**PROJECT TITLE:** An Assessment of the Potential Benefits of Seasonal Rainfall Prediction in Relation to Hydro-Electric Power Generation in Kenya: *A Case Study of the Impacts of the 1999/2000 drought and the accompanied Power rationing*

**PROJECT DURATION**: 12 Months

**PRINCIPAL INVESTIGATOR:** Dr. Christopher Oludhe

**INSTITUTION:** **Department of Meteorology, University of Nairobi, Kenya.**

## 1. INTRODUCTION:

Kenya have in the recent past experienced two major extreme climate events that led to severe socio-economic impacts such loss of life and property, damage to infrastructure, mass migration of animals and society, disruption of power supply, water shortage, famine among many other socio-economic miseries. Good examples of the potential hazards of the extreme climate events were demonstrated by the impacts of the 1997/98 El-Niño floods which was immediately followed by the 1999-2000 La Niña related drought, the worst in 50 years.

All economic activities such as planning, water resources and land use management, transportation and storage of products are dependent on weather and climatic conditions. It is therefore necessary to factor climate information and prediction products in the planning and decision-making processes account if sustainable development of socio-economic activities is to be achieved.

The energy demand in Kenya both for industrial and domestic activities (largely derived from petroleum and hydro-power) has continued to rise year after year since independence in 1963, averaging over 9% during the 1960s and 1970s, over 7% during the 1980s, and around 5% over the past decade. Inadequate rainfall during the prolonged 1999-2000 drought and the delay in the implementation of some of the planned power projects led to a serious shortage in the supply of electricity in Kenya. The consequence of this was the start of rationing power in September 1999 by the Kenya Power and Lighting Company. By June 2000, electricity generation in Kenya had fallen by 40%, prompting the Kenyan government to announce more stringent power rationing measures where residential power was cut from sunrise to sundown and industrial power was stopped from sunset to sunrise. During this time, Kenya required 180 MW to alleviate load shedding completely and to address the power shortage in the country, an Emergency Power Supply Credit of US$ 72 million was used to contract the supply of 105MW of power and provide fuel for the emergency generators. It is estimated that the energy crisis generated a loss to the economy of nearly US$100 million per month.

The 1999-2000 drought also interfered with urban and rural water supply, agriculture, food security, health and industrial production as well as loss of jobs and family income.

## 2. PROJECT GOALS:

The overall objective of the study was to assess the impacts of the 1999/2000 droughts on hydropower generation in the Tana River 7-Forks Power Stations and determine the benefits

that might have been derived from the uses of DMC-Nairobi Climate Outlook Fora (COF). The specific objectives include assessing:

- Variation of river flow in the Tana River basin and power generation during dry and wet periods.
- The overall costs resulting from power rationing to the country's economy.
- The cost of power rationing to the Industrial sector.
- The impact of power rationing on income loss and job layouts.
- How the forecasts were used in power generation decision-making.
- The potential benefits of using the seasonal climate prediction with respect to power generation decision-making.
- How the lessons learnt from the study could be used in future policy formulation regarding power generation as well as the planning and management of rationed power projections.

## 3. METHODOLOGY:

Several methods are used to address the goals outlined in this project. They include:

- Field survey of the major hydroelectric (7-Forks) dams along the Tana River Basin.
- Acquire river flow, dam levels and power generation data from the major dams in Kenya.
- Develop a questionnaire that would seek to determine the extent of economic losses incurred by various organizations such as KENGEN, COTU, KAM, KPLC and other manufacturing companies as a result of power rationing.
- Carry out statistical analysis of all the collected data
- Develop statistical prediction models for use in the energy sector.

The study has managed to gather all the relevant data and information needed in this project using all available tools as well as field survey using a structured questionnaire. The relevant places visited include:

- Tana River 7-Forks Dams such as Masinga, Gitaru, Kamburu, Kindaruma.
- Kenya Association of Manufacturers (KAM) Offices.
- Central Organization of Trade Union (COTU)
- Multinational Companies such as East African Industries, BAT and Kenya Breweries.
- Kenya Electricity Generating Company (KenGen) and Kenya Power and Lighting Company (KPLC).

The data obtained from KENGEN and KPLC companies included:

### 3.1 Dam Layouts and some technical data:

- Map showing the various dam sites and their years of commissioning
- Dam Capacity
- Catchments size (Area), Reservoir length, width and mean depth.
- Total Head (Highest attainable dam level (m), i.e. maximum operating level, critical power production level and Minimum Operating Levels), Optimum dam levels and fall Head.
- Number of turbines in each dam
- Maximum design flow for the various turbines
- Installed capacity, Nominal capacity of the turbines, rotational speed

- Recreational facilities around the dam vicinity, irrigation, erosion, siltation, frequency of dredging etc.
- Recent Map showing the Upper Tana River catchments area
- Catchments rainfall data (10 Years of data)
- Discharge data for the Tana River/Masinga dam catchments for at least 10 years.

