# URAdapt

## Managing Water at the Urban-Rural Interface: The key to climate change resilient cities

# Mainstreaming Climate Change Issues - the impact of climatic and non-climatic drivers on Addis Ababa Water Supply and Waste Water System

Addis, 29 May 2012

International Water Management Institute

# *Mainstreaming Climate Change Issues - the impact of climatic and non-climatic drivers on Addis Ababa Water Supply and Waste Water System*

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**Others Students:**

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**International lead and Collaborator:**

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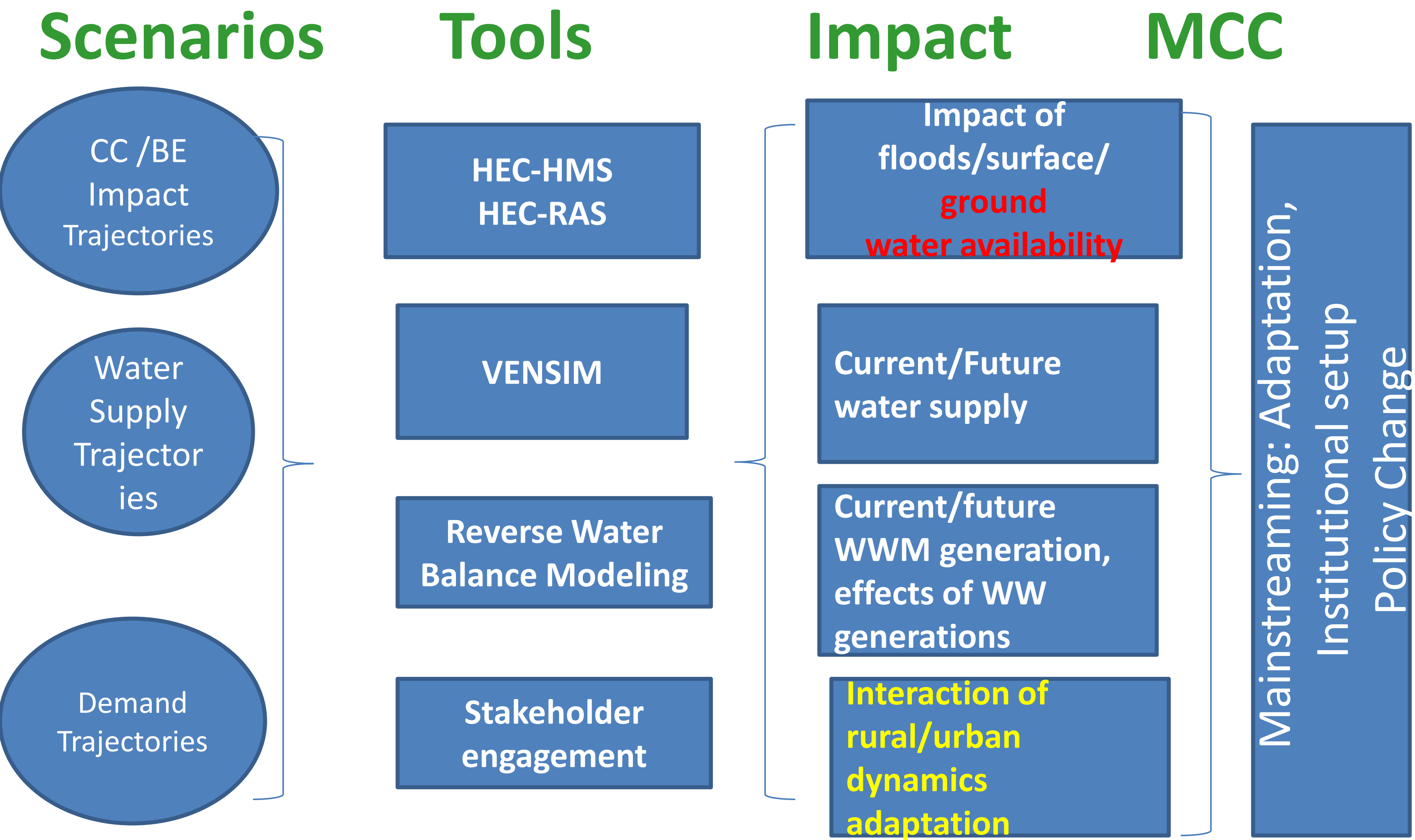
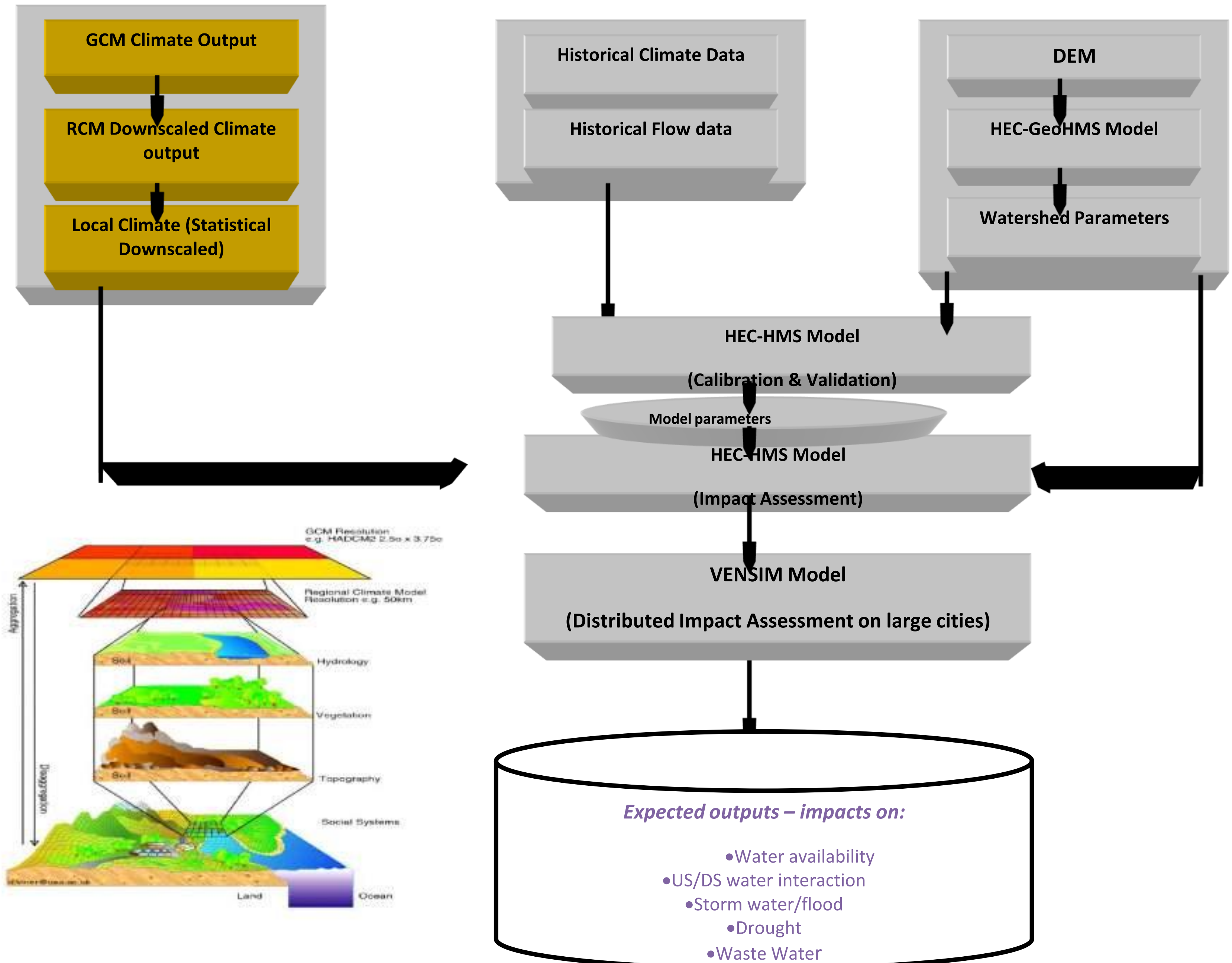
# I. Approach: Impact-Output Trajectories



