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Evaluating the vulnerability of Tana Beles hydropower network to climate variability impact in Ethiopia

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WEL COME To MY PRESSENTATION SESSION

Evaluating the vulnerability of Tana Beles Hydropower network to climate variability impact in Ethiopia

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PERESENTATION OUTLINE

- ❖ Introduction
- ❖ Problem statement
- ❖ Objectives of the study
- ❖ Data base and Methodology
- ❖ Results and Discussions
- ❖ Conclusions and Recommendations

Introduction

- Ethiopia lies in the eastern Horn of Africa covering about 1,221,900 sq. km as shown in the figure 1.1
- With a total population of 55 million.
- Of the total population, 90% of the people earn their living mainly from agricultural activity
- The annual rainfall distribution in the western part of the country has one maxima during July or August.

Introduction continued………..

- The rainfall seasonality of the country is determined mainly by seasonal change in the large-scale circulation, north south movement of ITCZ (Inter Tropical Convergence Zone).
- The Ethiopian economy is mainly based on rain-fed agriculture.
- Regardless of the presence of surface and groundwater resources, the failure of seasonal rains seriously affects the country's food production prospects

Introduction continued………..

- The central and most of the eastern half of the country have two rainy periods and one dry period.
- The two rainy periods are locally known as *Kiremt* (June to September) and *Belg* (February to May), which are the long and short rainy periods, respectively
- The dry period, which covers the rest of the year (i.e., October to January), is known as *Bega*.

Introduction continued………..

- The sub-basin has high rainfall with a number of perennial rivers, the potential agricultural land within the sub-basin and adjacent basins is very large, which requires more water than the available surface water.
- There is also a competition of water use for hydroelectric power, tourist attraction (Tis Abbay fall), irrigation and lake transportation

Introduction continued………

- The initial identified development sites are mostly centered on Lake Tana sub-basin).
- Because of the competing uses of water of Lake Tana and its sub-basins, assessment of water resources in relation to climate variability is critical for such development.
- The current study mainly deals with the interaction between same climatic parameters with Lake Tana sub-basin stream flow in Ethiopia

Introduction continued………..

- More specifically the study intended to investigate in depth
    - ✓ whether there are climate variability/extremes over the region
    - ✓ By considering same regional and global climatic factors and identify their effects on stream flow in relation to Tana Beles hydropower
- This paper responds the question of how one can use historic time series data to present a formal way of predicting the response of water level, and stream flow to climate variability and Extremes.

Introduction continued………..

➢Stream flow simulation and prediction have been widely used in water resources management,

- ✓Particularly for flood and drought analysis and for the determination of optimal operational rules for reservoir systems used for water supply and energy production.

➢Finally we include multiple linear regression predictive (MLR) model

➢In order to provide monthly as well as seasonal stream flow for Tana Beles hydropower sites in Ethiopia.

Introduction continued……….

- ✓ The out come of this study would help the policy-makers and Hydrologists in order to predict the over all stream flow fluctuation based on the climatic factors that might be minimize the intended poor management and poor hydroelectric generation capacity in Ethiopia.
- ✓ The use of such information would also be helpful for strengthening early warning systems in the processes of applying proper electric power utilization.

Description of study area

1. Topography and location of the study area

➢ Tana Reservoir is located in three administrative zones of the Amhara Region

In the North Gondar
- North
- North-west

In the South Gondar
- East
- southeast,

In the West Gojjam
- south
- south-west

Description of study area ………..

- Lake Tana has a surface area of 3120 km^2 at elevation of 1786 m.a.s.l

- Large portion of the Tana water surface (the reservoir) is located in north Gondar, and some portion in south Gondar and west Gojjam administrative zones as shown in the figure 1.2 and 1.3

Climate condition of the study area

- According to the study of NMSA (NMSA Bulletin Vol-1, Jan 1996) the Tana basin is identified to have two distinct dry and wet seasons.
- The Lake Tana basin is included in the rainfall regime designated as region-B,dominated by single maxima rainfall pattern.
- Region-B is subdivided in to three parts designated as b1, b2 and b3, where the wet period runs from February/March to October/November, April/May to October/November and from June/July to August/September respectively (Tesfaye and Yarotskaya, 1988).

Climate condition of the study area……………

✓The mean annual rainfall at Bahir Dar (south portion of the basin) is 1450mm, 1200mm at Addis Zemen (eastern portion) and 1050 at Gondar Air Port meteo station

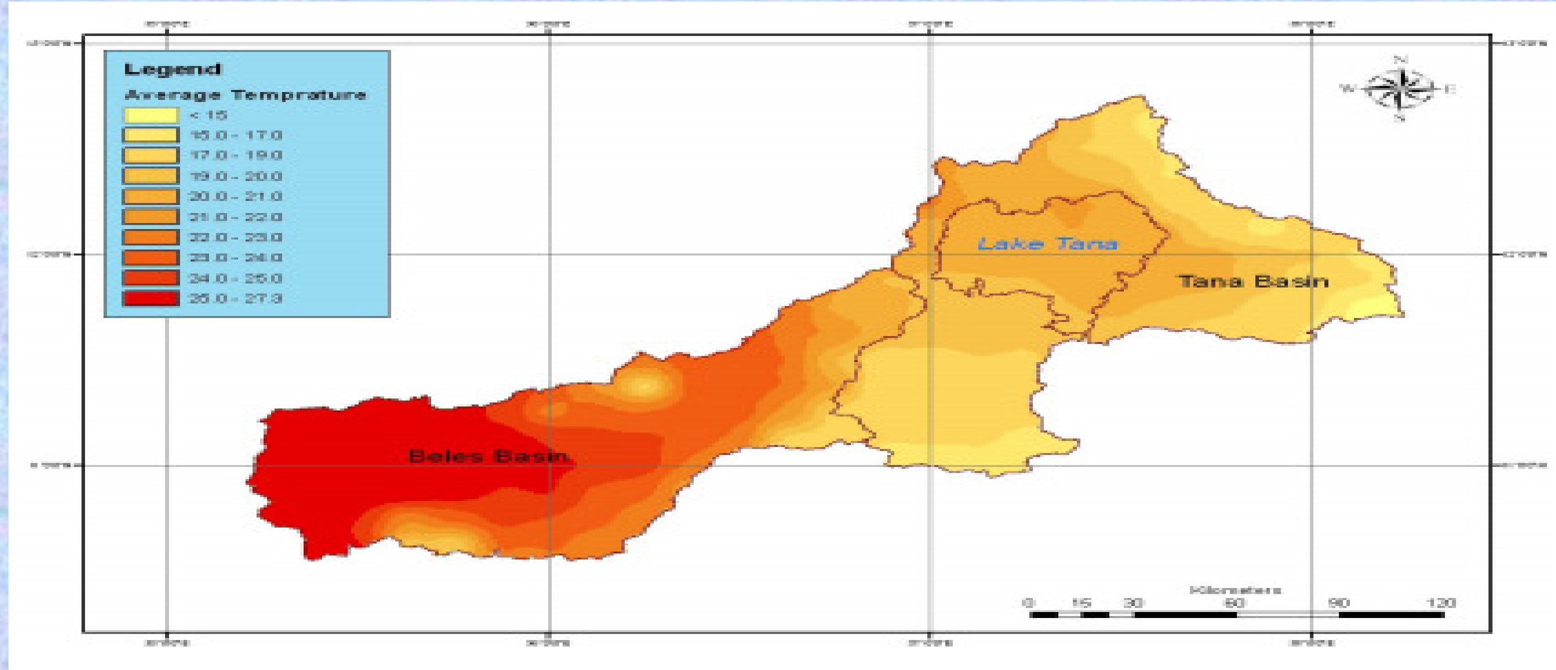
✓Rainfall distribution, both in time and space, decreases northwards in the basin See figure 1.4

