SUSTAINABLE WATER MANAGEMENT FOR SEASONAL RIVERS DELTAS, CASE STUDY: COPOROLO RIVER, ANGOLA

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ABSTRACT
Rivers deltas represent the most suitable area for development along river path. However, the sustainable water management plans for such place in seasonal rivers regions are very important and complex as many factors are involved. The river delta should be protected against floods and drought prior any development steps, a clean power should be ensured for the preserving of the natural condition of the river delta. Coporolo River delta represents a high potential area for development in a developing country like Angola. In this paper the river delta were studied and the previously mentioned factors were considered. The delta, as a special case for the Coporolo River, is subjected to both flood and drought risks that were both considered, the water requirements were estimated. Dams and storage locations alternatives were studied to reserve water for dry periods, for ground water recharge and to provide a clean power supply source. Prioritization plans were proposed for the sustainable development of the river delta area to ensure their feasibility.

Keywords: *Water Management; Seasonal rivers; Coporolo River; and Water Power.*

1. INTRODUCTION

Coporolo River is passing to the South-West of Benguela province, Angola. The upper reach of the river originates from the mountainous terrain and ends by a last reach of low level lands that is very fertile and was used for years for agriculture. This last reach of the river is about 15 km from the mountain edge to the ocean, figure 1. The river is semi perennial where about 4 to 5 months during the year are dry.

The low land at the end of Coporolo River is used for agriculture where the area was cultivated with mainly sugarcane. As a matter of fact sugar processing factory was established during the past years in the province. An irrigation scheme was implemented in the area where main irrigation intake channels and distribution channels were constructed.

Figure 1: Coporolo River Delta, General location

As the agriculture area is located in low lands the area was prone to heavy flooding from the river and surroundings. In fact couple of protection dikes was constructed along the river main stream to protect the cultivated lands. During the last decade some of the existing dikes were damaged and many agriculture lands were lost to flooding. Some lands are subjected to flood risks relatively higher than other parts due to low land level and/or the presence of protection measures such as dikes, Figure 2.

Photos 1 and 2: Agriculture area on Coporolo River banks

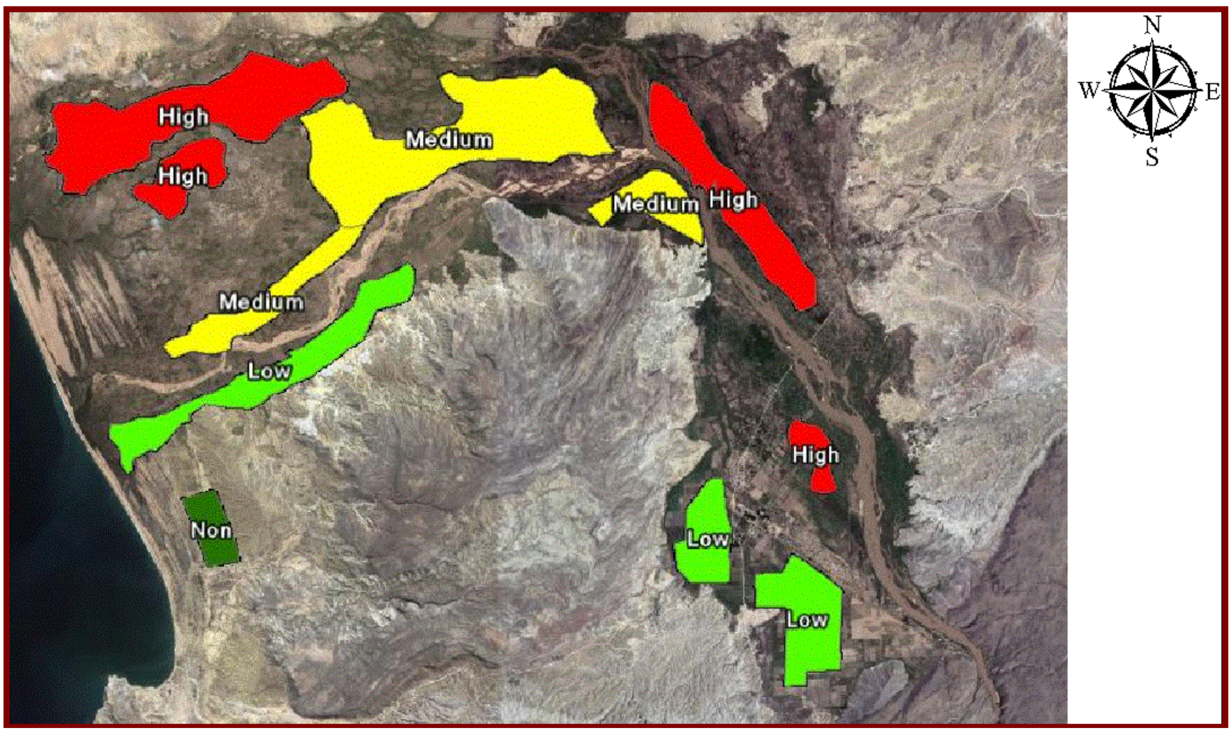

Figure 2: Flood risk map for the cultivated area

2. PROBLEM DEFINITION

The Coporolo River passes through the Angolan plateau then through mountainous area till it approaches Dombe Grande city where the low level lands close to the ocean starts and forms its delta. The farmers working in the area make use of all the possible lands and use it for agriculture production. The lands, which have levels lower than the river flood water levels, are usually flooded and this is not a small portion of the area suitable for irrigation. However, they can be classified to high and low flood risk areas, Figure 2. Photo 3 illustrates the fact that during the flooding period the agriculture lands are usually flooded.

