Water Resources Management (IWRM) policy and introduce both biological and physical conservation methods.	• IWRM policies. • A functional regional planning unit. • Regional planning policy in place. • Institutional capacity for implementing water conservation in the city.	AA Municipality and AAWSA.
Water demand management.	• Population increase leading to increase in water demand. • Increased per capita water consumption as a result of improved living standards and climate change (temperature rise). • Inequitable access (availability and usage) to water in the city. • Inefficient use of water by residential and industrial consumers.	• Implement demand-side management through the use of appropriate best technologies and practices that can ensure equitable provision and distribution of water supply. • Move from a pricing policy based on cost recovery to more efficient water use. • Review the pricing mechanism to reflect a tiered tariff system (larger users pay more). • Introduce policy with accompanying regulations/ incentives for implementing water-saving devices. • Education programs through the media, on water-use efficiency, water conservation, benefits of recycling, etc.	• Existence of policies which address issues around water demand. • Coordination between Addis Ababa and Oromia regions.	AAWSA.
Integrated Addis-Finfinne zone water supply and demand management.	• Increase in peri-urban/rural water demand (upstream/downstream of Addis Ababa) for domestic and irrigation use. • No integrated water supply and demand management practices.	• Develop and implement beneficial integrated watershed management (both biological and physical conservation methods) upstream of the reservoirs and stratified protection zones. • Review water needs of surrounding areas and develop joint programs for water infrastructure with the Oromia region. • Strengthen the high-level steering committee between Addis Ababa and Oromia, which ensures sustainable access to water resources. • Diversify water sources for peri-urban and rural uses (groundwater).	• IWRM policies. • A functional regional planning unit. • Regional planning	AAWSA, AA Municipality and Oromia Water Bureau.

STRATEGIC OBJECTIVE 2: INTEGRATED FLOOD RISK MANAGEMENT.

Sub-issues	Concerns	Strategic recommendations/actions	Enabling environment	Responsible organizations
Extreme flood events.	• Increase in flood peak and volume. • Increase in flood-susceptible areas. • No single organization to deal with flood management at city level, resulting in dispersed actions. • Absence of flood risk assessment procedures/ guidelines. • Inadequate climate information system for prediction and early warning of flood.	• Review the capacity of existing urban drainage infrastructure and improve maintenance. • Develop new design guidelines that incorporate climate change impacts and the influence of non-climate drivers on storm water flows, e.g., the intensity-duration-frequency (IDF) curve should be changed. • Establish a separate flood and drainage management organization at city level. • Develop best flood management practices. – Guidelines for open/green space to built-up area ratio during expansion of the built-up environment, including orientation of green space to maximize infiltration and retard surface runoff. – Enact a zoning policy that provides for buffer zones, green spaces, urban agriculture, etc. – Incorporate private sector management of parks and revenue collection to maintain facilities. – Strengthen Addis Ababa city fire and emergency services to improve early warning and increase community participation. – Create retention ponds upstream of the flood-prone communities to minimize surface flows.	• Appropriate flood and drainage institutional setup. • Provision of flood early warning system.	AA Municipality.
Managing flood vulnerability (risk management, infrastructure and social component).	• Settlement in flood-prone areas. • Poor housing conditions. • low level of water supply and sanitation services, compounding health risks.	• Develop flood risk assessment guidelines appropriate to the local context. • Develop resettlement plan for vulnerable communities. • Provide improved access to basic social services for these communities. • Install social insurance schemes for vulnerable urban communities.	• Integrated flood management policy in place.	AA Municipality and sub-cities.

STRATEGIC OBJECTIVE 3: DEVELOPING BEST PRACTICES FOR WASTEWATER MANAGEMENT.