✓Temperature generally decreases with altitude by about $0.7c^0$ per 100 m.

✓Annual temperature distribution in the project area is shown in Figure 1.5.

Climate condition of the study area……………

➢Average annual temperatures range from 13c^0 in the eastern part of the Tana basin to more than 25C^0 in the lower Beles basin



Average annual temperatures in the project area (degree C)

Reservoir Capacity and Stream Flow

- The capacity of the reservoir at 1786masl is estimated to be 29175mm^3
- The rivers and/or streams draining the Tana basin are categorized in four major sub basins namely
  - The Gilgel Abbay sub basin includes all the inflows from the south;
  - Gumara Sub basin includes all the inflows from the east;
  - Ribb Sub basin includes the inflows from northeast; and
  - The Megech sub basin includes the inflows from the north directions
- According to the study of the Tana-Beles project, the Lake Tana basin has a total catchment area of 15,320Km^2 to which the following contributes:

Problem statement

- The Ethiopian government has for long recognized that economic progress will depend principally on the development of the hydropower resources of the country.
- Ethiopia is endowed with abundant water resources distributed in many parts of the country however; this hydropower development highly vulnerable to the impact of climatic variability/extremes,
- This hydropower development highly vulnerable to the impact of climatic variability/extremes, which fluctuates the mean annual inflow and outflow of the reservoirs.

Problem statement……

➢Ethiopia has one of the lowest levels of per capital electrical consumption in the world. Out of hydropower potential of about 15,000-30,000 MW, only about 360 MW (i.e. less than 2 percent) has been exploited by 1997.

➢Ethiopia is poorly adapted to the current climatic variability, climate extremes and Climate changes, as a result so far no seasonal (annual) stream flow prediction for proper management of hydro-power resources in Ethio**pia.** However, the climate information, which issued in real-time may minimize risk and design proper electric utilization system according to seasonal climate outlooks.

➢Even as the hydropower networking techniques are getting sophisticated this problem has not got proper solutions as it continued to emerge from year- to- year

Objectives of the *study*

➢The main objective of this study is ,to assess the impact of climate variability and extremes on stream flow of Lake Tana in relation to hydropower.

The Specific objectives are

1. To formulate the relationship between climate variability indices with stream flow of Lake Tana
2. To identify the season in which the stream flow attain maximum peaks
3. To develop a statistical model that enables to assess and predict the stream flow of Lake Tana from difference Tributaries by using climate factors as input
4. To design policy planning on ways to use climate information in the process of proper electric utilization system

by using

Scope of the study

Station level rainfall and temperature data, ENSO indices (*SST and SOI)* data stream flow data of Lake Tana

The SYSTAT software were used to perform appropriate analysis in determining the linear linkage between stream flow Lake Tana and climate patterns, as well as MLR Models

Significance of the research

1.For Hydrologist, electric power disseminators and governmental body

2. Helps the Hydrologist and electric power disseminators to predict the stream flow fluctuation in seasonal basis,

3.Based on the skill of the designed predictive models the local community as well as hydropower managers could utilize information as primary input in designing early stage protective measure and minimize the adverse effect of climate-related fluctuation of inflow and out flow of the Lake Tana reservoir

LITERATURE REVIEW

➢ **The ENSO Current and Potential Impacts over Ethiopia**

Too much water due to positive phase of ENSO (La Nina)

Drought areas due to negative phase of ENSO (El Nino)

➢**Seasonal and annual Variation of runoff due to ENSO impact over Lake Tana**

Seasonal and annual runoff variations over Gilgel Abbay

DATA BASE AND METHODOLOGY

- **Data base**
- Monthly rainfall and temperature data used in this study are obtained from the Ethiopian National Meteorological Agency
- monthly stream flow of Lake Tana obtained from Ministry of Water Resources (MoWR).
- Global Sea Surface Temperature (SST) obtained from the ERSST and extracted from the site http://www.cpc.noaa.gov/products/africa-desk