# I. Approach: Impact-Output Trajectories



# I. Approach: Change/Impact Drivers

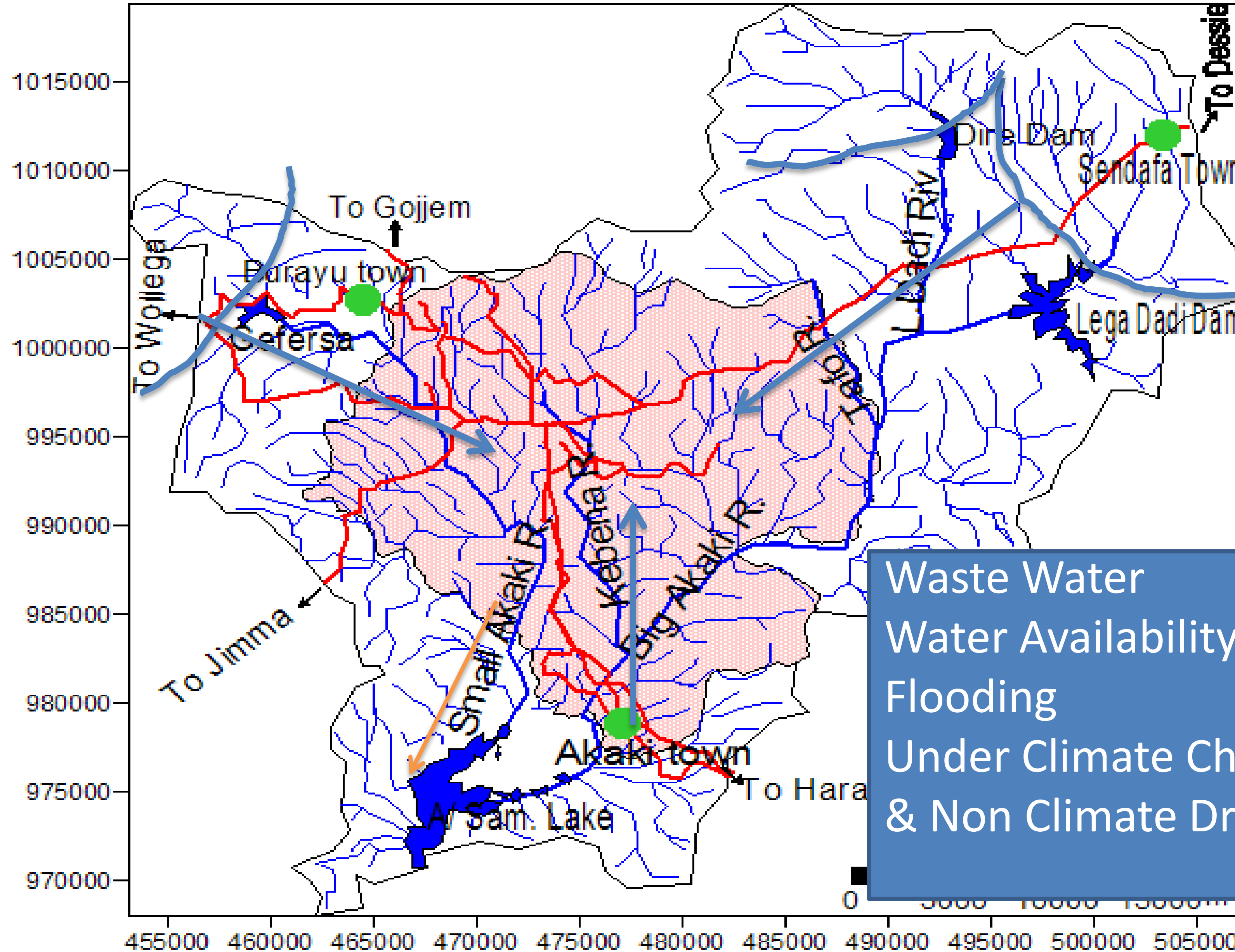
## 1. Climatic Drivers

- Precipitation change
- Temperature change

## 2. Non-Climatic Drivers

- Built Environment Change

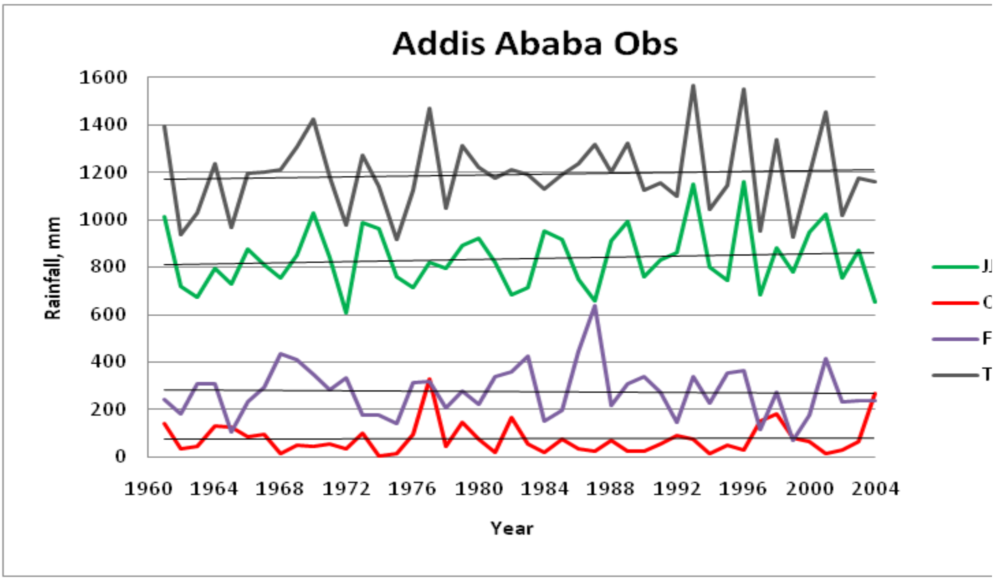
# I. Approaches: Study Description/problems

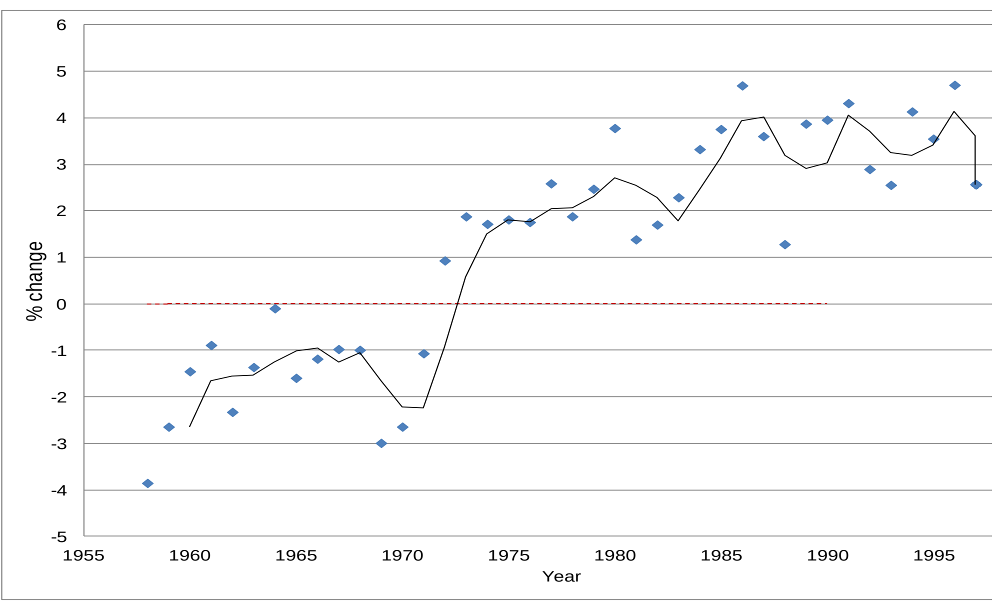


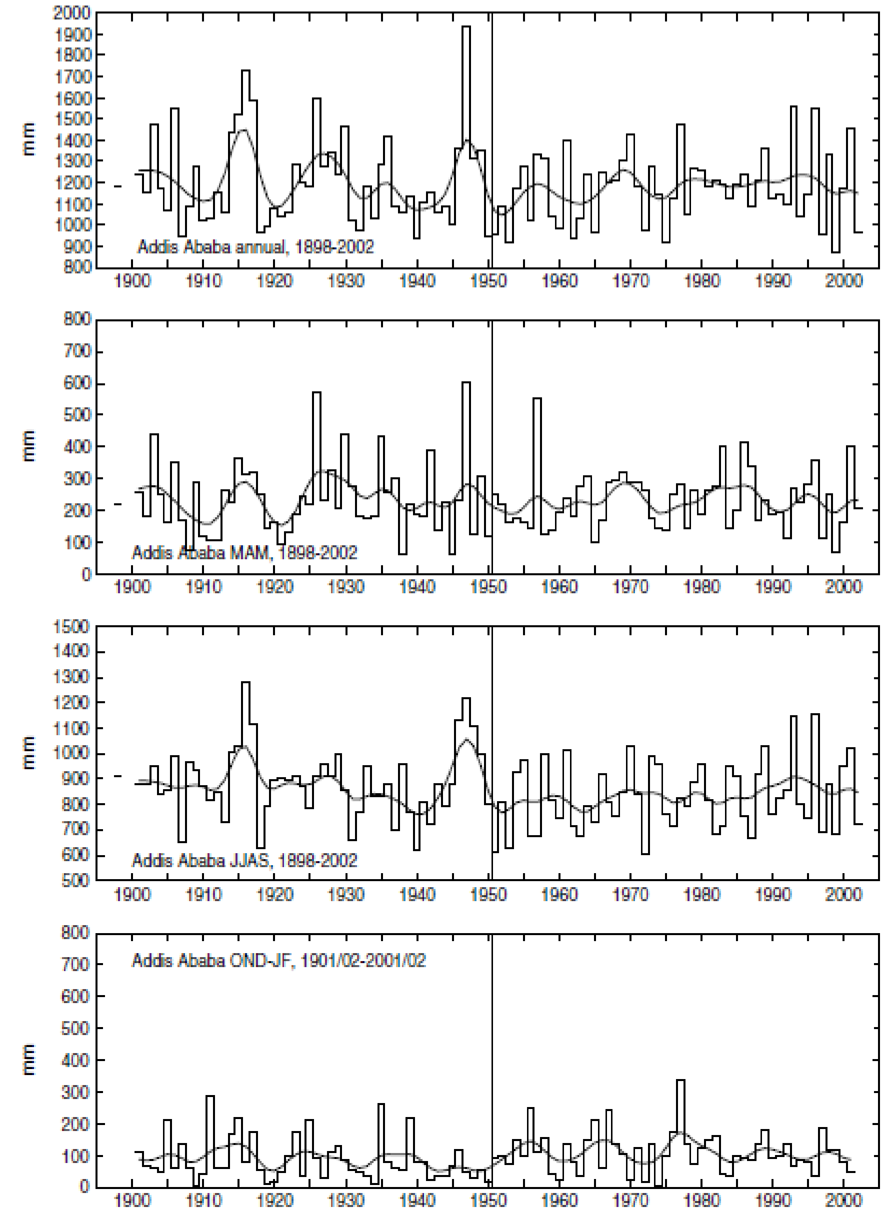

Waste Water
Water Availability
Flooding
Under Climate Change
& Non Climate Driver