Sub-issues	Concerns	Strategic recommendations/actions	Enabling environment	Responsible organizations
Wastewater generation and management.	• Increase in wastewater generation due to urbanization and climate change (temperature rise). • Low percentage of sewer coverage (about 10%). • Best management practices (BMP) for wastewater are not yet in place. • Inadequate capacity to implement the proposed wastewater master plan.	• Implement demand management (see strategic objective 1). • Encourage decentralized wastewater disposal and treatment systems that minimize greenhouse gas emissions. • Design an incentive-based pollution abatement policy for industrial wastewater management. • BMP to include policy on wastewater recycling and safe use in agriculture. • Institute mechanisms for the sale of treated wastewater for recycling in downstream agriculture. • Initiate the implementation of the wastewater management master plan.	• Separate institutional arrangements for wastewater handling with related policy and legislation in support of this.	AAWSA, AA Municipality and AA Environment Bureau.
Water quality deterioration.	• Increased industrialization and urbanization in and around AA escalates water quality deterioration. • Low enforcement of existing policies and standards. • No inter-regional monitoring and enforcement of water quality standards.	• Install water quality monitoring stations at key river reaches in AA, industrial outlets, upstream of the reservoir inflow sites and at reservoir sites. • Reinforce groundwater quality monitoring. • Strengthen capacities of regulatory agencies to adequately enforce existing EPA regulations.	• AA and Oromia Environment Bureau to play a proactive role in enforcing legislation.	EPA, and AA and Oromia Environmental Bureaus.

Background to the project

Growing cities strain basic service provision

In many parts of sub-Saharan Africa, rapid urbanization outpaces the ability of city managers to adjust basic service provision, including water supply, sanitation and flood protection (Mafuta et al. 2011). Urban water management systems become subject to a range of pressures. Unplanned urban developments within watersheds may pollute surface waters and complicate water source protection. Land clearance, deforestation and the expansion of impermeable surfaces increase the risk of flooding, and slow the rate of infiltration and aquifer recharge. As storm and surface water runoff flow through built-up areas, their pollution loads increase, particularly where the necessary solid waste management practices are lacking (Palaniappan et al. 2010).

Cities change local ecologies

The absence of water and sanitation services, alongside inadequate drainage and flood protection mechanisms, increase the disease burden on urban populations and the vulnerability of urban communities to weather-related disasters. New disease vectors or new infections emerge among urban populations.

Urban water management is a complex undertaking

Urban water management goes much beyond providing water and sanitation services and overseeing related infrastructure. It also includes mitigating the risk of floods, landslides and other water-mediated disasters, as well as managing solid waste and storm water drainage. Conventionally, these services have been delivered in isolation. Yet, greater integration is key to safeguarding cities and water resources (Bahri 2012).

Silo-thinking' is not limited to city managers. At the basin-level, water resources management often fails to account for the interdependencies between freshwater, wastewater, flood control and storm water (Parkinson et al. 2010).

Cities need water for residential, commercial and other uses. Yet, water may be located far away and is unlikely to be at the disposal of cities alone. Moreover, prevalent management practices make little distinction between different water qualities. A wide range of water needs are met using high-quality water, thereby exacerbating resource scarcity (van der Steen 2006). The situation is further complicated by the myriad authorities and legislative frameworks that govern urban water management.

Sustainable water management practices in cities benefit not only urban communities but also those in surrounding areas. URAdapt enrolled a wide range of stakeholders and devised an integrated research framework to account for the mutual dependencies between water sources, water use sectors and water management scales.

Climate change and urban water-mediated vulnerabilities

A changing climate demands that the management of water is approached in a different way. Research on climate change adaptation has focused mostly on rural agriculture, neglecting the shift of populations towards cities. At the same time, urban infrastructure responses to climate change have concentrated on transport and energy sectors, and only minimally on water and wastewater systems.

Water will mediate climate change impacts on ecosystems, livelihoods and the well-being of societies in urban areas and beyond (UN-Water 2010). Climate change is expected to influence the intensity, timing and reliability of rainfall.

In many developing cities, existing infrastructure struggles to cope with current weather conditions. Climate change will place further strain on water, transport, energy and ecosystems. Where no safety nets are in place, basic service provision is interrupted, local economies come to a halt and urban populations may be forced to seek new livelihoods elsewhere. Within cities, existing inequalities will be made worse (UN-Habitat 2011). Yet, current projections of water and sanitation supply and demand only account for population increases, and not for the impacts of climate change.

Urban water demand can be expected to increase in the future as a result of growing populations, rising temperatures, and more frequent and extreme heat events. Changes in temperature and precipitation patterns are predicted to impact the availability (in terms of both quantity and quality), treatment and distribution of water (WHO and DFID 2009).