Methodology

By using 1. SYSTAT software

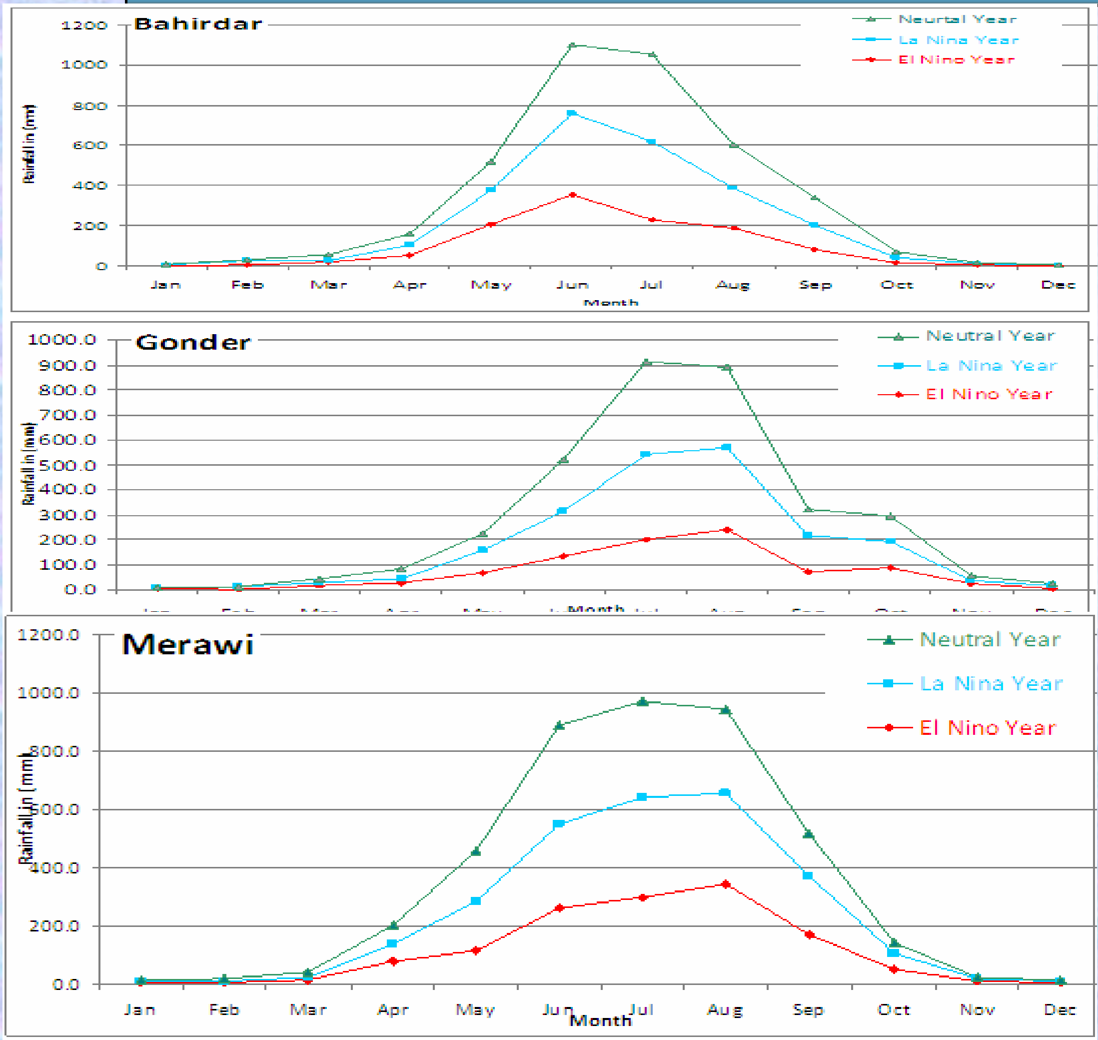
2. correlation analysis ,

3. Finally, by using SYSTAT software, multiple linear regression model (MLR) developed

RESULTS AND DISCUSSIONS

- **Assessment of Kiremt rains over Lake Tana Sub- basin stations based on ENSO events**
- Over Lake Tana Sub-basin stations ENSO can lead to seasonal shifting of the normal rainy season resulting in shorting or lengthening
- Even though JJAS is a major rainy season over Lake Tana Sub-basin the ENSO events have thought to be shifting the normality of rain and apparently the water storage of the Lake Tana
- ENSO Changes the mean monthly rainfall resulted into
  1. Disturbs the normal stream flow of Lake Tana sub-basin
  2. The fluctuation of mean monthly inflow (QIN) into the hydropower networking systems of Tana Beles hydropower.

RESULTS AND DISCUSSIONS……..



Stationwise mean monthly rainfall amount(mm) during El Nino ,La Nina and Nuetral episodic years

- Over all results shows that the mean monthly Kiremt rainfall amounts over Bahirdar, Gonder and Merawi significantly increased during La Nina events
- During El Nino events Kiremt rainfall is weakened and decreases
- During La Nina event increases the stream flow and runoff into the reservoir of Lake Tana

RESULTS AND DISCUSSIONS……..

- The shift in Kiremt season over Lake Tana Sub-basin stations evident due to the changes in the strength and position of synoptic systems that govern the Kiremt seasons during ENSO events
- To examine the overall impact of ENSO on regional rains, all-Lake Tana Sub-basin Kiremt rainy season averages were computed based on three stations distributed over the region for the periods 1982-2008 as shown in figure 4.2 bellow
- As it has been depicted in Fig. 4.2, the rainfall deficient occurred in 1983, 1984,1987,1991,1994 and 1997.

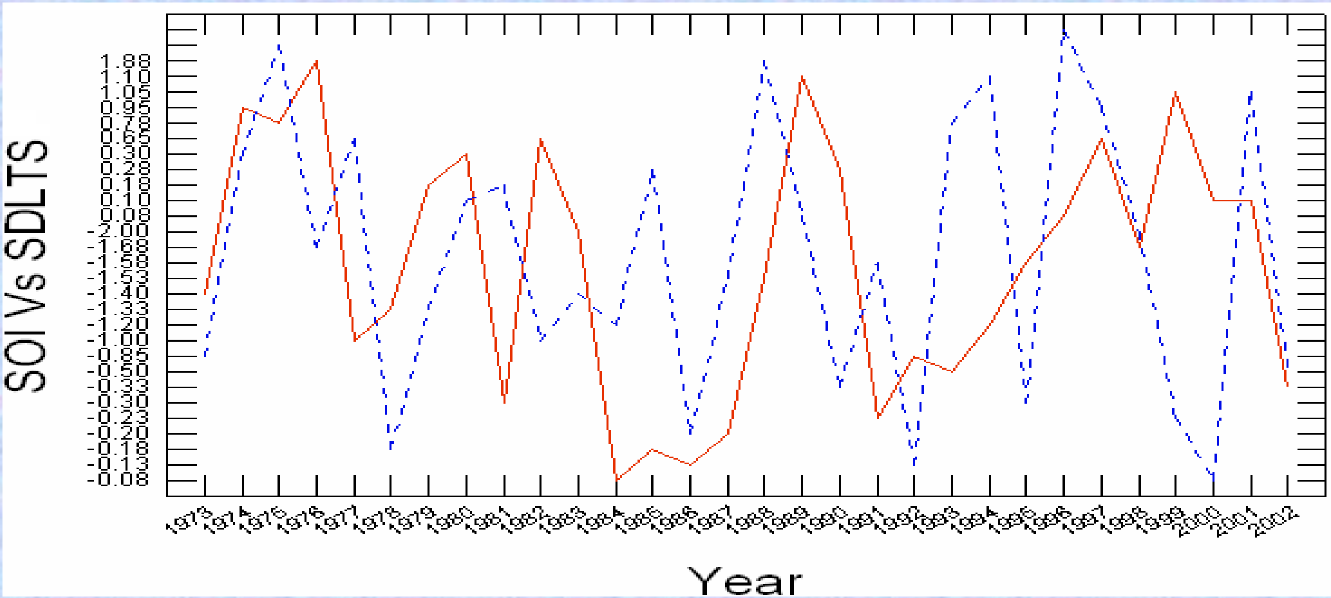
RESULTS AND DISCUSSIONS……..