Photo 3: Flooded area along Coporolo River

The catchment area of the River is in the order of 15,674 km^2 and it extends to almost 200 km inland, figure 3. It is to be noted that during the period November to March the river experience high flood flows due to heavy rains in the upper catchments of the river with an average rainfall depth of 260 mm/month while the dry season is during the period from May to September with an average rainfall depth of not more than 2.5 mm/month. In addition to the high water levels that cause flooding of the agriculture lands, houses and the roads, the river banks cannot contain the flood within the river narrow section (main channel) causing flooding to most of the agriculture area.

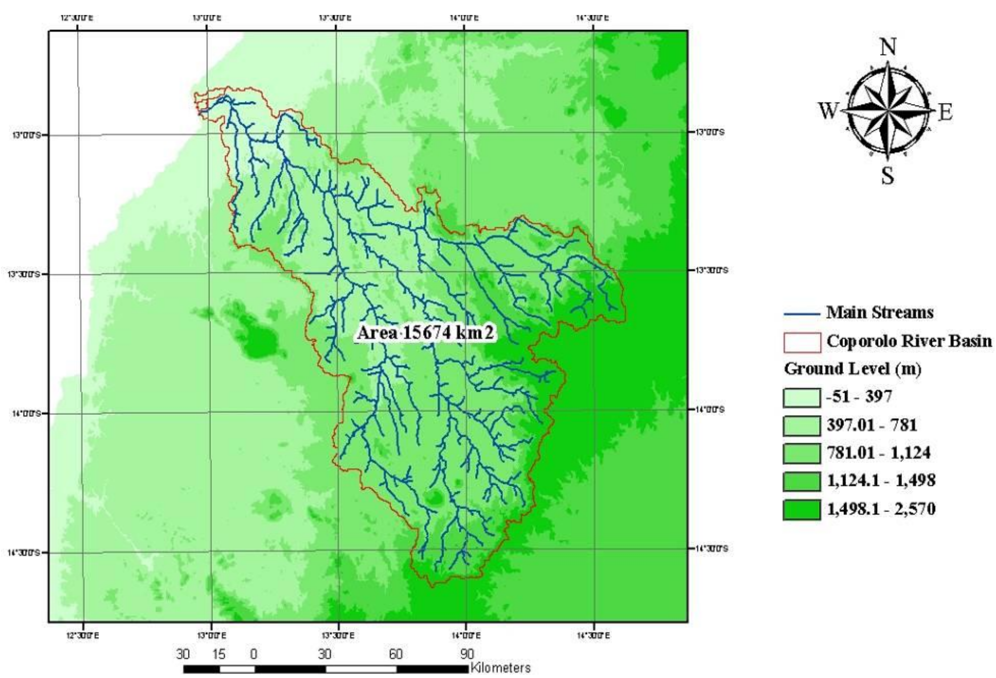

Figure 3: Coporolo River basin

3. OBJECTIVE

The main aim of the development plan is to allow for irrigation all year round, despite being subjected to flood hazard and save water for drought year time. The objective of this paper is to ***develop an execution plan for water management actions necessary for sustainable development of the Coporolo Delta*** that will focus on the following main items;

1. Insure the safety of the river delta residents;
2. Eliminate the problem of floods and droughts;
3. Flood protection for the required agriculture areas and the area reserved for other facilities surrounding it;
4. Provide sustainable solutions that support Irrigation of the required agriculture lands of the river delta;
5. Provide a clean power supply source for sustainable development;
6. Maximize the use of water for agriculture in order to optimize the use of these natural resources; and

4. RAINFALL DATA ANALYSIS

Figure 4 shows the average monthly rainfall data for the Dombe Grande city, located on the left bank of the river delta.

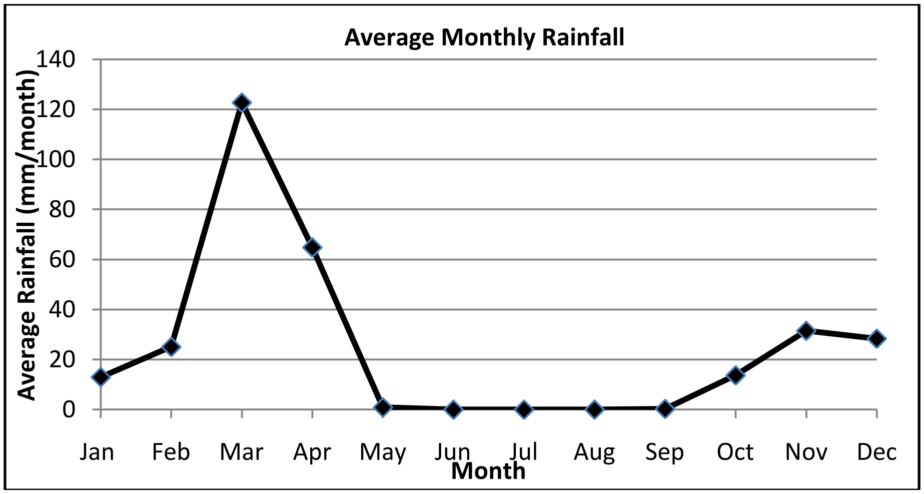

Figure 4: Dombe Grande city average monthly rainfall
Source; International Water Management Institute (IWMI) web site.