# II. Climate Change Driver

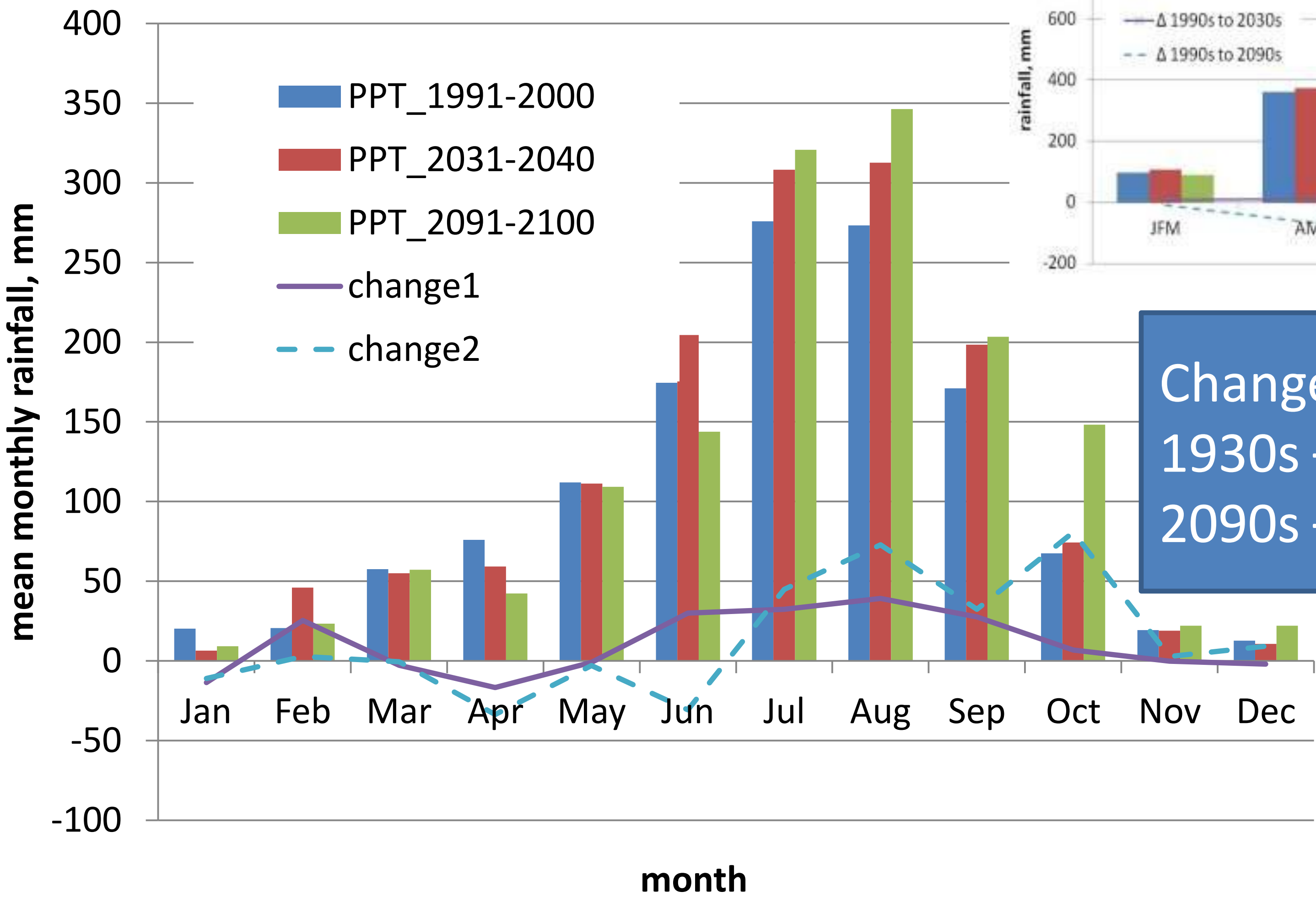
## a. Observational Evidence

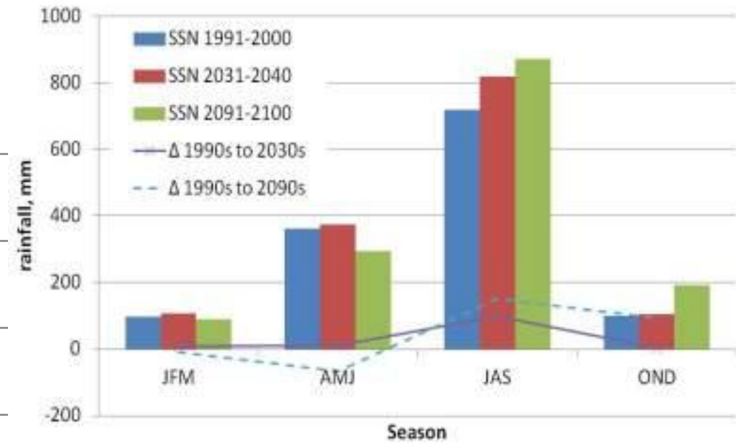


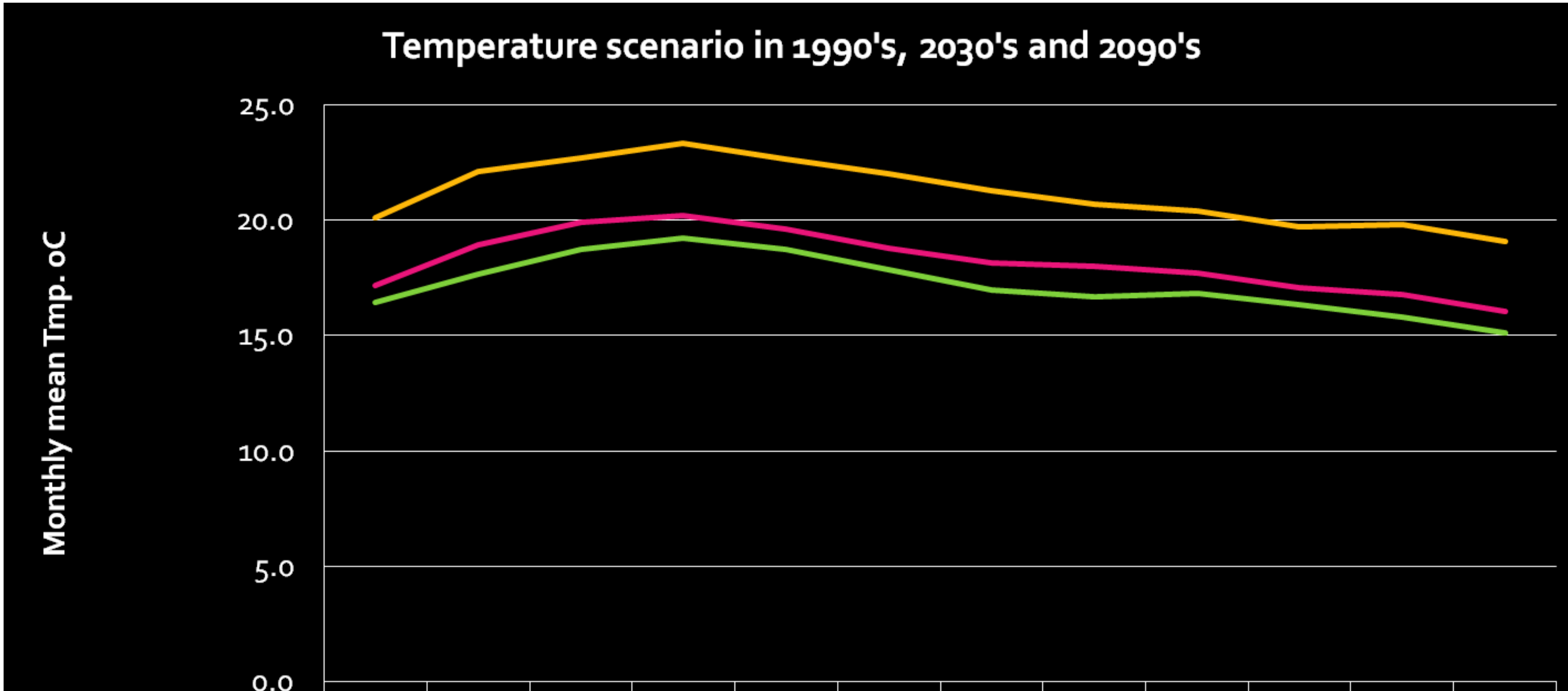
# II. Climate Change Driver
# b. Model Output: Rainfall Change