Figure 4.2 Standardized Kiremt rainfall anomalies for three Lake Tana sub-basin stations from 1982 – 2008

- Excessive wet conditions occurred in 1998, 1999,2000,2001,2003 and 2006.
- Most of these years are coincided with El Nino episodes while excessive rains matched quite well with La Nina events.
- Nino events in 1991,1994, and1997 which falls by one standard deviation of all Lake Tana sub-basin rainfall
- The strong La Nina events that occurred in 1999, 2000, 2001 and 2006, which was above one standard deviation of all Lake Tana sub-basin

1. **Inter-annual fluctuation of stream flow over Lake Tana sub-basin in relation to Southern Oscillation Index (SOI)**

- **Annual stream flow fluctuation over the Lake Tana sub-basin revealed inter-annual fluctuations that more or less resembled with the patterns of Southern Oscillation Index (SOI) as shown in fig. 4.3**

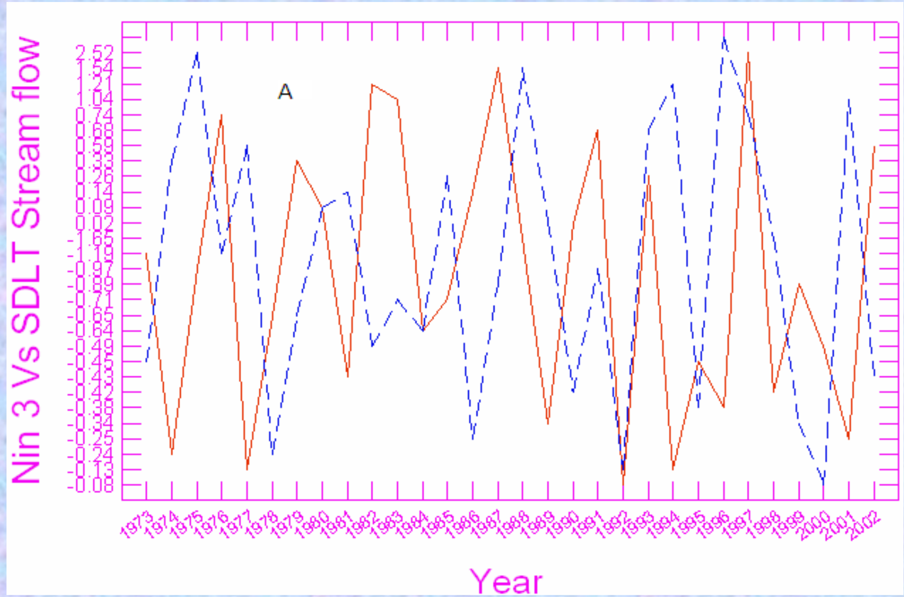


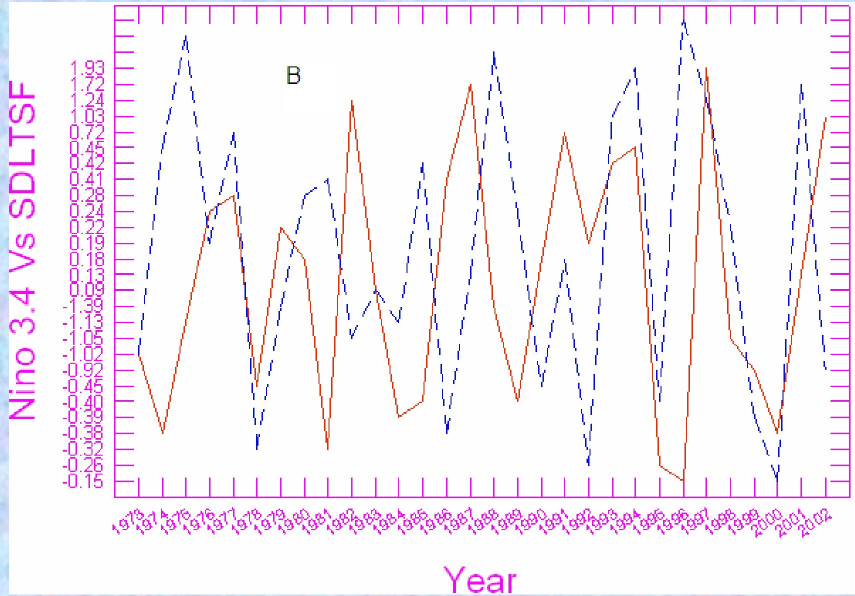
The time series of annual stream flow fluctuation of Lake Tana in relation to Southern Oscillation index (SOI)

Inter-annual fluctuation of stream flow over Lake Tana sub-basin in relation to Nino 3 and Nino 3.4 Sea surface temperature anomalies

- The annual stream flow fluctuation of Lake Tana sub-basin has shown strong inter annual fluctuation, with out visually apparent ,it reveals inverse relation with Nino3 as well with Nino 3.4,

- Inter annual fluctuation of Lake Tana the stream flow shows high fluctuation in relation to Nino 3 rather than Nino 3.4 regions as shown in the figure

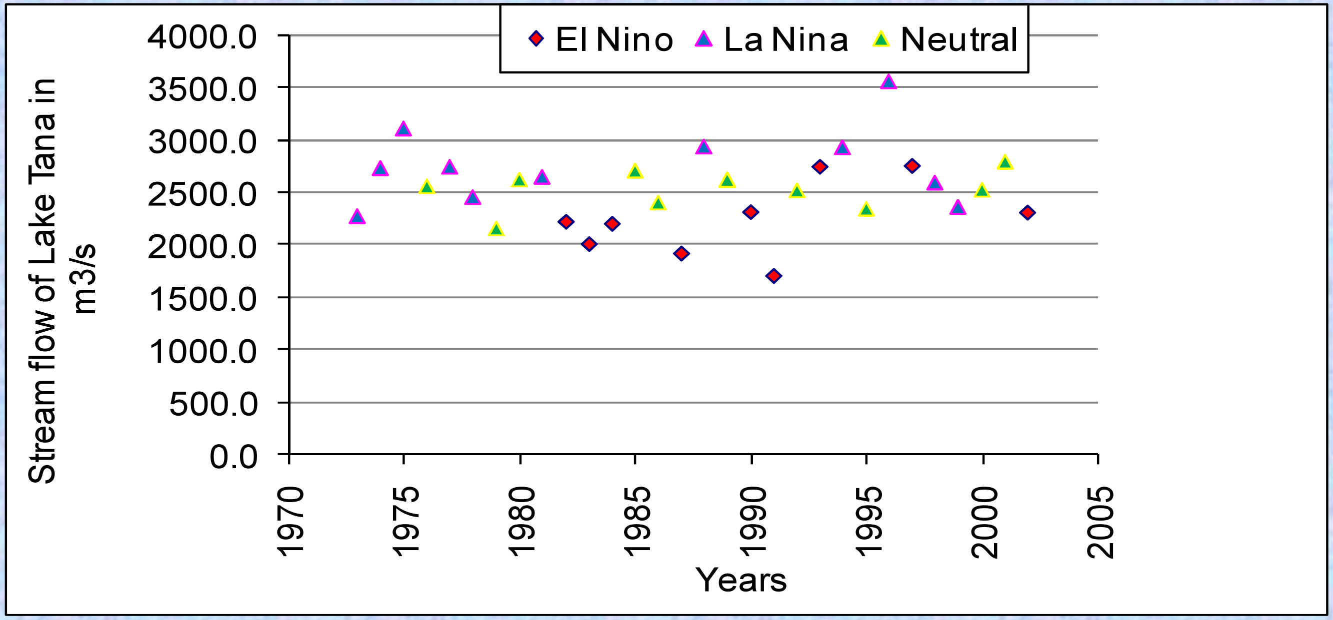




Time series of annual Lake Tana sub-basin stream flow fluctuation in relation to Nino3 and Nino 3.4 SST anomalies

➢The stream flow storage of Lake Tana reservoir is getting high during La Nina and Neutral years than in El Nino years as depicted in fig 4.5.