The rainfall over the whole catchment is much higher than that of the Dombe Grande as most of the catchment is located in the mountain area of South Angola. Figure 5 shows the average monthly rainfall data over the mountains of Coporolo River Basin that is almost as twice as that of Dombe Grande city.

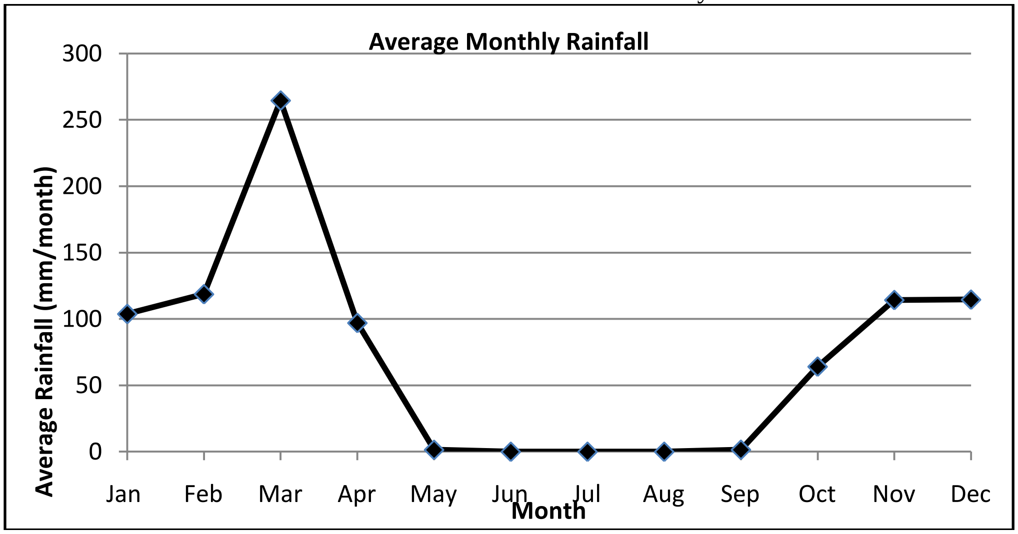

Figure 5: Coporolo River basin average monthly rainfall
Source; International Water Management Institute (IWMI) web site

The analysis of the rainfall data, the soil type, and land use of the Coporolo River basin shows an average volume of rainfall per month that ranges between 1,600 m^3 during flood period, and 22 million m^3 during dry season with a runoff coefficient ranges between 60% to 30%, figure 6.

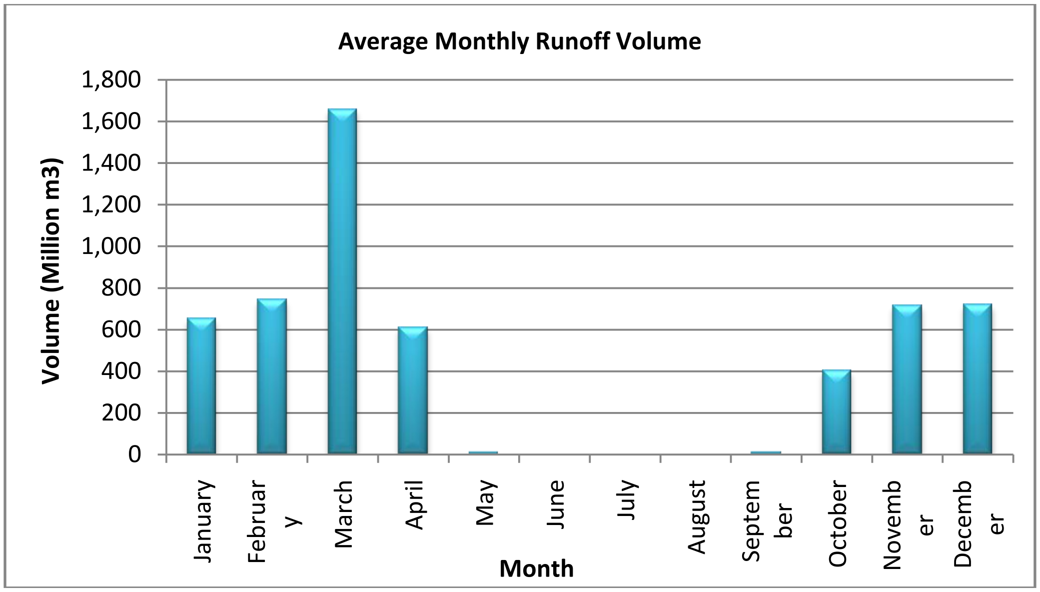

Figure 6: Coporolo River basin average monthly Runoff

5. WATER REQUIREMENTS

The irrigation of the fields should be done the whole year at different rates according to the water requirements. Dombe Grande has good climate and soil suitable for planting. It overlooks the Coporolo River as its delta provides a suitable land for planting crops and the presence of agriculture and food industries. There is no doubt that the area is endowed with sufficient natural resources base for the development of the residential and agriculture area and it will benefit the economy of the local people living in the city. As the main source of water for the agriculture sector is the Coporolo River water, which only flows for about 8 months of the year, another source of water should be investigated to provide water during this period.