Change in Flow
1930s – 1990s = 8%
2090s – 1990 = 13 %

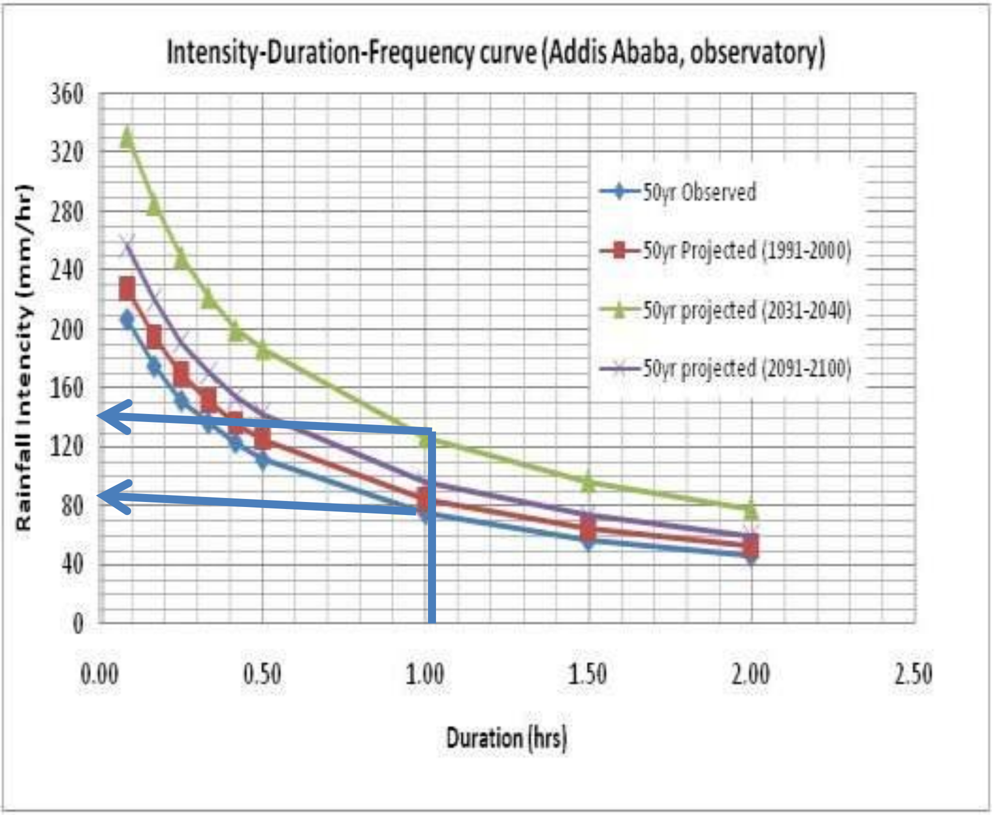
# II. Climate Change Driver
# d. Model Output: Temperature

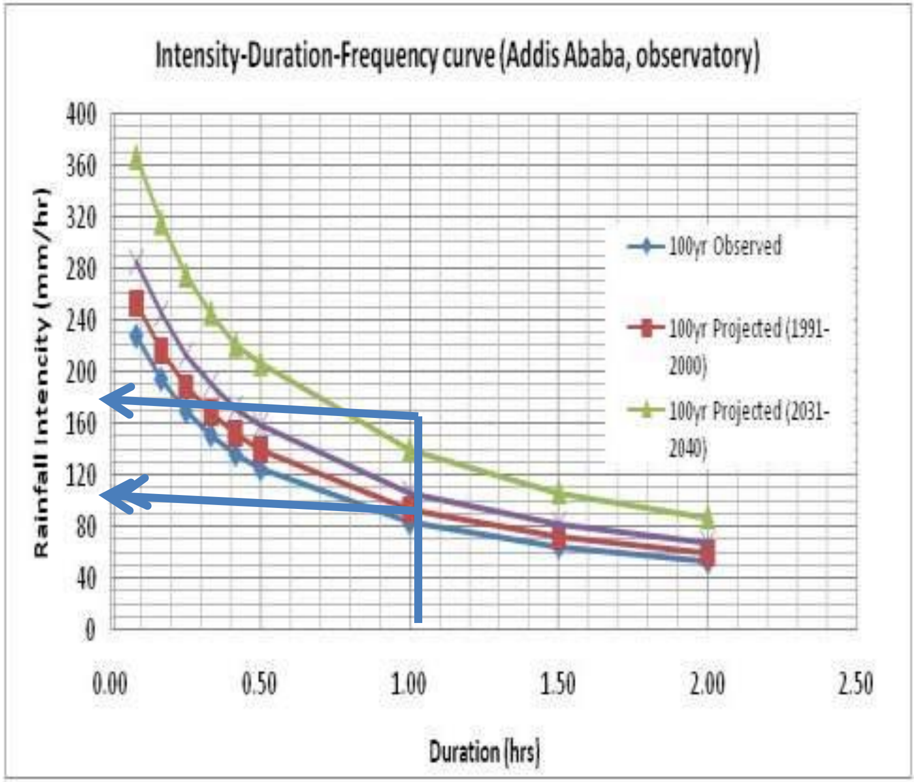



| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tmp_1991-2000 | 16.4 | 17.7 | 18.7 | 19.2 | 18.7 | 17.9 | 17.0 | 16.7 | 16.8 | 16.3 | 15.8 | 15.1 |
| Tmp_2031-2040 | 17.1 | 18.9 | 19.9 | 20.2 | 19.6 | 18.8 | 18.2 | 18.0 | 17.7 | 17.0 | 16.8 | 16.0 |
| Tmp_2091-2100 | 20.1 | 22.1 | 22.7 | 23.3 | 22.6 | 22.0 | 21.3 | 20.7 | 20.4 | 19.7 | 19.8 | 19.1 |

# III. Climate Change Driver

## a. Impact on Intensity & Flooding - Kebena



# III. Climate Change Driver

# a. Impact on Intensity & Flooding - Kebena

| Return Period | 24-Hour-Depth-Frequency | | |
|---|---|---|---|
| | Observed | Projected | |
| | 1991-2000 | 2031-2040 | 2091-2100 |
| 2 | 46.37 | 61.16 | 52.19 |
| 5 | 54.67 | 74 | 62.39 |
| 10 | 60.16 | 82.51 | 69.14 |
| 25 | 67.1 | 93.25 | 77.67 |
| 50 | 72.25 | 101.23 | 84 |
| 100 | 77.36 | 109.14 | 90.29 |

On average the flood extremes will likely increase by 37 % in 2030s and 15 % in 2090s

Which means, 10 yrs T flood in 2030s

# III. Climate Change Driver

## a. Impact on Intensity & Flooding - Kebena

| Observed | | Projected | | | |
|---|---|---|---|---|---|
| 1991-2000 | | 2031-2040 | | 2091-2100 | |
| Return Period | Risk | Return Period | Risk | Return Period | Risk |
| 2 | 75 | 11 | 99 | 4 | 92 |
| 5 | 67 | 68 | 100 | 13 | 95 |
| 10 | 65 | 200 | 100 | 32 | 96 |
| 25 | 64 | 869 | 100 | 104 | 98 |
| 50 | 63 | 2582 | 100 | 246 | 100 |
| 100 | 63 | 7602 | 100 | 580 | 100 |

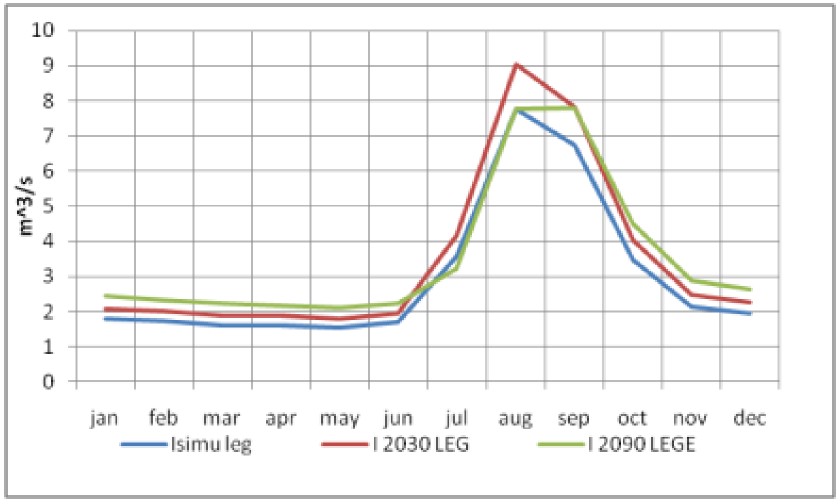
# III. Climate Change Driver
## a. Impact on Intensity & Flooding - Kebena