➢During the El Nino years the stream flow storage of Lake Tana reservoir is getting more or less low as compared with the two episodic years



Time series showing annual stream flow fluctuation in m3/s under different episodes from

Correlation and regression for prediction of Lake Tana stream flow fluctuation during Kiremt season by using El Nino/Southern Oscillation (ENSO)

- The prediction of Lake Tana stream flow is moderately possible based on ENSO pattern in terms of historical SSTs recorded at Nino regions and the southern oscillation index as shown in fig 4.6

- Overall results revealed that El Nino events are weakly correlates with the stream flow of Lake Tana in Belg season (concurrent correlation) given table 4.1

- Using April and May Nino3.4, and April and May SOI states can be used to predict the stream flow fluctuation of Lake Tana

The Prediction model relies on
- April Nino3.4
- May Nino3.4
- April SOI
- May SOI

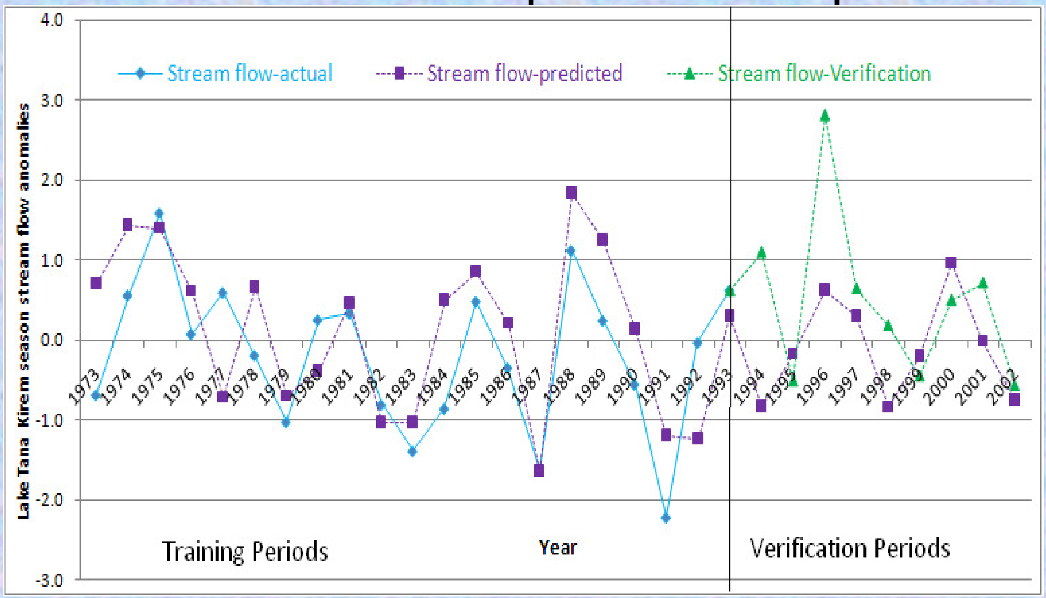
- Hence, the developed model (MLR) equation has the form

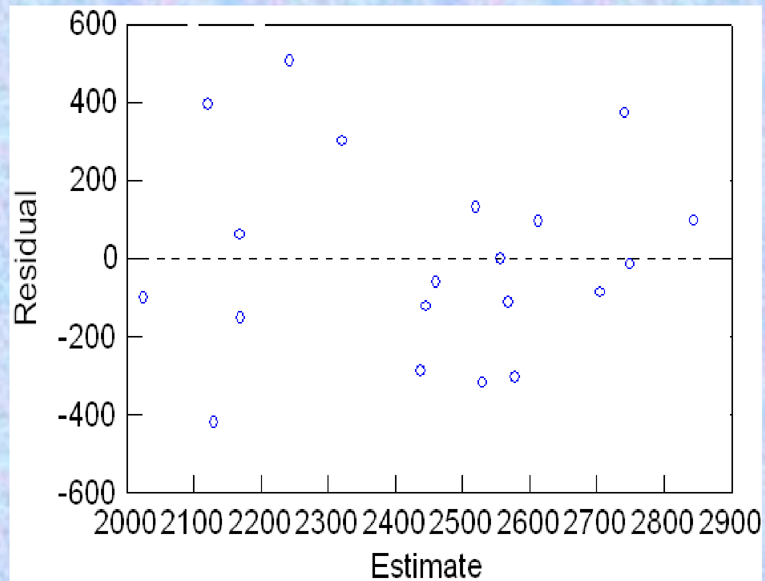
Prediction continued…..

$$Lake\,Tana\ stream\ flow = 2432.814 + 87.825April\_SST - 306.996May\_SST$$
$$+ 44.539April\_SOI + 68.786May\_SOI$$

$$Multiple\,R^2 = 0.474\ \ , Adjested\,R^2 = 0.333$$

➢The fitted model equation is 47.4 % of the total variance of Lake Tana stream flow is well explained and predicted by ENSO (fig 4.7).





Prediction continued…..

- Prediction skill of the multiple linear regression (MLR) models evaluated with the help of analysis of variance (ANOVA) given in the table 4.2

- The correlation between observed and predicted values as generated by the fitted model equation is 0.688

Source	Sum-of-squares	df	Mean-Square	F- ratio	P
Regression(SSR)	1083747.335	**4**	270936.834	3.375	0.037
Errors(SSε)	1204215.214	**15**	80281.014		

CONCLUSION AND RECOMMENDATION

➢ **Conclusion**

➢ The aim of this study was to investigate the impact of climate variability and extremes on Tana Beles hydropower networking system

➢ The overall analyses are used to provide useful insight into the preparation of an early warning system over Tana Beles hydropower projection sites.

➢ The results of this study showed that year-to-year fluctuation of the stream flow and surface water storage of Lake Tana determined by fluctuation of rainfall, mainly during Kiremt season because of ENSO events.