The water demands, figure 7, were calculated based on the climatic factors of the study area such as the temperature, percentage of sunshine hours, wind speed …etc, one of the proposed scenarios is to plant the available agriculture area with Banana Trees, which is the common crop in the area as can be seen in photo 4 and it also has a high water requirements. So if the water was available for this type of crops it could be used if replaced with other crop type.

Photo 4: Banana trees fields, Coporolo River Delta

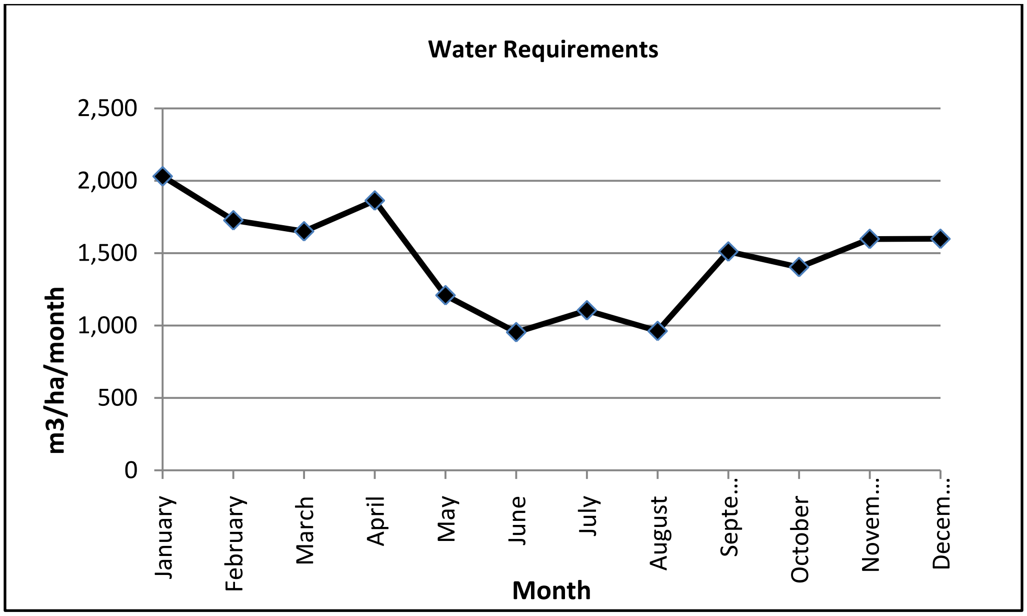

Figure 7: Monthly water requirements for of Banana trees per hectare

6. WATER MANAGEMENT PLAN

To achieve the objectives is to find practical aspects and implemental steps that could be achieved by performing the following main activities;

1- Undertake the necessary flood protection precautions for the available cultivated land and for the purpose of alleviating the severe problems that occur periodically and affect it. These works shall minimize the severe damages on this area and protect the delineated agricultural areas against flooding which may render them unsuitable for planting.
2- The construction of a sustainable well field system to feed the agriculture lands as applicable.
3- Conduct the irrigation schemes for the available cultivated land, and conforming to the analysis of irrigation water requirements considering year round irrigation.
4- Construction of dams for water storage and power generation.
5- Provide a priority construction plan for the proposed items to maximize the benefit from the saved lands for irrigation, figure 14.

7. PROPOSED MANAGEMENT SCENARIO FOR FLOODING PERIOD

The flood protection plan can be summarized and prioritized in the following steps;

1. Channelizing the main stream of the Coporolo River to convey the average floods.
2. Construction of protection dikes at the edge of the river right and left banks to control the higher floods within a narrower width than the current one and to facilitate the use of the previously flooded land in agriculture. These dykes should be high enough to protect the lower lands against increased flood water level and protected to stand against the erosive action of the flood water especially at the bend location which is experiencing excessive erosion.
3. A diversion dam/dike (Figure 8) downstream the Dombe Grande city and in the place of the old breached dike to ensure the flow of the Coporolo River in its proposed path.

Figure 8: Proposed diversion dike

4. Construction of flood protection channels at almost the inner perimeter of surrounding mountains to collect the flood water and divert it to the irrigation network, storage reservoirs or to the main river course.

Figure 9 shows that at least additional 1000 ha could be added to the available agriculture area after construction of the ultimate flood protection scheme.