**3.2 Power Generation data included:**

- Generation Capacities from
  - Hydro,Thermal,Geothermal,Wind and Others
  - Quantity of power imported and costs
  - New (additional) generators/micro hydropower installed during drought period.
  - Number of installed Generator sets and their costs.
  - Total additional Cost for installed (New) generators.
  - Starting date of power rationing and the total generated power then.
  - Type of power consumers and their power demands
  - Total power demand and trend (month by month) over the last 10 years.
  - Net power (month by month) shortfall over the last 10 years.
- Total Generation Capacity (10 years data)
- Total month to month Generation Capacity (10 years data)
- Generation problems encountered during and after El-Nino/La-Nina period
- Monetary losses during the 1999-2000 drought.

Other activities that were explored included:

**3.3 Receipt and usage of climate outlook information from KMD/DMC:**

- How are the weather and climate information received at KENGEN/KPLC (Mode of information receipt)
- How is this information utilized in decision making (increasing/decreasing generated power)
- Have the past climate outlook fora been of any use in the generation of power?
- Any other relevant information.

At the moment, the data that have been gathered from the above sources are now being subjected to various analyses such as:

- Analysis of the dam capacity and water level records in relation to rainfall within the Tana River catchments.
- General Statistical Analysis of the acquired data and the development of prediction relationships between rainfall and dam levels.
- Economic evaluation of the results obtained from the questionnaire.

## 4. RESULTS AND ACCOMPLISHMENTS:

***Impacts of the 1999-2000 drought onto the 7-Forks Power Stations***

The 7-Forks cascade hydropower stations are located on the upper Tana River basin and consists of five power stations, Masinga (40 MW), Kamburu (84 MW), Gitaru (225 MW), Kindaruma (40 MW) and Kiambere (144 MW).. The sixth and the seventh power stations

along the same river are yet to be completed and include Mutonga (60 MW) and Grand Falls (140 MW). The Seven Forks provides about 65% of the country's electricity requirement.

Masinga Dam, with a catchment area of 7,335 $km^2$ is the main storage reservoir of the seven forks cascade. It has a storage capacity of 1,560 million cubic metres (mcm) or just 1560m and regulates the flood flows of Tans river and its tributaries. Any inflow greater than the generation capacity is stored in the dam and gradually released during dry months when the inflows are inadequate to meet generation requirements. The Minimum Operating Level (MOL) for Masinga dam is 1035m.

During the 1997/98 El-Nino floods, the Masinga dam was full to capacity and resulted in a 9 month cascade water spillover between mid November 1997 to mid August 1998. A major rainfall deficit between the short rains of 1998 and those of 2000 lead to inadequate inflows into the major rivers into the 7-forks dams. The low water levels in the dams consequently led to closure of some turbines, and under performance of the others, which resulted into below average electricity generation. This caused a power deficit of nearly 197MW. The country had to call for emergency independent diesel power generators for the first time since independence.

It was noted that climate outlook information was used to regulate river flow and also ration power. The situation would have been much more disastrous if the climate advisories were not used. The future study would attempt to develop other simple models of seasonal rainfall-stream flow, dams levels and the associated hydropower production risks levels.

The reservoir levels reached their lowest record levels as follows:

- Masinga, 1018.68m on 19th October 2000 (Minimum Oparating Level is 1035m)
- Kamburu, 992.58m on 25th May 2000 (Minimum Oparating Level is 995m)
- Kiambere, 675.84m on 25th January 2000 (Minimum Oparating Level is 670m)
- Turkwel, 1100.01m on 22nd April 2000

Kamburu Power Station

As a result of inadequate inflows and storage levels at Masinga Dam, the cascade operation was sustained and managed through Masinga's Low Level Outlet (LLO) releases of water between 29th June 2000 (1033.13m) and 10th January 2001 (1035.01m)

***The table below shows the effects of deepened power rationing on some companies (not named) in Kenya.***

***Note: Exchange Rate,*** US $ = 76.0 Kshs.

| | **Company Name**<br><br>**(Confidential)** | **Monthly estimated additional operating cost** | **Monthly estimated loss of profit** | **Monthly estimated loss of revenue to the government** | **Employees laid off** | **possibility of closure due to prolonged power rationing** |
|---|---|---|---|---|---|---|
| 1. | A- Limited | KHz. 2 Million | KHz. 1.4 Million | KHz. 600,000.00 | Not yet | Yes |
| 2. | B-Textile Limited | KHz. 4 Million | Kshs. 1.25 Million | Kshs. 330,000.00 | Not yet | No |
| 3. | C -Industries | Kshs. 10 million | Drop by 20 - 30% | Kshs. 40 Million | Expected to be 25% | - |
| 4. | D- Foods | - | Drop by 38.8% | Kshs. 300,000.00 | 7 | No |
| 5. | E- Plastics | - | Kshs. 1.6 Million | Drop by 50% | 66 casuals | Yes |
| 6. | F-Plastics | - | Kshs. 2 million | Kshs. 2.2 Million | Expects 60% Reduction | Yes |
| 7. | G-Bottles | - | Drop by 12.5% | Kshs. 500,000.00 | Expected to be between 60 - 75% | Yes |
| 8. | H-Farmers Company | - | Kshs. 17 Million | Kshs. 17 Million | Expected to between 200 - 300 | Yes |
| 9. | I- Manufacturing | Kshs. 2 Million | Kshs. 8 Million | Kshs. 3.8 Million | 86 | Yes |

Dr. Christopher Oludhe
Department of Meteorology,
University of Nairobi,
P. O. Box 30197, Nairobi, Kenya
E-mail: coludhe@uonbi.ac.ke.