➢ Results from the analysis of stream flow fluctuation of Lake Tana in relation to Southern Oscillation index (SOI) and in relation to Nino3 and Nino 3.4 SST anomalies showed

1. The current levels of stream flow widely responding to both SOI and
2. Nino values of Eastern Equatorial Pacific sea surface temperature anomalies (SSTA)

CONCLUSION…………………

➢This studies made on the relationship between short-term climatic variations, stream flow fluctuation and their impact on hydroelectric generation capacity of Tana Beles hydropower has not yet well assessed

➢Such studies could be used for predicting stream flow fluctuation and its impact on hydroelectric generation capacity during the two seasons

➢Over Lake Tana, the stream flow and surface water storage are increased during La Nina and Nuetral years than in El Nino years

➢High rainfall amount occurring in kiremt due to La Nina impact are highly increases Qin into the hydropower networking systems that in turn increase the overall electric power generation capacity of Tana Beles.

➢stream flow fluctuation showed that similar phase with SOI

➢Inverse phase with Nino values of Eastern Equatorial Pacific Sea Surface Temperature anomalies (SSTA).

➢The developed models used to monitor the stream flow fluctuation of Lake Tana during the pre- season

Recommendation

- We identified some climatic factors as precursor indicators for the stream flow fluctuation over Lake Tana.

- Nevertheless, further study should be undertaken by considering
  a) The effect of runoff,
  b) Sedimentation,
  c) By calculating ground water balance and other unidentified factors in order to evaluate the performance of hydroelectric generation capacity of Tana Beles.
- ENSO events are found to affect the local rainfall and stream flow patterns, which in turn create electric power fluctuation over Tana Beles

- Thus, ENSO related information and associated implications to stream flow and rainfall variation to be given for

a. The hydrologist, hydroelectric management body and agricultural communities so that early planning can be undertaken in advance.
b. ENSO Information is deed to provide policymakers with useful information to guide electric power disseminators in order to rearrange their total power and patterns of disseminating the electric to the communities.

Recommendation…………………

- Besides, during La Nina episodes high surface water storage and stream flow are observed and the converse is true during El Nino years over Lake Tana were witnessed.
- Therefore, the hydrologist, and hydroelectric management body should use and disseminate the following adaptation option during the two episodic years

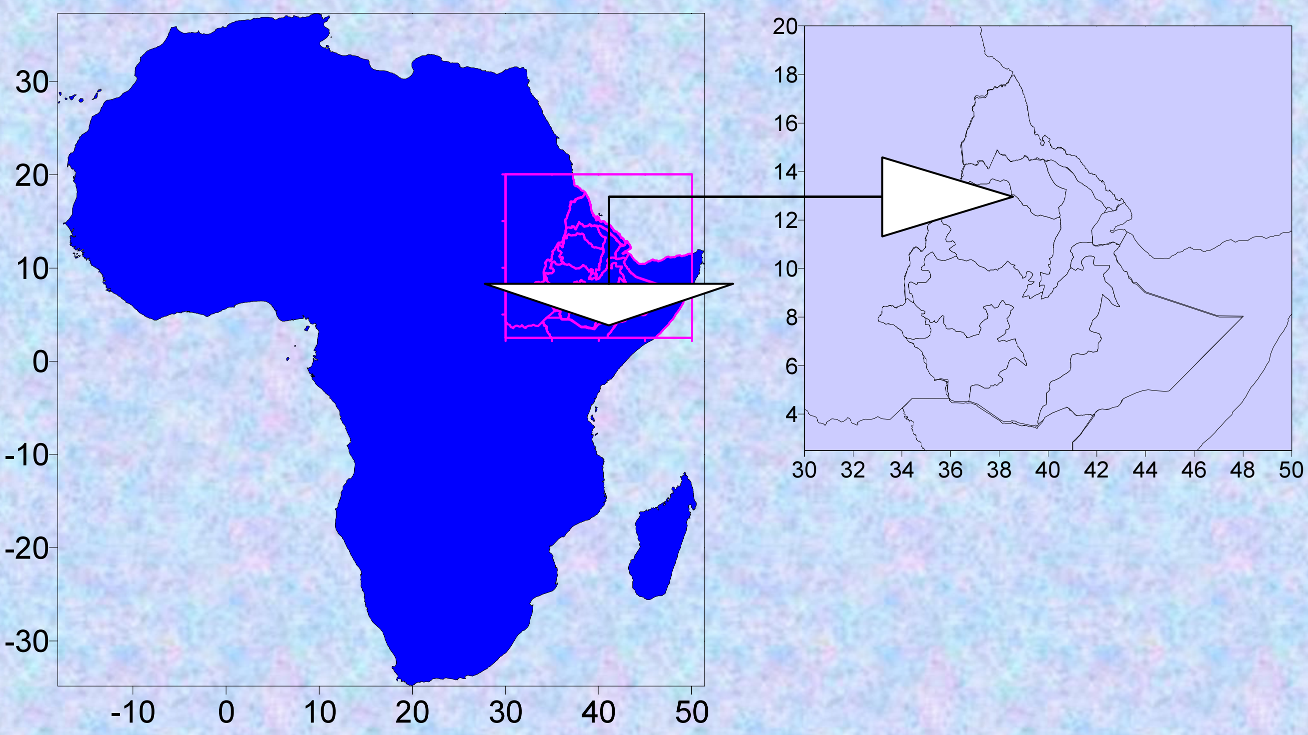
1. If an upcoming wet season is reliably predicted to be wetter (La Nina phase) than normal somewhat lower water reserves might be carried into the wet season, somewhat higher water use might be appropriate in the early weeks of a wet season.
2. If an upcoming dry season is reliably predicted to be drier (El Nino phase) the converse was true

- In this study ENSO events have shown strong associations with stream flow fluctuation.
- Therefore, government support in the direction of
  a. Power failure insurance, providing real time climate information and
  b. The appropriate use of power and recognition of other source of power systems to the communities this may reduce vulnerability of energy system from climate variability and weather extremes