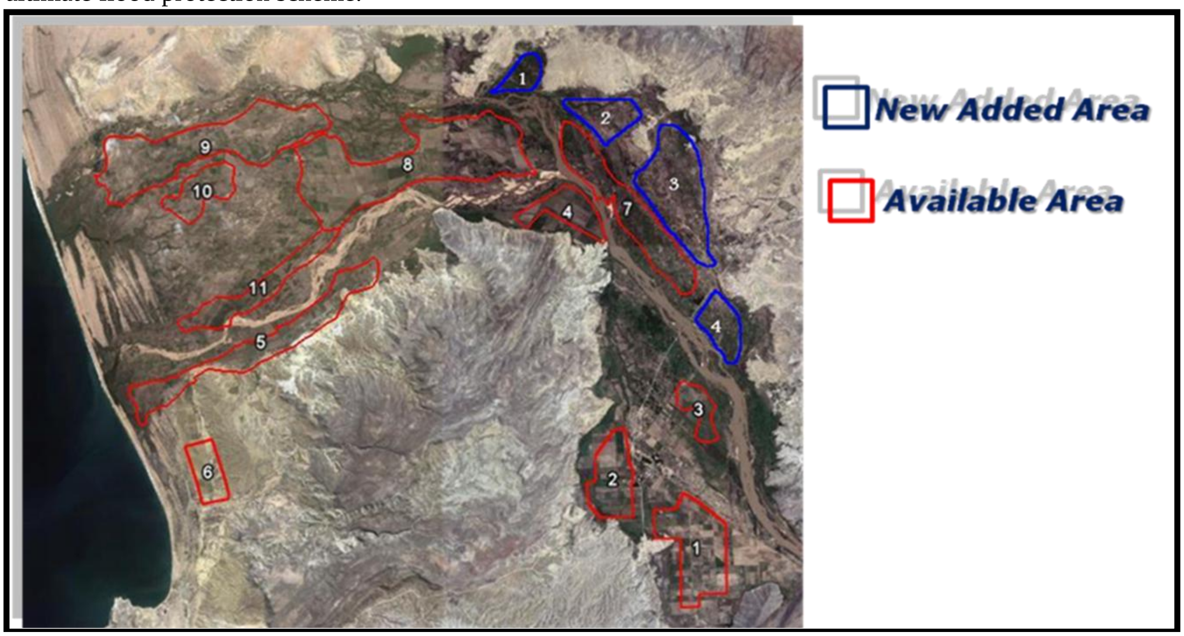

Figure 9: New added agriculture area

8. PROPOSED MANAGEMENT SCENARIO FOR DRY PERIOD

Storage of water is the solution for sustainable water source during the dry period. This can be achieved through storing surface water or usage of ground water.

8.1. water storage on ground surface

A storage dam at the South, Figure 10, on one of the Coporolo River tributaries is proposed to store the water for irrigation purposes during the dry periods. This could provide water supply for almost all river delta specially the left part of the river.

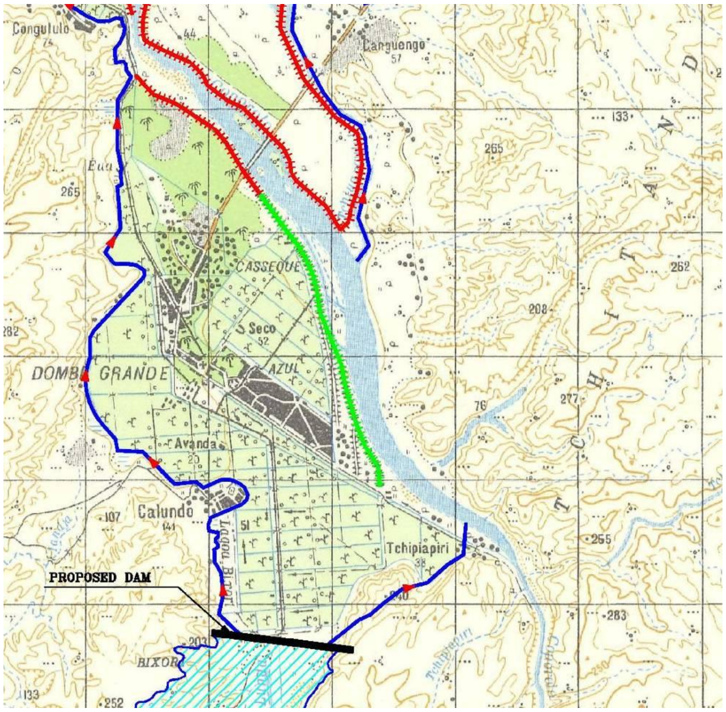

Figure 10: Proposed dam location

Also the use of the existing natural lake at the North, figure 11 and to the right of Coporolo River for storage of irrigation water will provide water for irrigation to the north part of the river delta. Then it could be connected with flood protection channels at the north boundary for the overflow conditions.