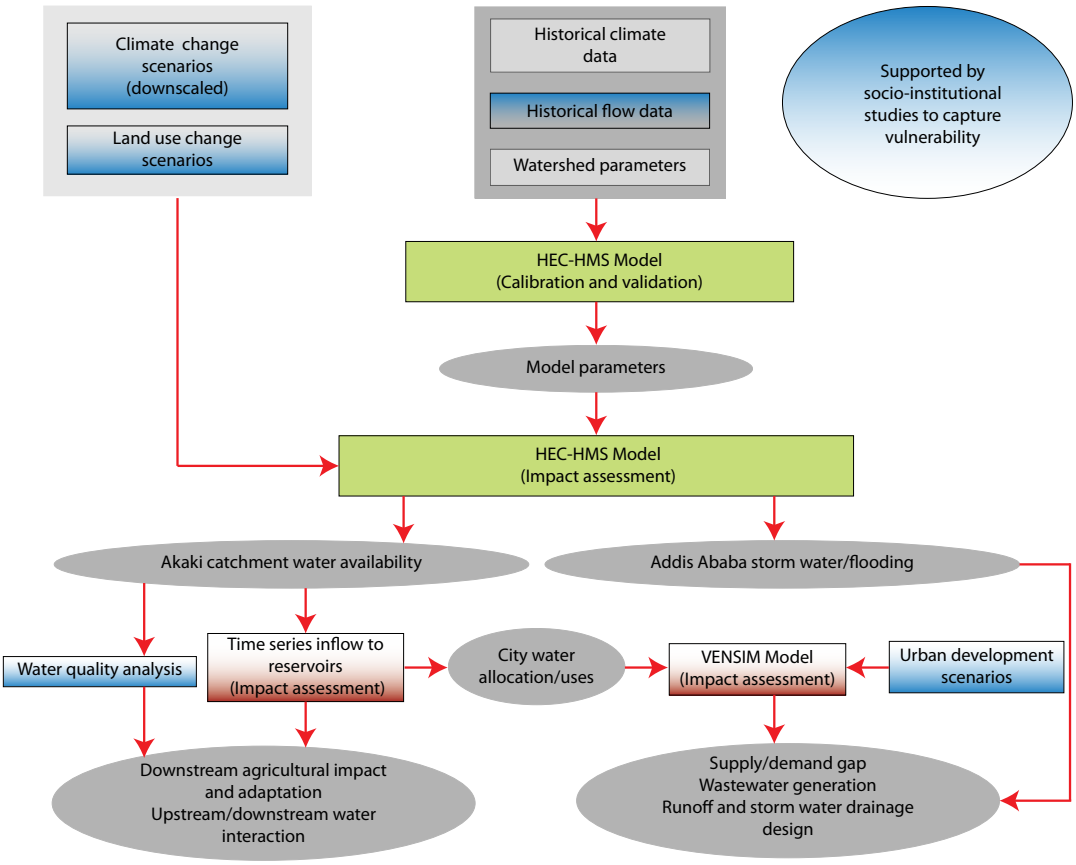
More rain and heightened flood risks imply higher costs for road, drainage and flood protection infrastructure. Some lands may no longer be habitable.

Climate change will impact water-based sanitation. In areas where precipitation decreases, water-dependent sewerage systems may be damaged. Elsewhere – particularly in cities with combined sewer networks – treatment facilities may flood, leading to water contamination and public health risks (Tucci 2009). Simultaneously, in areas where groundwater levels are expected to rise, pollution caused by pit latrines may become more difficult to manage (WHO and DFID 2009). As a whole, sewage treatment lags behind coverage. Under climate change, performance requirements, costs and potentially also the carbon footprint of wastewater treatment will increase (Bahri 2009).

Half of the world's population live within 3 km of freshwater bodies (Kummu et al. 2011). The lack of basic sanitation facilities in major cities of the developing world leaves a large 'negative' water footprint, thus exposing large populations to the adverse impacts of water pollution. Farmers downstream of cities using these polluted water sources for agricultural purposes have to face the combined effects of pollution and climate change.

URAdapt builds city resilience to climate change by generating scenarios for future water resources management in, and for, cities in light of population increases and climate change.

Generating knowledge for decision support



Conceptual research study framework

Definition of the research framework

URAdapt devised an integrated analytical framework to produce new knowledge on climate adaptation in support of decision-making. The project has taken as its starting point the interdependencies between water sources, scales and sectors that cut across the urban-rural continuum.