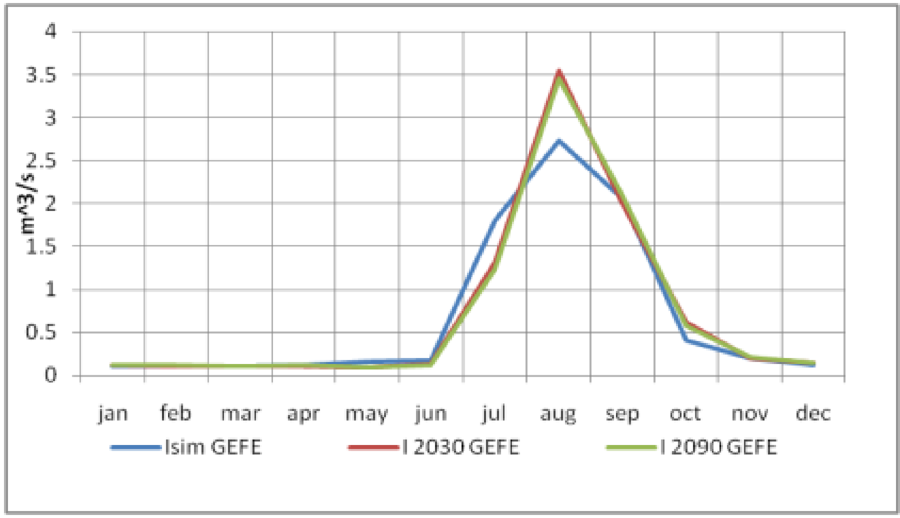
- 10 years return period flood in 1990s is equivalent to 2 years return period of flood in 2030s and is about 4 years return period of flood in 2090s
- 50 years return period flood in 1990s is equivalent to less than 5 years return period of flood in 2030s and about 10 years return period of flood in 2090s
- 100 years return period flood in 1990s is equivalent to less than 10 years return period of flood in 2030s and it is only about 25 years return period of flood in 2090s

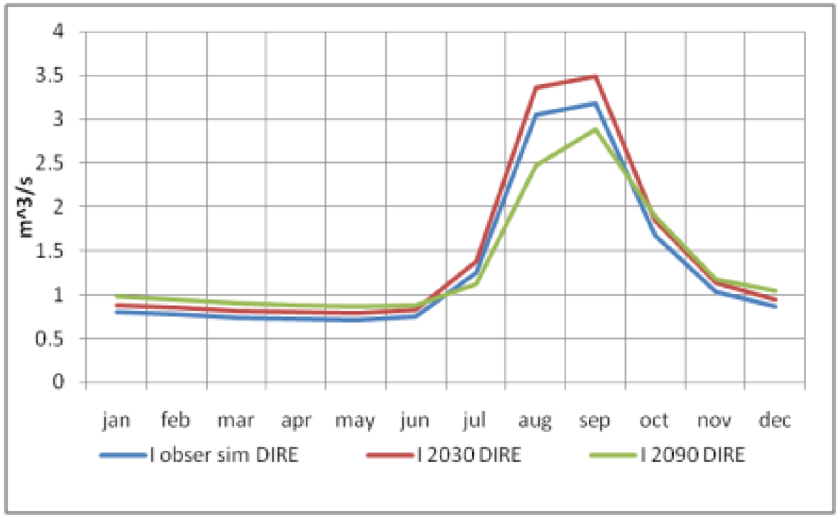
Re-thinking Urban Drainage Infrastructure design guidelines to be modified/reviewed

# III. Climate Change Impact

## b. Impact on Water Availability – Inflow to Reservoirs

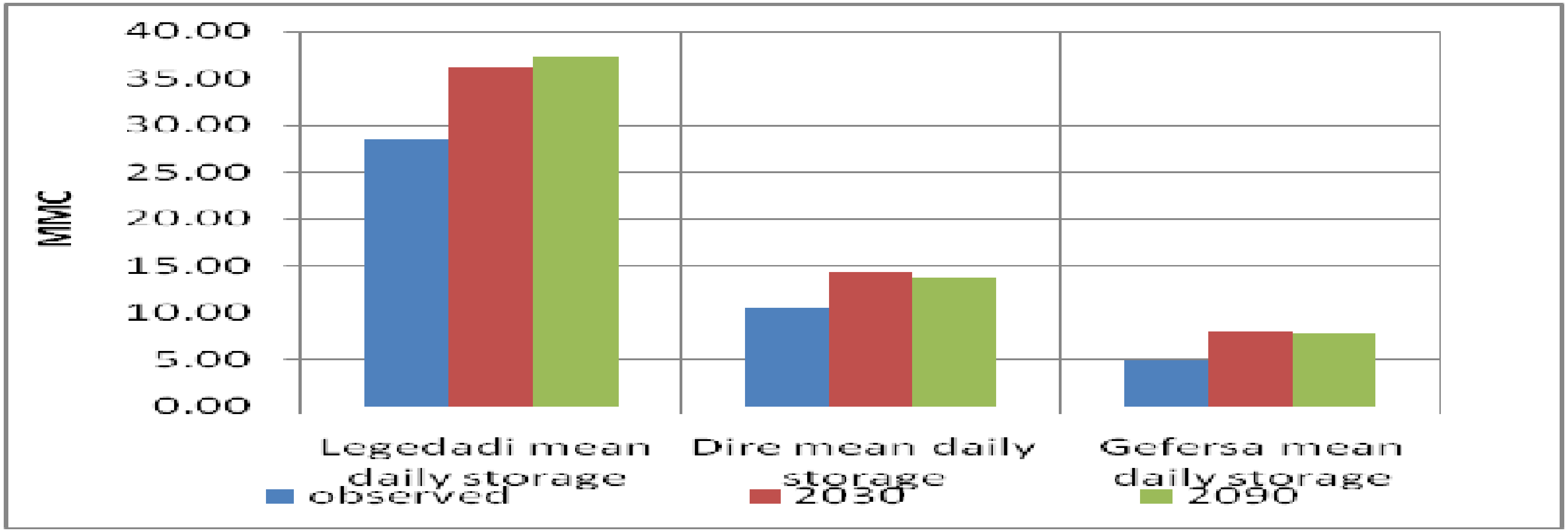



| Dam | Inflows | | % use | % CC | |
|---|---|---|---|---|---|
| | m3/s | MCM | | 2030s | 2090s |
| Legedadi | 2.9 | 91.0 | 50.9 | **+15.8** | **+14.8** |
| Dire | 1.2 | 37.0 | 41.4 | **+9.0** | **+3.0** |
| Gefersa | 0.7 | 21.5 | 49.6 | **+5.0** | **+3.8** |

# III. Climate Change Impact
# c. Impact on Water Availability – Storage




| Dam | Inflows | | % CC | |
|---|---|---|---|---|
| | m3/s | MCM | 2030s | 2090s |
| Legedadi | 2.9 | 91.0 | **+20.9** | **+19.2** |
| Dire | 1.2 | 37.0 | **+26.5** | **+23.8** |
| Gefersa | 0.7 | 21.5 | **+37.8** | **+37.6** |

# III. Climate Change Impact
# d. Impact on Water Availability

- The increase in water availability from the inflow and storage reservoir is a good news to Addis Ababa
- But because AA sits at the head water system (small water sources) in general it is not enough to offset the growing demand requirement beyond 2020s
- Ground water availability was not considered in this study