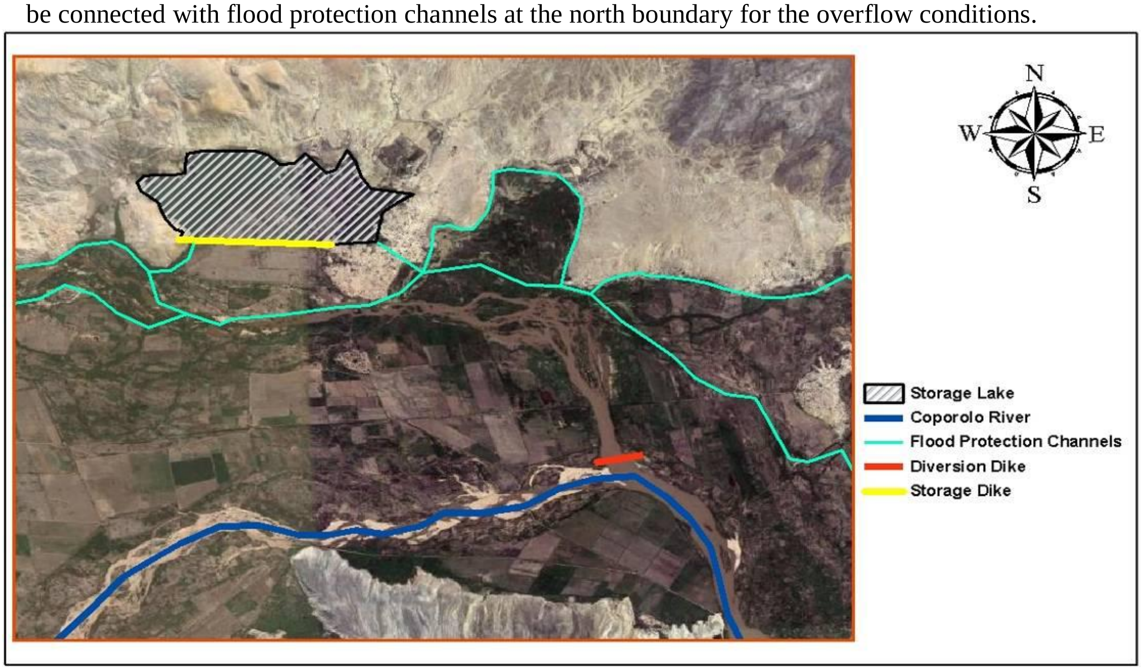

Figure 11: Proposed Storage Lake at to serve the North West part of the project

8.2. Groundwater from pumping well field.

The strategy of charging groundwater for irrigation requires the determination of the existence of suitable aquifer(s) below the study area. This task will can be mainly completed through a hydrogeological investigation. The objectives from the site investigations will be to:

- Map and identify the stratification of the ground formations along each control or proposed production well-field.
- Determine the hydro-geological parameters for the main aquifer(s) underneath each groundwater control or proposed supply well-field.

Particular emphasis should be given to the groundwater condition and permeability at river delta site and its variation both with location and time, as this will influence the design criteria and well construction techniques. The investigation may also include a geophysical survey. Surface and borehole geophysics is a valuable tool for hydrogeological mapping. It provides information on rocks and fluid properties both in vertical and lateral extents. The objectives of this kind of investigations is to assess the thickness, continuity and possible displacement of the main geological formations in order to delineate the geometry of main aquifer systems, and assess the distribution pattern of fresh, brackish and saline water in the subsurface due to the proximity of the project to the sea. This sould be performed on the aquifers which are required to meet future water demands.

At this stage of the study, data that indicates the possible well yield is not available. As such it is difficult to anticipate the well yield and hence the number of wells needed to meet the irrigation demand during the dry season.

9. IRRIGATION SCHEMES

The irrigation intervals can be divided into two main intervals. During dry period, this is the period from the beginning of May till the end of September, and during the floods which is the remaining of the year. The proposed irrigation scheme is based on the evaluation and upgrading of the existing irrigation network of about 100 km length channels to be used with the new system.

- **during flood seasons (September – April)**

  During this period the river flow can be used in irrigation by construction of intake structures and required channels on the river to uptake the required water consumption of the agriculture area. This scheme could use the existing irrigation channels and will require the construction of following items;

  (a) Controlled intake to control the diverted discharge from the river to the main channels.
  (b) Irrigation channels upgrade.
  (c) Small intake structure to divert water to the irrigation channels
  (d) Escape structures to maintain water levels in the irrigation channels so as these channels are not flooded

- **during dry seasons (May - August)**

  During this period, and as per the water requirement presented in Figure 7, the irrigation could depend mainly on ground water and/or stored water in lakes and reservoirs.

10. POWER GENERATION

A suitable strategy for future development requires defining locations of the different dams/lakes structures that can be used for power generation. The proposed system of dams and/or storage reservoirs will have an emergency spillway connected to the main river path. Figures 12 and 13 show the locations of proposed dams and reservoirs and their area-capacity curves along with the proposed spillway channels path and channels connecting between dams for higher level of control and management of stored water. It should be noted that it is important to provide enough time during the dry season to dredge the sedimentations from the reservoir bed to increase the lift time of dam and reserve the head required for power generation at its maximum limit.