URAdapt has recognized that contextually relevant and sustainable solutions can only arise out of mutual learning and collective action. With this in view, the project applied a Participatory Action Research (PAR) approach, which involved setting up the Research into Strategic Action Platform (Re-SAP). This platform provided an opportunity for a novel constellation of stakeholders to come together to discuss how Addis Ababa can reduce its vulnerabilities to climate change through improved and integrated urban water management. The Re-SAP has provided critical input into research activities through data provision, monitoring of progress, and evaluation of research quality and relevance. A smaller Core Group was available for more detailed discussions on relevant issues as needed.

Using regional climate models (RegCM4), URAdapt scientists downscaled global circulation models to the level of the Akaki Basin, serving Addis Ababa, in order to understand its exposure to climate change under Intergovernmental Panel on Climate Change (IPCC) scenario A1B.

This information was fed into a hydrological model (HEC-HMS) which modelled runoff in the catchment, and projected water availability and allocation under different climate and basin water use scenarios. At the city level, URAdapt investigated urban water and wastewater interactions, including the water supply-demand gap under different scenarios of per capita water use and population growth. Addis Ababa surface runoff was modelled using the US Soil Conservation Service (SCS)-based storm runoff model, and the impact of climate change on flood design parameters was studied. The project also examined vulnerability in terms of exposure to flooding and service levels for water supply and sanitation, and the associated adaptation responses of vulnerable communities, including those of downstream farmers exposed to poor water quality. Finally, urban-rural interactions around water use and management were studied with respect to Addis Ababa and the Finfinne zone surrounding it.

Selection of stakeholder groupings (boundary partners)

Stakeholder selection was guided by two principles: the reflection of multiple perspectives on urban water management, and the participation of organizations and individuals in positions of incorporating project knowledge into policy debates and everyday working practice. More specifically, the project sought to enrol actors who could account for the following:

- The continuum of water use and management across urban and rural spaces (rural water supply, agriculture, irrigation), and reflect both the basin and national water resource management perspectives.
- Climate change (climate change lead organization in the government, implementers of adaptation measures and disaster risk mitigation).
- Socioeconomic factors that may compound vulnerability to climate change and be able to convey the voices of vulnerable women, urban slum dwellers and communities living in flood-prone areas.
- Local-level water governance (urban and rural local authorities, including those in charge of water supply and wastewater in the two project cities).
- Any health-related issues (including flooding and water contamination from poor sanitation).

The platform itself ensured that its composition continued to reflect the purpose of the project, and the in-built flexibility of the project ensured that new actors could be invited to platform meetings as and when needed. The specific tasks and operational mode of the platform were defined by stakeholders themselves. The Re-SAP also sought alignment with other water- and climate-related initiatives in Addis Ababa.

Process for stakeholder engagement in order to have impact

The Re-SAP and Core Group have served as the main channels for stakeholder engagement. Collectively, they have discussed findings and their implications for policy formulation and implementation, and in this way, continually provided further definition to the types of impacts that the project could pursue.

In pursuit of wide-scale impact, the URAdapt project team and Re-SAP members have participated in climate change-related policy consultations and networked with communities of water management practitioners, both in Ethiopia and elsewhere. They represent a resource base that can be drawn upon in future work on climate change, water resources and cities.

At a more local level, URAdapt carried out targeted engagement with the Addis Ababa Municipality. This involved learning about the structure and functions of the key departments, as well as their information needs and data availability. More focussed discussions took place with the city manager and his technical teams (particularly those related to water, sewerage and drainage), and the Addis Ababa Water and Sewerage Authority. As a result, the project was able to remain up-to-date on municipal initiatives and identify opportunities for integrating URAdapt research into the ongoing work of the local authority. The project also interacted closely with vulnerable communities as part of the case study analytical process.

At the final stages in support of the uptake of the research findings, one-on-one meetings were held with high-ranking officials of the city municipality including the City Manager and other key actors responsible for the implementation of the agenda. The Climate Change Forum-Ethiopia, a non-government actor, was also enrolled to support future uptake of recommendations.