# IV. Non-Climate Drivers
## Expansion of Built Environment

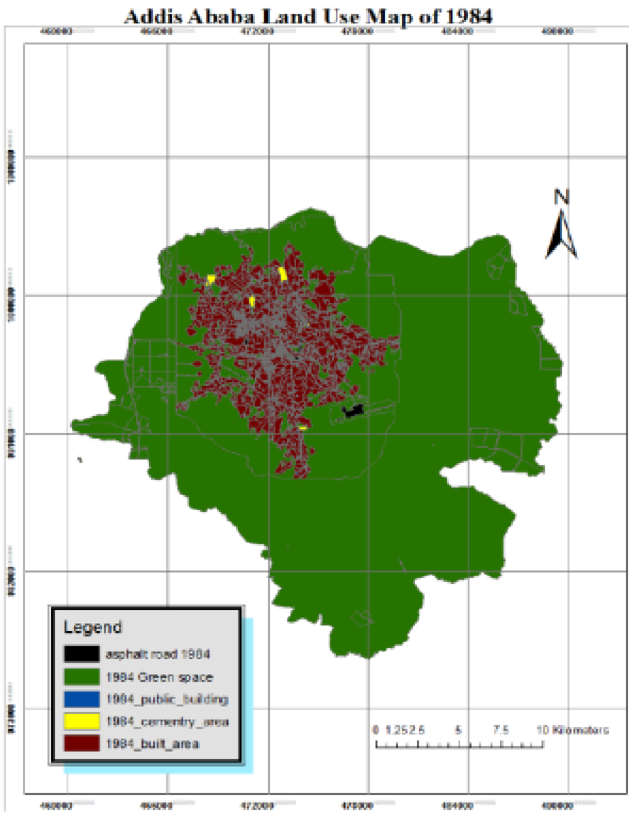


Figure 3.3 Land use map of 1984

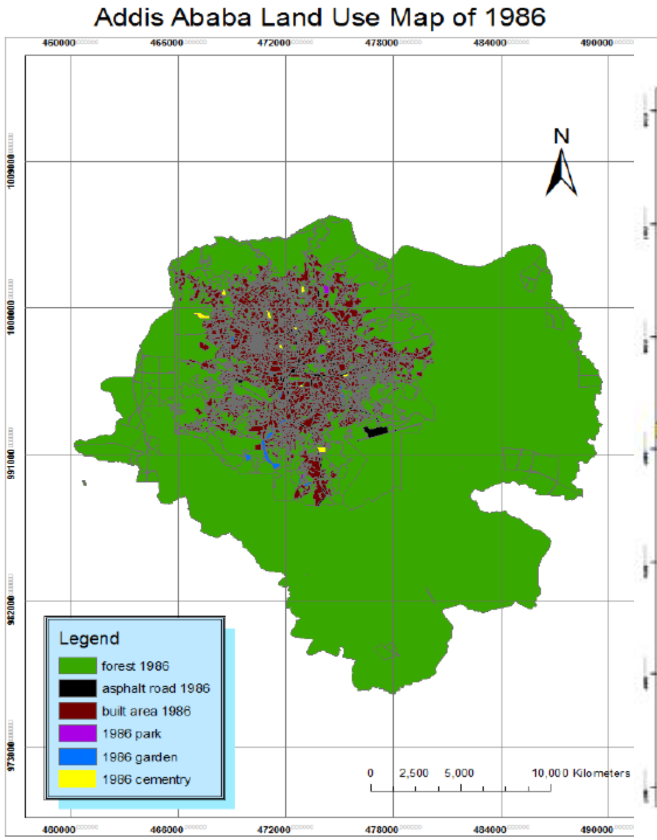


Figure 3.4 Land use map of 1986

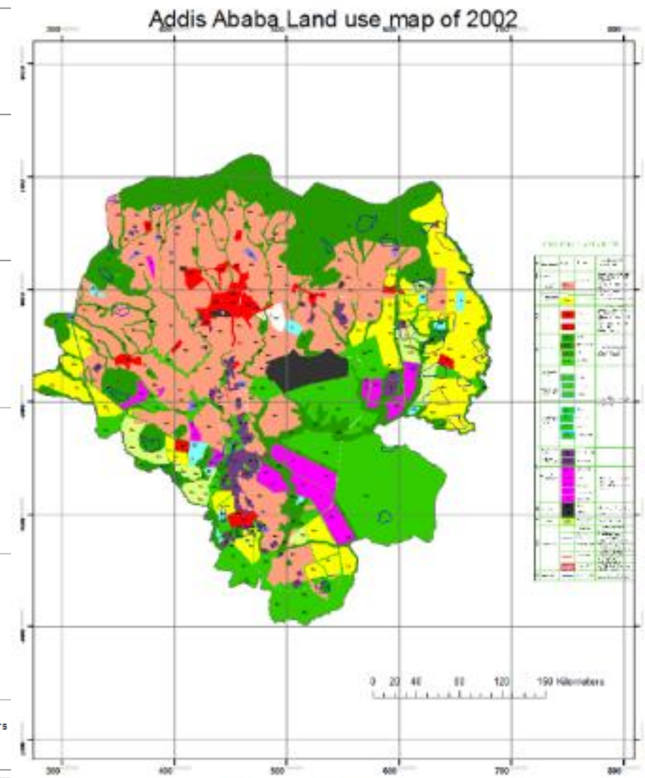
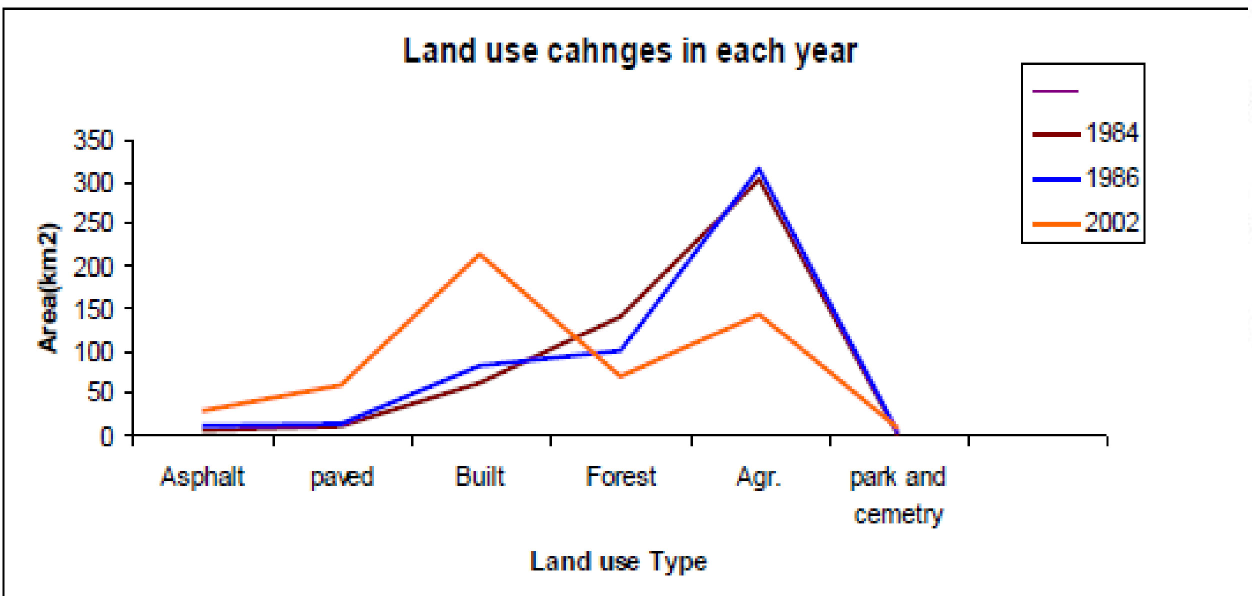


Figure 3.5 Land use map of 2002

# IV. Non-Climate Drivers: Expansion of Built Environment

| Year | Total Area ($km^2$) | Land use Type | | | | | |
|---|---|---|---|---|---|---|---|
| | | Impervious Area | | | Pervious Area | | |
| | | Asphalt ($km^2$) | Paved ($km^2$) | Built ($km^2$) | Forest ($km^2$) | Agriculture ($km^2$) | Cemetery and park ($km^2$) |
| 1984 | 517.87 | 4.72 | 11.16 | 60.15 | 139.023 | 301.7 | 1.09 |
| 1986 | 517.87 | 10.734 | 12.864 | 80.173 | 98.062 | 314.67 | 1.38 |
| 2002 | 517.87 | 27.704 | 57.358 | 212.733 | 68.717 | 142.87 | 8.43 |



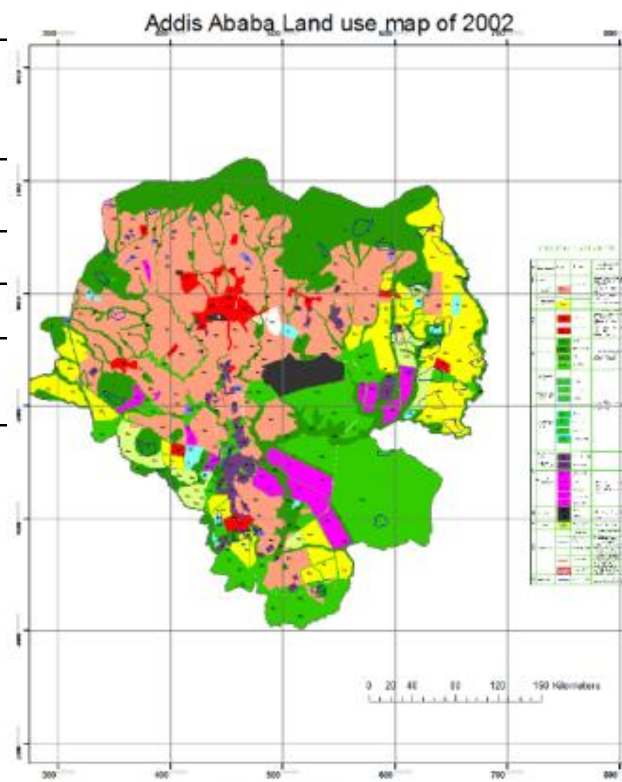




Figure 3.5 Land use map of 2002

# IV. Non-Climate Drivers:
# Change in the Built Environment

1984

| Landuse type | Asphalt | Paved | Built | Forest | Agriculture | Cemetery and park |
|---|---|---|---|---|---|---|
| Area(km2) | 4.716 | 11.155 | 60.146 | 139.023 | 301.7 | 1.09 |
| Area (%) | 0.91 | 2.15 | 11.61 | 26.85 | 58.26 | 0.21 |

1986

| Land use type | Asphalt | Paved | Built | Forest | Agriculture | Cemetery and park |
|---|---|---|---|---|---|---|
| Area(km2) | 10.734 | 12.864 | 80.173 | 98.062 | 314.666 | 1.375 |
| Area (%) | 2.07 | 2.48 | 15.48 | 18.94 | 60.76 | 0.27 |