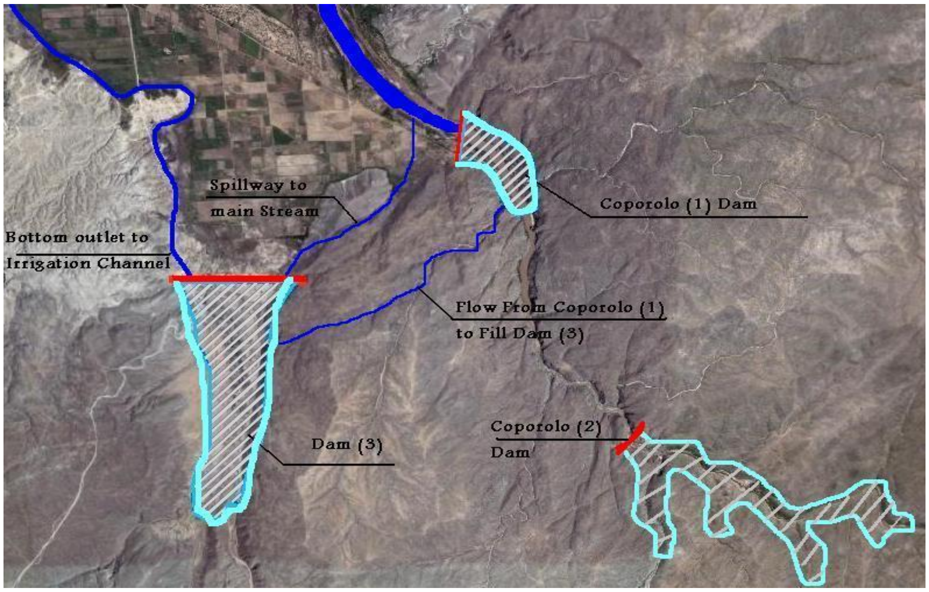

Figure 12: Proposed dam locations at the U.S. of the study Area

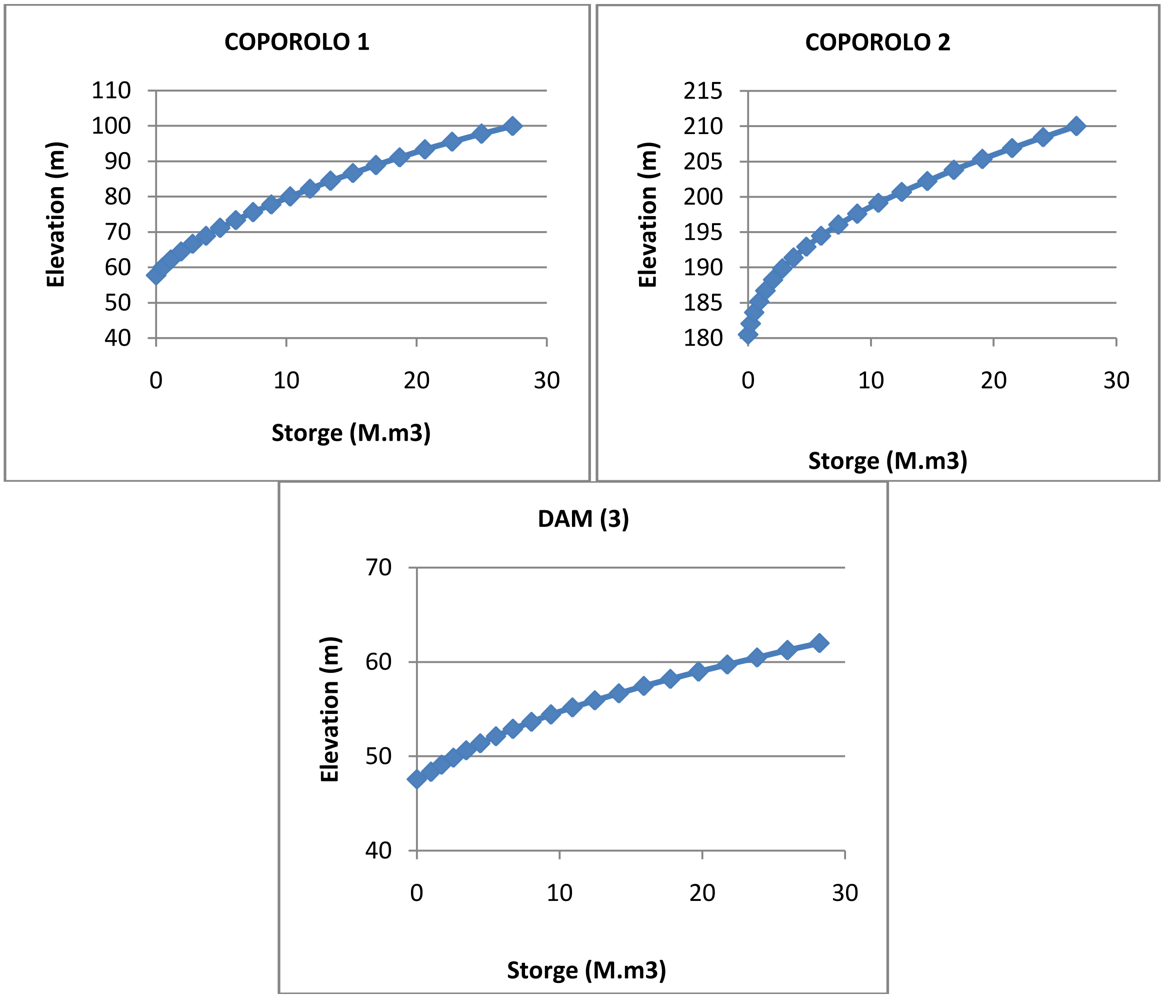

Figure 13: Reservoirs capacity curve

11. CONSTRUCTION PRIORITIZATION PLAN

It is very important to come up with a construction prioritization plan for the sustainable water management measures. It will be mainly following the necessary measures to assure the safety of inhabitants first then rehabilitate the damaged items of the existing irrigation and flood protection networks before the start of construction of new works. Based on the previous sections information and findings, the proposed scheme can be categorized, according to importance, into the following construction phases as shown in figure 14:

phase 1;

1- Construction of the main diversion dike that was destroyed in the last high event as shown in figure 12, to bring back the situation to the previous conditions. This will reduce the flood risk of the area downstream the dike and allow for cultivation of the previous irrigated lands.
2- Rehabilitate all the existing irrigation systems serving the project area.
3- Rehabilitate of all the existing groundwater wells serving the project area.
4- Rehabilitate the existing roads, bridges and electrical networks serving the project area.

phase 2;

1- Rehabilitate/Replace of the existing protection dikes constructed on the main river banks from both sides.
2- Construction of new proposed dikes as indicated on the scheme of figure 14, some of these dikes will add to the available agriculture area an additional area of about 1000 ha, figure 9.
3- Construction of the required ground water well-field to serve the agriculture area during the dry season and complement the water stored in the pond.

phase 3;

1- Upgrade the intake structures serving the existing and expanded irrigation system.
2- Construction of the proposed flow diversion/flood protection channels to divert the river and flood water to the proposed storage area and/or directly to the sea.