Case studies and findings

Research theme	Research/study topic	Main findings/likely scenario
Climate downscaling and impact of climate and non-climate drivers on urban hydrology	Evaluation of the impact of climate change on the extreme flow hydrology and water availability of Akaki Basin using different emission scenarios.	• Likely increase in flow volumes and flooding. • There will be a 13% increase in the annual flow volume of Akaki Basin in the 2030s and a 15% increase in the 2090s. • The extreme floods will likely increase by 37% in the 2030s and by 15% in the 2090s.
	Evaluation of the impact of climate change on the water supply reservoirs of existing Gefersa, Legedadi and Dire dams, and other future water supply sources to Addis Ababa.	• Inflows to, and storage in, the three reservoirs are likely to increase significantly. – *Inflow to Legedadi increases by 14 and 16% for 2030 and 2090, respectively, whilst the storage increase in the reservoir is 21 and 19%, respectively (significant).* – *Inflow to Dire increases by 9 and 3% for 2030 and 2090, respectively, whilst the storage increase in the reservoir is 26.5 and 24%, respectively (significant).* – *Inflow to Gefersa increases by 5 and 4% for 2030 and 2090, respectively, whilst the storage increase in the reservoir is 38 and 37%, respectively (significant).*
	Impact of built environment on hydrological regimes of Addis Ababa.	• The non-climatic driver of increase in area of the built environment has increased the runoff coefficient from 28 to 45% over the last 20 years, with a continued increase expected in the foreseeable future. • In terms of volume, this represents a 62% increase in runoff volume within Addis Ababa. • With the rapid changes observed in the built area, flood volumes are currently anticipated to be higher.
	Mainstreaming the impacts of climate change in the design of urban drainage infrastructure.	• The return periods of peak floods have changed, so the design guidelines for drainage infrastructure have to be revised. • Ten-year return period of floods in the 1990s (60.1 m^3/s) is equivalent to two-year return period of floods in the 2030s (61.2 m^3/s). This is equivalent to about five-year return period of floods in 2090 (62 m^3/s). • Similarly, the 50-year (72 m^3/s) and 100-year (77 m^3/s) return period of floods become equivalent to the five-year and 10-year return period, respectively in the 2030s.
Urban water system trajectories and impacts	Evaluation of water and wastewater management under conditions of climate change for Addis Ababa City (Using the VENSIM Model).	• Current water supply provision is not adequate for Addis Ababa City. There is a gap of 28% between supply and demand which has to be met. • Despite additional planned water supply development, by 2030, the water supply of Addis Ababa City will still be insufficient due to the increased demand related to temperature rise, demographic growth and the improved well-being of people. For an average scenario of per capita water demand, the gap between supply and demand is expected to increase to 47%. • If expected demand is met, wastewater generation in the City of Addis Ababa will triple by 2030. • Of the net supply of water, 17.5% is consumed by as few as 107 consumers.
	Assessing water conservation and management options for meeting the increasing water supply-demand gap in Addis Ababa City.	• A net gain of 34.4% of water to bridge the gap would be possible with water conservation and management measures. • Current non-revenue water is about 39.5% (unaccounted for water in the distribution system). • Most of the water distribution facilities are old and badly maintained. By replacing old fixtures with new and efficient ones, 20% of the water can be regained.
	Understanding the situation of wastewater irrigation in the Akaki catchment.	• The quality of water in the Akaki River has deteriorated over the last 40 years. • Wastewater generation has increased the availability of water for vegetable production in dry seasons. • Unexpected intensity of rainfall during the dry season and at the onset of the rainy season increases pollutant levels in the Akaki River. Consequently, the frequency of sickness and death of cattle increases. • Of the annual income of farmers, 75% is derived from wastewater irrigation in the dry season.

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Case studies and findings (Continued)