2002

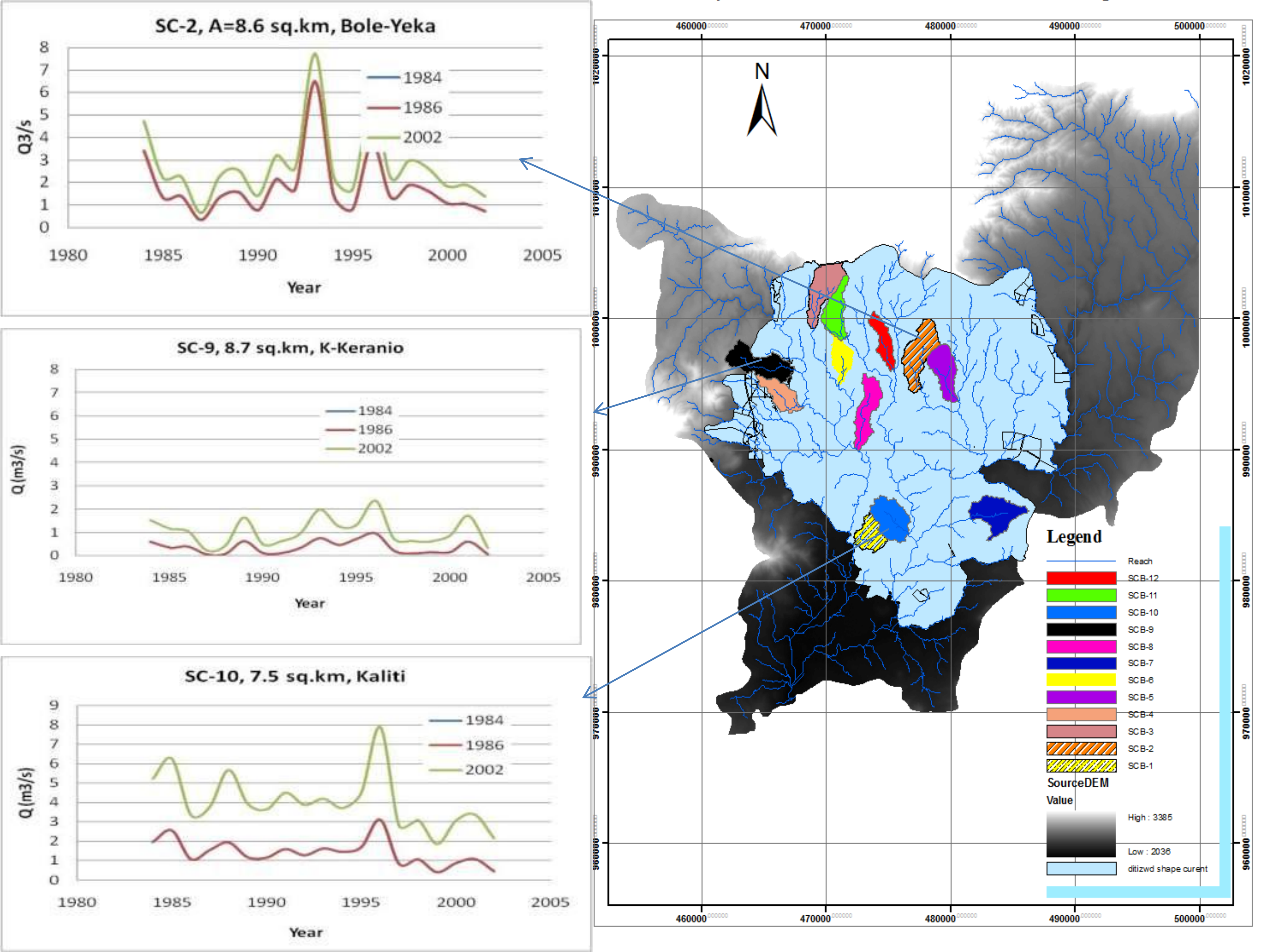
| Land use type | Asphalt | Paved | Built | Forest | Agriculture | Cemetery and park |
|---|---|---|---|---|---|---|
| Area(km2) | 27.704 | 57.358 | 212.733 | 68.717 | 142.870 | 8.425 |
| Area (%) | 5.35 | 11.08 | 41.08 | 13.27 | 27.60 | 1.63 |

# IV. Non-Climate Drivers:

## The Impact : Increased Flood and Runoff

### i. Runoff Volume

| Land use period | Annual Average Rainfall (mm) (1984-2002 | Annual Average Runoff (mm) | Annual Average Runoff (MCM) | Runoff Coefficient (R.C.) | % Runoff Volume Increase |
|---|---|---|---|---|---|
| 1984 | 791 | 221.4 | 114.7 | 0.28 | - |
| 1986 | 791 | 239 | 123.8 | 0.30 | 7.90 |
| 2002 | 791 | 358.4 | 185.6 | 0.45 | 61.9 |
| 2010 | ???? | ???? | ???? | ???? | ???? |


SC-2, A=8.6 sq.km, Bole-Yeka
Q3/s
Year
1984
1986
2002
SC-9, 8.7 sq.km, K-Keranio
Q (m3/s)
Year
1984
1986
2002
SC-10, 7.5 sq.km, Kaliti
Q (m3/s)
Year
1984
1986
2002
N
460000
470000
480000
490000
500000
960000
970000
980000
990000
1000000
1010000
1020000
Legend
Reach
SCB-12
SCB-11
SCB-10
SCB-9
SCB-8
SCB-7
SCB-6
SCB-5
SCB-4
SCB-3
SCB-2
SCB-1
SourceDEM
Value
High : 3385
Low : 2036
ditizwd shape curent

# IV. Non-Climate Drivers:
## The Impact : Increased Flood and Runoff

- **Flooding**
  - Volume and peak of flood will enormously increased due expansion of impervious surfaces (increased built environment)
  - This affects not the Intensity-Duration-Frequency (IDF) relationships like CC
    - but the flood peak-duration-frequency relationship (QDF) change will be significantly affected
    - additional issue necessitating Urban Infrastructure design Guideline to be changed
  - Compounded with climate change increases, the risk to city drainage infrastructure and the city as a whole will
    - Need to incorporate the CC or Non-CC impacts in infrastructure development