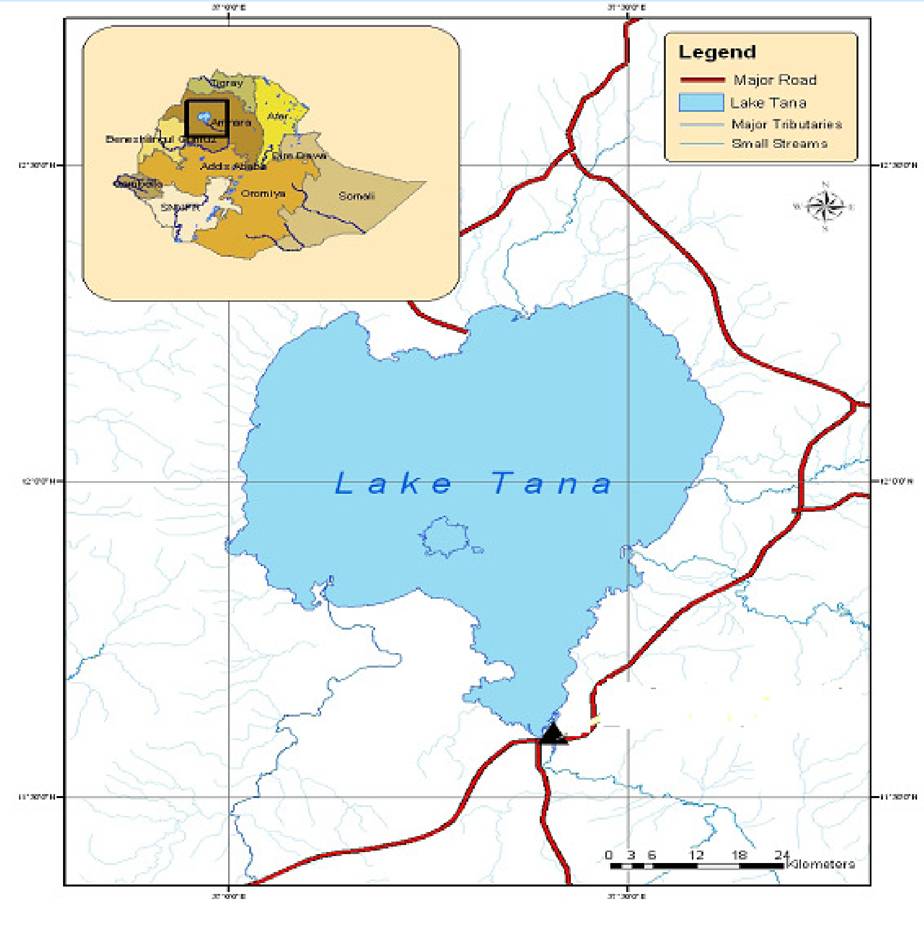
The End

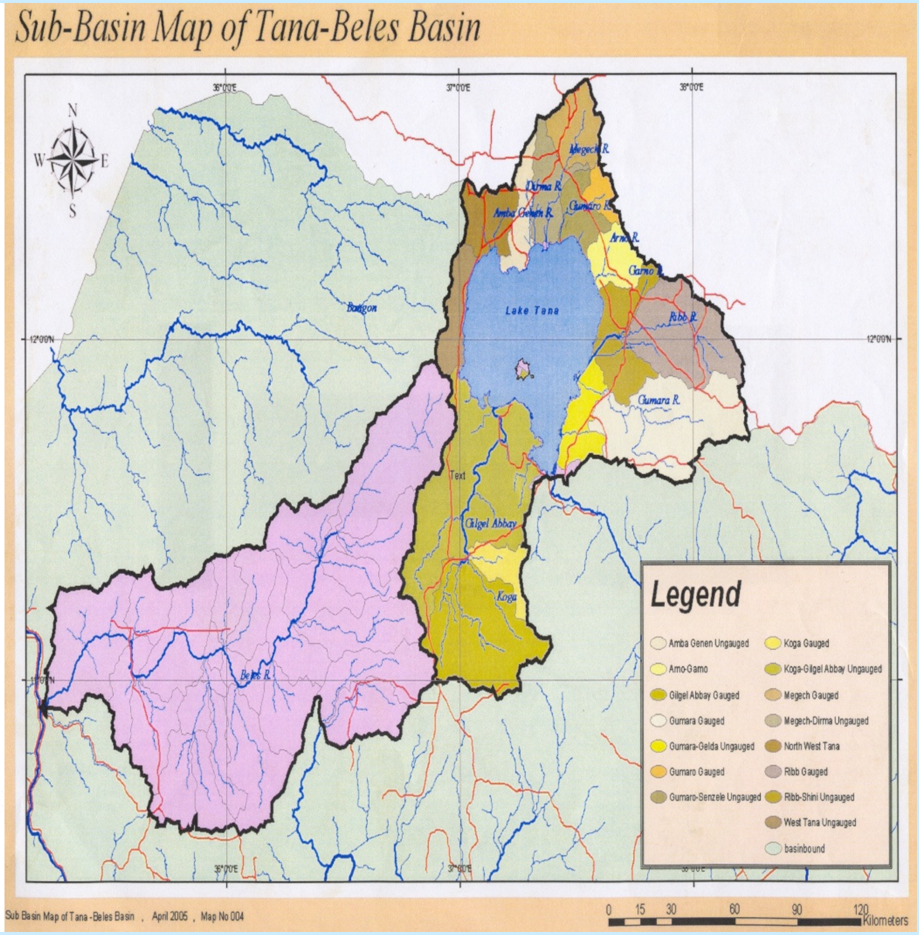
Thank You for Your Attention

The location of Ethiopia in the African continent

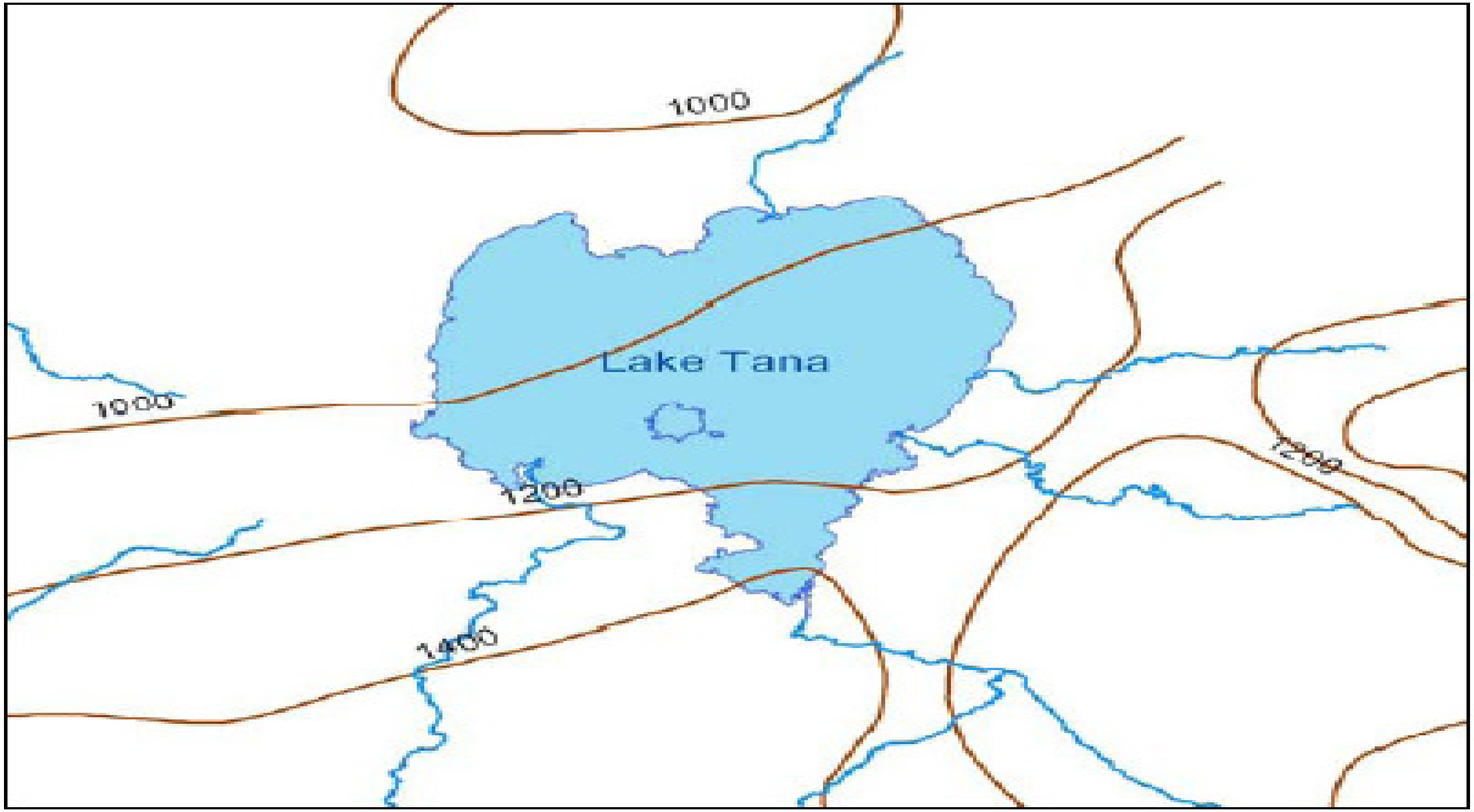


Description of study area





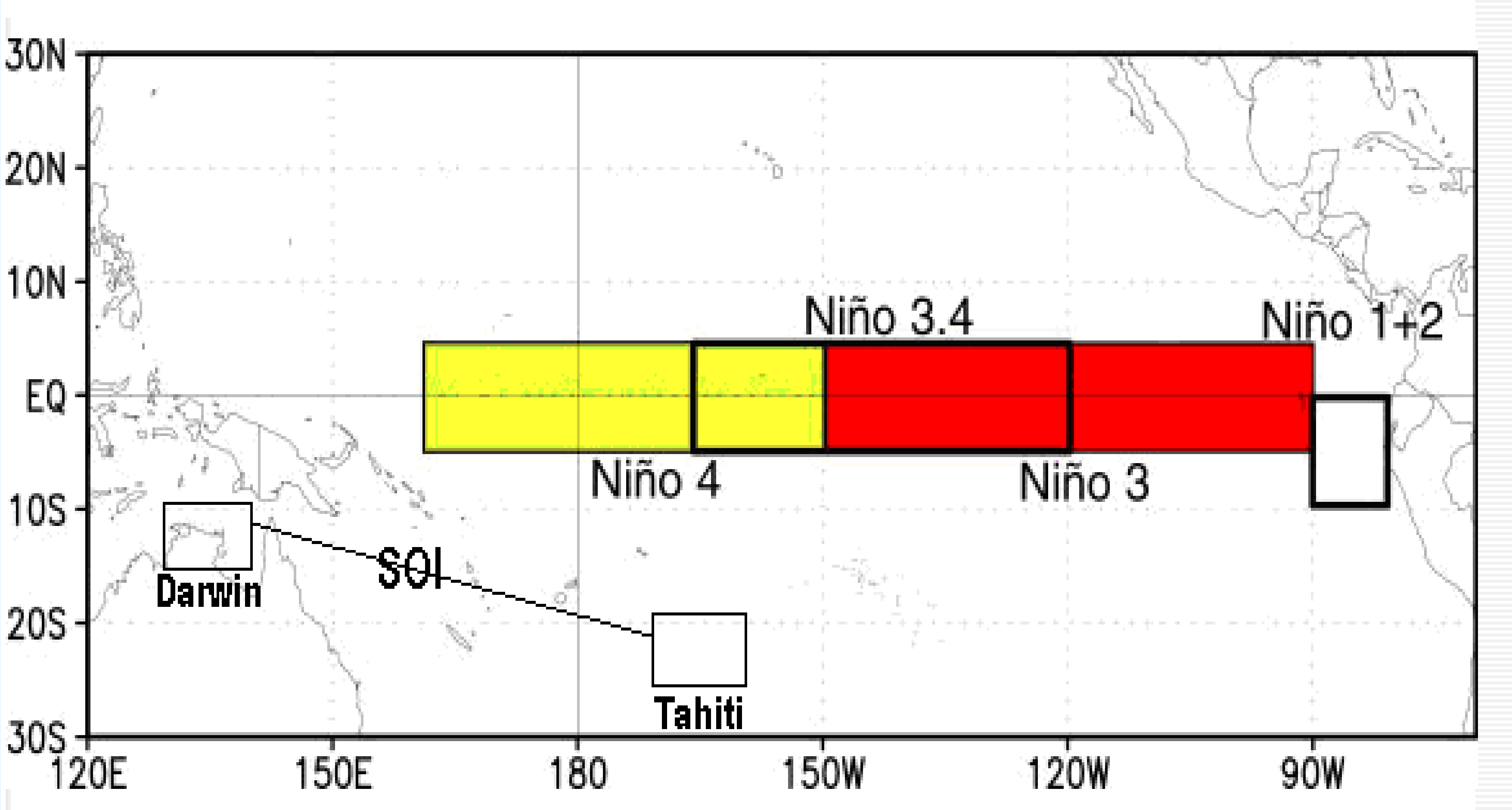
Lake Tana reservoir Rainfall Isohytal Map



Lake Tana *Sub-Basin distribution*

Lake Tana Water Surface	3060Km^2
Megech (North) sub Basins	2620Km^2
Ribb (north-east) sub Basin	2464Km^2
Gumara (East) sub Basin	1893Km^2
Gilgel Abbay (South) sub Basin	5004Km^2
Other Tributaries	279Km^2
Total	**15320Km^2**

Geographical location of Nino and SOI regions



Simple linear Correlation coefficient (r) as computed based on Lake Tana

NO	Oceanic indices	Correlation values (r) with Belg season Lake Tana stream flow	Correlation values(r) with Kiremt season Lake Tana stream flow
1	April Nino 1+2	-0.1	-0.2
	May Nino 1+2	0.1	-0.3
2	Feb Nino 3	-0.06	-0.35
	March Nino 3	-0.06	-0.33
	April Nino 3	-0.03	-0.35
	May Nino 3	-1.17	-0.41
3	April Nino 3.4	0.11	-0.35
	May Nino 3.4	0.21	0.39
4	April Nino 4	0.3	-0.4
	May Nino 4	0.3	-0.4
5	April SOI	-0.15	0.27
6	May SOI	-0.38	0.21