Research theme	Research/study topic	Main findings/likely scenario
		• Farmers seek other sources of income during the rainy season due to the flooding of farmlands. With climate change and expansion of the built environment, the period of flooding is likely to expand.
	Investigation of upstream/downstream linkages in relation to the urban water cycle for the City of Addis Ababa.	• Due to urbanization and industrialization, there will be competition for groundwater use from the Akaki well-field (serving Addis Ababa) for the surrounding areas. • Of the population in the Finfinne zone, 20-25% is urban with increasing water needs. • There is a large livestock population that uses rural water sources and already face water shortages in the dry season.
Human and institutional vulnerability	Assessment of the physical and socioeconomic vulnerability of Addis Ababa to water-mediated impacts of climate change (water supply, urban flooding and wastewater management).	• Differentiated vulnerability of communities to flood incidents and diverse coping strategies adopted: – *The city experienced severe floods at least 25 times between 1978 and 2010. Excluding the downstream Oromia District, at least 15,000 people were severely affected. Of the population, 58% living close to the banks of the Akaki River have low-quality houses and are more vulnerable to flood incidence (from secondary data sources).* – *Amongst the people exposed to flood incidence, 38.7% are in Addis Ketema, 32.2% are in Akaki-Kaliti and 30.8% are in Arada sub-cities. Sub-cities of Akaki-Kaliti, Lideta, Arada, Nifas-silk-Lafto and Cherkos are the most exposed to flooding.* – *Some adaptation measures taken by vulnerable communities to floods included reinforcing of river banks, changing cropping patterns, cleaning drains and sheltering affected people in community shelters as well as forming strong social networks as a risk insurance strategy.* – *Downstream farming communities (4,108 farm households) involved in peri-urban agriculture (3,560 hectares and substantial livestock) are vulnerable to crop failure and livestock deaths as a result of flooding and waterlogging problems (33% of respondents reported severe flood damage).* • Urbanization, poverty levels and low access to basic social services and housing make the city and its populations more vulnerable: – *The city more than doubled its built-up area from 1975 to 2000 showing a physical expansion from 6,050 to 14,672.7 hectares.* – *With a projected city population of 5 million by 2030, migration to the city is seen as a major contributor (46.9%).* – *Of the houses in the city, 24.8% are in very poor condition and increases their vulnerability to climate extremes.* – *Of the population of Addis Ababa, 32.5% are living below the poverty line. The communities that are most vulnerable, due to their extreme income poverty, live in Akaki-Kaliti, Cherkos, Yeka and Arada.* • Current level of development makes the city more vulnerable to water supply and sanitation deficits, with different levels of exposure among different social groups: – *Of the population of Addis Ababa, 27% do not have access to improved water supply. Any future reduction in water supply will exacerbate their vulnerability. The 73% that have access will also be affected, but to a lesser degree.* – *In the very poorly served sub-cities of Akaki-Kaliti, Gulele and Arada, between 40 and 47% lack access to improved, affordable and sufficient water supply. In better-served areas such as Addis Ketema, Gulele, Kolfe Keraneo and Arada, about 35% of the population are subject to interruptions in water supply services.*

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Case studies and findings (Continued)

Research theme	Research/study topic	Main findings/likely scenario
		– *Of the city population, 83% use pit latrines while only 17% of the population in high-income areas have access to flush toilets. In Akaki-Kaliti, in particular, and Cherkos sub-cities, between 85 and 90% of the population have only the basic sanitation services.* – *Additionally, low-income areas with pit latrines, which are at risk from flooding, face potential health risks.* – *Less than 15% of the urban area is sewered, and 30% of the solid waste is dumped in open spaces, river banks, road sides, etc.* • Existing road infrastructure of the city is more vulnerable to flooding due to the likely increase in intensity of rainfall and under-design of drainage systems. – *Out of the current road networks of 3,324 km in the city, about 1,662 km of asphalt is vulnerable to the impacts of climate change as this was not considered during construction.*
	Review of policy and institutional arrangements to assess the adaptation capacity of the city to water-mediated impacts of climate change.	The policy and institutional analysis identified the following features (strengths and weaknesses) that influence the capacity of the city to adapt to water-mediated impacts of climate change. • National institutions and processes provide a supporting environment for adaptation to climate change: – *Though climate change is not directly mainstreamed in the Growth and Transformation Plan (GTP) of the country, the overall development goal of eradicating poverty, as stipulated in it, is a strength that builds the city's adaptation capacity. The medium-term plan focuses on pro-poor development, addressing the most vulnerable segments of the city.* – *Climate change is internalized, albeit indirectly, in the existing environment, water resources management, disaster prevention, preparedness and early warning policies, and the health policy.* – *International donor aid for development provides opportunities for financing climate change adaptation programs.* • At the city level, the existing constitution, institutional arrangement as well as the organizational structure of the administration, reflects or creates more capacity for the city to adapt to water-mediated impacts of climate change. – *The constitution and the water policy provide the city with the right to utilize water resources within and outside its boundary. There is provision for establishing a special joint committee with the neighboring Oromia region for resource utilization and regulating discharge of pollutants.* – *Mandates are clearly identified for all levels of the institutional structure, including federal, city, sub-city and district levels.* – *The city is autonomous and prepares its own sectoral policies, strategies and development programs; it allocates a budget to development programs and follows-up on their implementation. For effectiveness of such mandates, the city has its own decentralized structures that stretch from city to district levels.* – *There are informal community risk sharing schemes, which are organized by members, and led by democratically elected leaders that provide an insurance service to members only.* – *There is a strong willingness of the local community to participate in and contribute to the planning and implementation of adaptation programs which will help to build their resilience to climate change. Better design of adaptation programs is possible with local community participation (results of focus group discussions).*