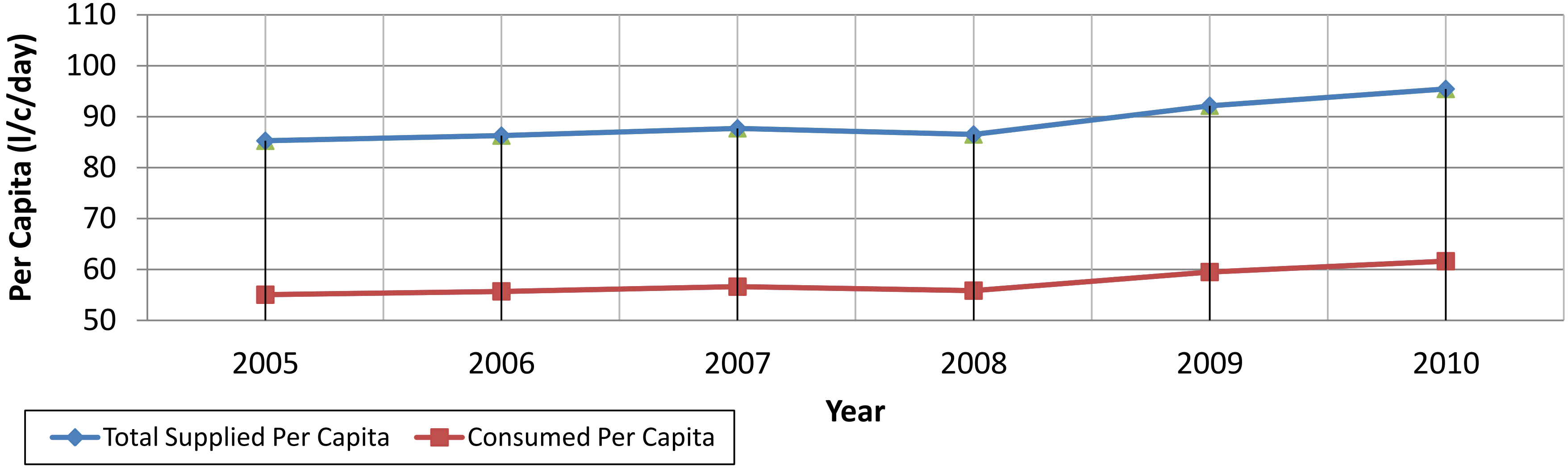
# Some Associated Risks

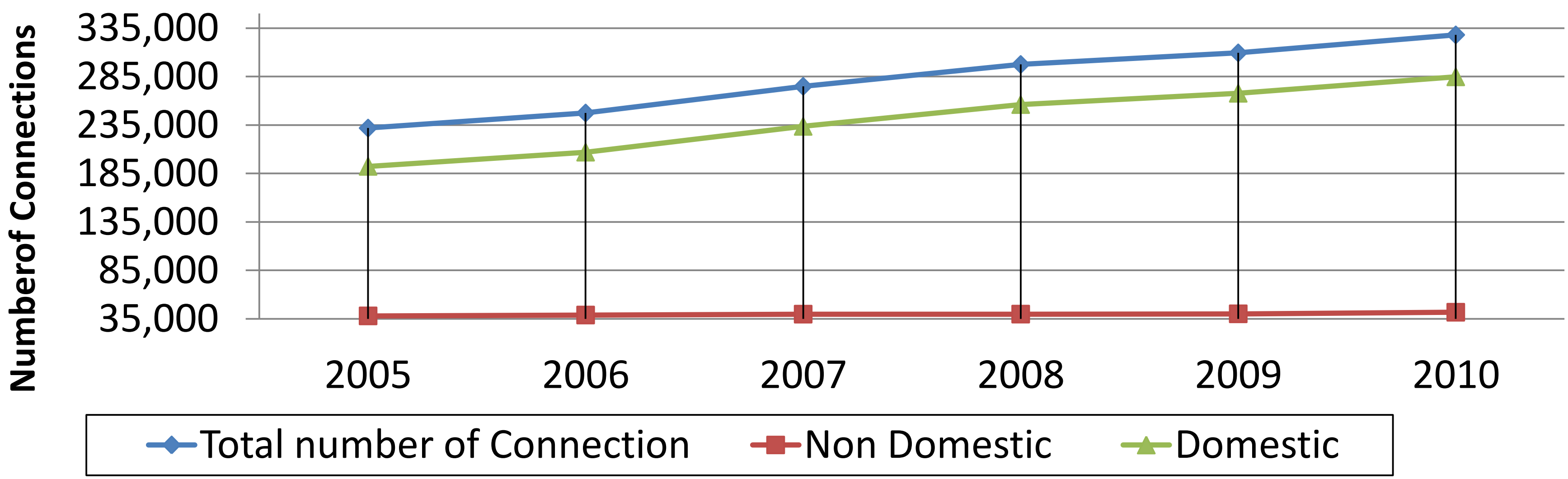
- Existing Drainage infrastructures may not cope with the situation
- Flooding may affect vulnerable communities
- Regular inundation of Street/blockage
- Water Supply Deficit increase is highly associated to demand increase
- Waste water treatment will be affected (higher T)
- Downstream communities will be affected

# V. Water Supply-Water Demand
## a. Water Supply

- **Increase Water Demand and shortfall water supply**
  - **Water Supply (2010 G.C) - 300000 m3/d**
  - **Projected Water Demand (2009 G.C ) - 454,208 $m^3$/d**
  - **Current shortfall of water supply(2009) -192,208 $m^3$/ d**
    - **Deficit/shortfall in 2009 = 42%**
    - **Deficit/shortfall in 2010 = 34%**
  - **Projected Water Demand (2040)- 2,706,088 $m^3$/ day, a 16% an increase annually for the next 30 years**
    - **Significant Shortfall by 2040**

# V. Water Supply-Water Demand
# a. Water demand increase



# V. Water Supply-Water Demand
# a. Water demand increase

- The current non-revenue water (NRW) level in the city of Addis Ababa is 38.2Million $m^3$/year (39.5% system input volume)
  - Potential economically recoverable volume is about 25% of the water total loss
  - Climate change (**temperature**) may increase demand

# V. Impact On Water Supply-Demand:
# b. Water Demand

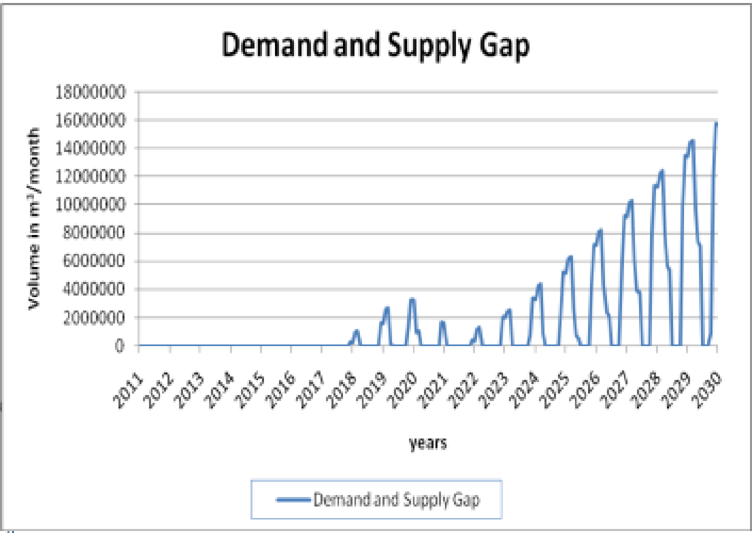
- Climate Change (T) significantly increase water demand in the city as well as U/S of the city
- Expansion of Built Environment – significantly increase per capita consumption and total water demand due to
  - i) population increase, ii) increasing wellbeing and iii) Temperature, iv) water distribution increase

# V. Impact On Water Supply-Demand Balance

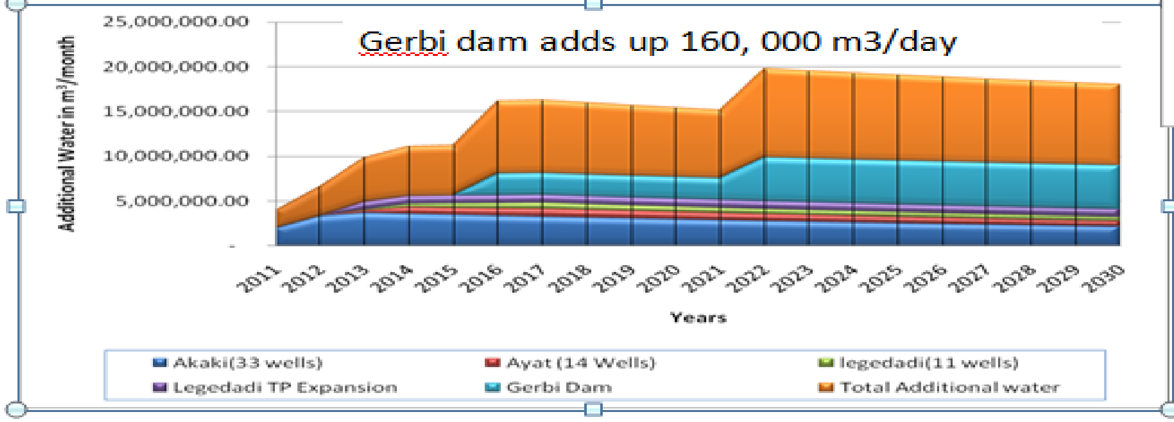
| *Type of Consumer* | *Consumption %* | *Remedial Action(%)in their Consumptions* | | | | *Total (%)* | *Additional Gain water from total supplied (%)* |
|---|---|---|---|---|---|---|---|
| | | *Self supply* | *Water use management and wastewater reuse* | *Use rain Water* | *Leakage reduction* | | |
| Domestic Use | 40.344 | | 10 | 20 | | 30 | 12.1032 |
| Non Domestic Use | 17.656 | | 20 | 5 | | 25 | 4.414 |
| Higher Consumer | 14.00 | 30 | 5 | 1 | | 36 | 5.04 |
| Industrial Use | 8 | 10 | 5 | 20 | | 35 | 2.8 |
| Leakage | 20 | | | | 50 | 50 | 10 |
| ***Total*** | ***100*** | ***5*** | ***8.7*** | ***10.7*** | ***10*** | | ***34.4*** |

Short term Water Supply Source: ground water (2011-2015)

| Well field Site | Potential in m3/day | Exportable Potential in % | Net Supply in m3/day | Average safe yield of Wells(l/se) |
|---|---|---|---|---|
| Akaki | 223,200 | 90 | 200,880 | 60 |
| Ayat | 100,000 | 80 | 80,000 | 30 |
| Legedadi | 100,000 | 80 | 80,000 | 30 |
| Total Supply from Ground Water | | | 360,880.00 | |




Medium Term Water Supply Source Development Plan (2016-2025)




AA will have critical water shortage after 2023

Distance water supply is an option (e.g. Sibilu or other sources

# VI. Impact On Waste Water

- Demand increase is related to waste water increase (80% becomes waste water)
- Climate Change (T) may significantly increase water demand thereby enhncing waste water generation
- Expansion of Built Environment – significantly increase per capita consumption and total water demand enhancing also waste water generation

# V. Suggestions to future Adaptation

## 1. ADAPTATION TO FLOOD IMPACTS

- ***Technical***
  - Re-evaluation of design guidelines of drainage structures - for new infrastructures
  - Regular maintenance and monitoring of existing infrastructures and retaining walls after flood season
- ***Institutional***
  - Reinforcing Institutional setup that deals with "flood and drainage" – NEED DEPARTMENT FOR FLOOD & DRAINAGE
  - Develop best management plans that focuses more on **flood absorbing than flood removing** (IUFM) – though distributed beneficial ponds, infiltration galleries, green area. WH

# V. Suggestions to future Adaptation

## 2. ADAPTATION TO WATER SUPPLY DEFICIT

- **In the medium term**, **sustained investment** is required
  - Improving water conservation and management practices and developing regulatory frameworks
    - E.g. large buildings such as Condos, Hotels, and real State Apartments can have water harvesting structures
  - Tapping on the potential of runoff generated in the city – Distributed Runoff Harvesting ( more than 100 MCM)
  - Developing the planned additional water sources
    - Gerbi dam, additional wells
- **In the long term**, **Bold Investment** is required
  - Distance Water Supply development

# V. Suggestions to future Adaptation

- **Waste Water Increase:**
  - Use of Water conservation Facilities
  - Distributed treatment systems and water recycling
  - Considering to liaise with downstream communities to provide treated water for their agriculture
  - Promote industries using the slug (as fertilizer) and (treated waste water) for production of feeds

# Planned Additional Studies from University side

- Assessment of Distance Water Supply
- Assessment of CC on ground water
- What does the City and AAWSA expects and how does we enhance collaboration in the future??

# Thank You