The above three phases allow for direct use of the project area to produce regular crops such as sugar cane, wheat and vegetables. Further phase will improve and upgrade the agriculture area and its irrigation system and will increase the cultivated lands. Following phase 3, the area could be irrigated all year round or at least a large portion of the area could be cultivated all year round and accordingly different kinds of fruits that have high rate of water consumption can be cultivated such as banana.

The next phases of Construction cover the long term development of the area.

phase 4;

1- Construction of the storage pond and related works such as small dam and spillway.
2- Construction of the proposed dam at the Coporolo River tributaries to store the water for irrigation purposes during the dry periods. This tributary catchment has an area of about 460 km2 and this may not be sufficient enough to fulfill the water requirements during the dry period as the average flood volume during regular events is about 2.5 million m^3/year. As such a diversion spillway from the dam constructed on Coporolo River should be constructed to allow for more storage in this dam.
3- Construction of a dam (Coporolo 1) on the main river, figure 12 that could supply the main system with water during dry season and may be used to generate energy for the developed areas.

phase 5;

Construction of a dam on the main river (Coporolo 2), figure 12. This dam will be used mainly to generate energy for the whole developed areas.

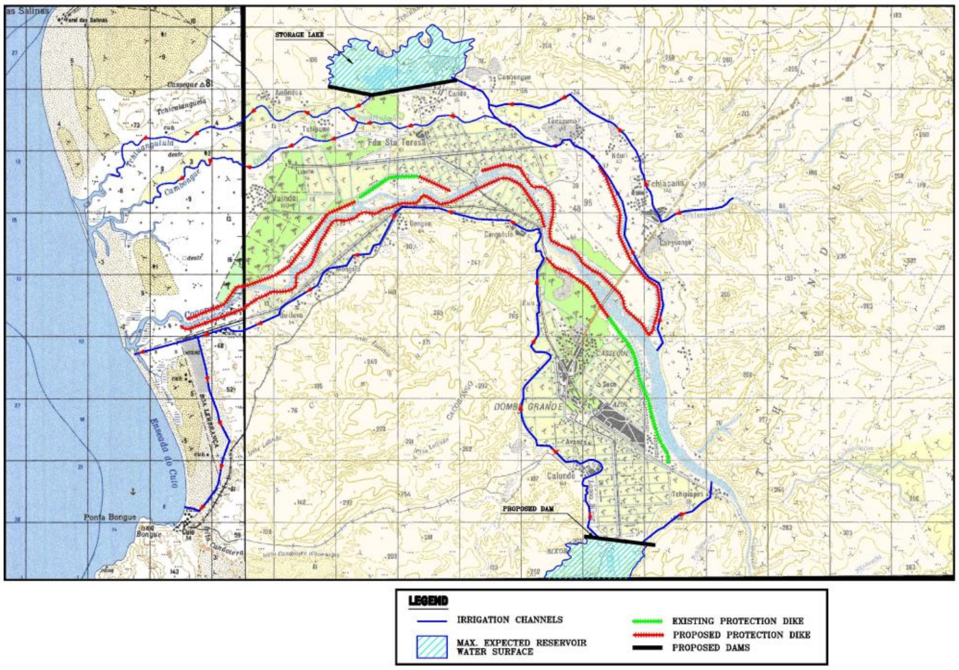

Figure 14: Construction Phases Plan

12. CONCLUSION

Throughout the previous studies and interpretation of the conducted analysis of the case study of Coporolo seasonal river's delta, the following could be concluded;

- The sustainable management for seasonal rivers delta could be achieved through two main plans of action. First is flood protection plan then water storage plan.
- Providing sustainable source of power plays a main rule for the management plan.
- Hydrological studies and hydro-geological investigation are two main information required prior the proposing of a water management plan.
- For ground water, recovery tests are to be conducted to find out whether the aquifer is an extended aquifer or a limited aquifer and whether the aquifer is recharged laterally or vertically. Following the completion of the hydro-geological site investigation work, the findings should be compiled to provide design parameters for recharging and pumping wells.
- Sustainable water resources management plan should start with saving the inhabitants from flood hazards and dry risks allow for continuation of execution of next phases of proposed plan.

REFERENCES

[1]. Feio M, "On the evolution of the great escarpment in the southwest of Angola". Garcia de Orta, (1964) 12:323–354.
[2]. Guilcher A, "Dynamics and morphology of the sandy coasts of Atlantic Africa". Cahiers d'Information Géographique (1954) 1:57–68
[3]. Kelebogile B. Mfundisi, "Overview Of An Integrated Management Plan For The Okavango Delta Ramsar Site, Botswana". WETLANDS, Vol. 28, No. 2, June (2008), pp. 538–543
[4]. Mfundisi, K. B., "Sustainable environmental planning for the Okavango Delta, Botswana: a landscape approach". M.S. Thesis, (1999) University of New Haven, West Haven, CT, USA.
[5]. Rebecca L. SCHNEIDER, "Integrated, watershed-based management for sustainable water resources". Front. Earth Sci. China (2010), 4(1): 117–125
[6]. Turton A, Brynard P, Meissner R., "Four strategic policy issues for consideration by the Permanent Okavango River Basin Water Commission (OKACOM)". Paper presented at the 3rd WaterNet/Warfsa Symposium on Water Demand Management for Sustainable Development, Dar es Salaam 30–31 October (2002).
[7]. Wellington JH., "A new development scheme for the Okovango delta, Northern Kalahari". The Geographical Journal, (1949) CXII (January–June), pp 62–69