(Continued)

Case studies and findings (Continued)

Research theme	Research/study topic	Main findings/likely scenario
		• Some implementation gaps were identified that may weaken the adaptive capacity of the city. – *Although the special committee for water resources management between Addis Ababa and the Oromia region has been established, clear mandates, processes and related institutional arrangements are still lacking to make it functional.* – *Low implementation capacity across different organizations at the city level. This is reflected in poor planning, low implementation of targets, poor enforcement of existing policy (e.g., pollution), low motivation of district officials and low coordination capacity (e.g., between AAWSA and AACRA).* – *Narrow revenue base (business tax, non-public employee tax, etc.) and low revenue collection capacity (at city level) impedes adequate budget allocation for climate adaptation programs.* – *Low awareness of local community about water-mediated impacts of climate change.* – *No clear understanding for integrating development plans with climate change adaptation plans.* – *Early warning system exists at city and sub-city levels, but there is no involvement of the local community in the planning and implementation of this system.* – *The command–and–control policy of environmental pollution cannot be implemented due to institutional weaknesses.* • Policy and institutional gaps that are likely to affect effective adaptation are: – *The water resources management policy ignores efficiency in tariff setting, as it only considers the full cost recovery of the investment and operation and maintenance costs in water service delivery.* – *There is no policy instrument that encourages the use of water-efficient technologies.* – *There is no wastewater management policy and the existing wastewater treatment plants in the city have no mandate to sell or recycle treated wastewater (as a possible adaptation option).* – *There is no urban agriculture policy and strategy. This hinders the productivity of the sector and the safe use of wastewater in irrigation, despite the huge volumes of wastewater produced and the willingness of urban farmers to buy and practice safe wastewater irrigation.* – *There is low private sector participation in waste management. Higher participation could improve service levels.* – *Absence of formal insurance schemes for climate-related risk management.*

Research gaps and suggested further studies

- Developing a scalable approach or methodology for addressing urban adaptation to climate change impacts which are applicable across African cities.
- Water demand management and options for developing alternative water sources (rainwater harvesting, greywater/wastewater recycling, groundwater and water conservation).
- Decision support system for IUWM to mainstream climate change.
- Modelling water allocation in the Akaki Basin (and other potential water basins serving the city) under future climate and development scenarios.
- Applying regional downscaling models to understand climate change impacts in other major cities in Ethiopia.
- Coupling the expansion of the built-up environment with climate change, and consequences for the design of urban storm drainage systems.
- Climate information and attribution of impacts in understanding urban flooding in Addis Ababa.
- Improving urban flood hazard and risk mapping methods, and developing a current risk map for Addis Ababa.
- Designing and integrating locally appropriate flood management and adaptation measures into the overall city management plan.
- Community participation and management for addressing flood adaptation.
- Developing appropriate institutional mechanisms for enforcing existing and new environmental regulations.
- Quantitative microbial risk assessments and health impact analysis across flood-prone areas in Addis Ababa.
- Costing adaptation measures for informed decisions.
- Understanding and facilitating organizational change for mainstreaming climate change adaptation into working practices.

Boundary partners

Representatives/individuals from the following organizations participated in the Research into Strategic Action Platform (Re-SAP) meetings.

Addis Ababa Environmental Protection Authority
Addis Ababa Municipality
Addis Ababa University, College of Development Studies
Addis Ababa University, Department of Civil and Environmental Engineering
Addis Ababa University, Environmental Economics Policy Forum for Ethiopia
Addis Ababa Water and Sewerage Authority
Addis Ababa Women and Children Affairs Office
Akaki Water Office
Association of Citizen Solidarity for Campaign Against Famine in Ethiopia
Climate and Health Working Group of Ethiopia
Climate Change Forum - Ethiopia
Ethiopian Civil Society Network on Climate Change
Ethiopian Development Research Institute
Ethiopian Environmental Protection Authority
Forum for Environment - Ethiopia
International Water Management Institute
Ministry of Water and Energy - Department of Research Coordination
Ministry of Water and Energy - Water Supply and Sanitation Directorate
Ministry of Water and Energy - Department of Hydrology
National Meteorology Agency
Oromia Special Zone Office
Oromia Water, Mineral and Energy Bureau
Sebeta Awas Woreda Water, Mine and Energy office
Urban Agriculture Extension Service

Lead partners:
International Water Management Institute (IWMI); and Department of Civil and Environmental Engineering, Addis Ababa Institute of Technology, Addis Ababa University (AAU).

Lead researchers:
The research team for the development of the Strategic Agenda includes Dr. Semu Ayalew Moges, Dr. Geremew Sahilu and Mr. Tadesse Animaw Sinshaw, from Addis Ababa University; Dr. Alebel Bayru from Ethiopian Development Research Institute; and Dr. Liqa Raschid-Sally and Mr. Edmund K. Akoto-Danso from the International Water Management Institute (IWMI).

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The Climate Change Forum - Ethiopia, represented by Mr. Gebru Jember, has been associated with the project from the outset, and will support the dissemination of the research findings and the strategic recommendations.

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List of acronyms

Acronym	Name
AA	Addis Ababa
AACRA	Addis Ababa City Road Authority
AAWSA	Addis Ababa Water and Sewerage Authority
BMP	Best Management Practices
DFID	Department for International Development
EPA	Environmental Protection Authority
GIS	Geographic Information System
GTP	Growth and Transformation Plan
IDF	Intensity-Duration-Frequency
IDRC	International Development Research Centre
IPCC	Intergovernmental Panel on Climate Change
IUWM	Integrated Urban Water Management
IWRM	Integrated Water Resources Management
PAR	Participatory Action Research
Re-SAP	Research into Strategic Action Platform
SCS	Soil Conservation Service

Glossary and terms used

Climate change: is a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

Climate variability: refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events.

HEC-HMS: A hydrologic modelling system for modelling runoff at the catchment scale.

Integrated urban water management (IUWM): seeks to change the impact of urban development on the natural water cycle, by managing the urban water cycle as a whole.

IPCC Scenarios A1B and B1: These are scenarios constructed on the basis of 4 narrative story lines (A1, A2, B1 and B2), used to explore future developments in the global environment and their impact on climate. The A1 scenario story line emphasizes globalization, with intensification of market forces and rapid globalized economic growth. B1 emphasizes sustainability, with equity globalized, and extensive sustainable development. Scenario A1B is a subset of A1 indicating balanced energy across all sources both fossil and non-fossil (http://www.ess.co.at/METEO/CCS.html, and http://www.ipcc.ch/ipccreports/tar/wg1/029.htm).

RegCM4: A regional climate model for dynamic downscaling of outputs of Global climate models (GCMs).

Solid waste: Non-liquid, non-soluble materials ranging from municipal garbage to industrial wastes that contain complex and sometimes hazardous substances.

Storm water: the rainfall that flows over yards, streets, alleys, parking lots, farms and buildings, and enters the storm drain system.

VENSIM: The Ventana Systems Environment model (VENSIM) is a visual modelling tool that serves to conceptualize, document, simulate, analyze and optimize models of dynamic systems.

Wastewater: Water carrying wastes from homes, businesses and industries that is a mixture of water and dissolved or suspended solids.

Waterborne diseases: are caused by pathogenic microorganisms which are directly transmitted when contaminated freshwater is consumed.

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For further information, contact:

Semu Ayalew Moges (PhD)
semu.moges@aait.edu.et; semu_moges_2000@yahoo.com
Chair, Climate, Hydrology and Water Resources Systems (CHWRS)
Addis Ababa University, Addis Ababa Institute of Technology (AAiT)
Department of Civil and Environmental Engineering
P. O. Box 385, Addis Ababa, Ethiopia
Office: +251-111-232437 || Mobile: +251-921-606078

Geremew Sahilu (PhD)
gsahilu@gmail.com
Addis Ababa University, Addis Ababa
Institute of Technology (AAiT)
Department of Civil and Environmental Engineering
P. O. ,Box 385, Addis Ababa, Ethiopia
Office: +251-111-232437 || Mobile: +251-911-620361

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