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IRRIGATED RICE POLDERS IN THE DELTA OF THE TANA RIVER, KENYA

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Abstract

Within the context of a National Food Policy the Government of Kenya wishes to develop an irrigated rice farm of 10,000 ha in the Delta of the Tana River. As the Delta is flooded twice a year, adequate measures have to be taken to protect the irrigation areas.
During the years 1981 and 1982, a detailed feasibility study was carried out, in which technical, ecological, sociological and economic aspects of the irrigation project are analysed and evaluated.
Various considerations and constraints, such as soil suitability, topography, flood diversion and existing network of natural drainage channels, river morphology, irrigation lay-out, ecological interface and mechanized farming, have led to an optimal design of three separate irrigated rice polders, each of them inclosed by flood embankments.
This paper deals in the first place with general findings of the feasibility study and discusses some of the main considerations and criteria relative to the polder design. Finally, a brief summary of project economics is presented.

1 The project area

1.1 Location and Physiography

The project area is situated on the left bank of the lower Tana River, approximately 35 km from the coast (Figure 1) and 8 km east of the rural town of Garsen .

Most of the Delta area is subject to seasonal flooding and refered to as a floodplain, the mean altitude ranging between 15 and 30 m above sealevel. Two major physiographic units can be distinguished in the floodplain, viz. the low lying River Basin Land and the somewhat higher River Levee Land along the present and former river courses. The River Basin Land is generally flat to very gently ondulating with shallow depressions and is covered by tussock grasses and sedges with scattered bush and woodland on the higher spots. Vegetation type of the Levee Land varies from grass land to riparian forest.

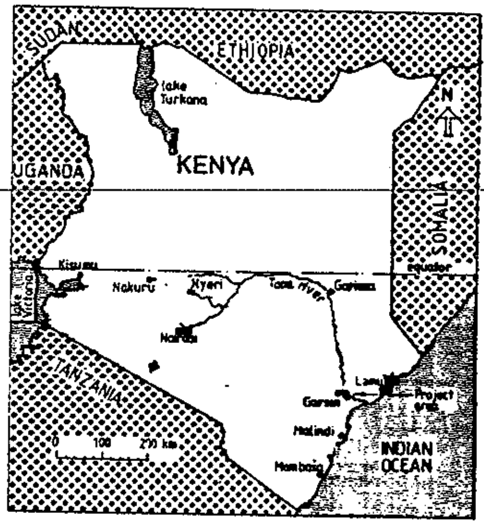


Figure 1 Location of project area

The third physiographic unit occurring in the project area is refered to as Terrace Land, which is associated with older alluvial sediments, deposited in a predominantly marine environment. Terrace Land is generally flat and can be found adjacent to the floodplain proper and in non-flooded, high lying inliers (erosion remnants). It is usually covered with grasses and scattered bushes.

1.2 Soils

Soils of the River Basin Land are generally uniform and heavily cracking clays ('vertisols') of recent fluviatile origin, poorly to imperfectly drained and non to slightly saline. The soils of the River Levee Land are deep and often stratified, well to imperfectly drained and have a neutral to moderately alkaline reaction. They have higher proportions of medium and coarse textured layers.
Finally, the soils of the Terrace Land consist generally of coarse to fine textured materials and are often strongly saline and/or sodic.

Measured hydraulic conductivity in the project area varies between 1 and 11 mm/day, the median being 7 mm/day.

1.3 Climate

The climate is affected by the movement of the inter-tropical convergence zone, resulting in a bi-modal rainfall pattern. The main rainy season starts in March or April and generally lasts until the beginning of June, whereas a second but less distinctive rainy season occurs during the months of November and December (short rains). Mean annual rainfall in the project area is in the order of 600 mm, whereas mean monthly temperature ranges from 25°C in July and August to a maximum of more than 28°C in March. Relative humidity is rather constant throughout the year with an annual average of 76%. The calculated free water evaporation (Penman) averages at some 2,200 mm per annum, with maxima occuring in March and October (7 mm/day). The climate may be classified as semi-arid, as potential evapotranspiration exceeds rainfall in virtually all months of the year.

1.4 Hydrology

The Tana River, which has a catchment area of some 95,000 km², rises on the easterly slopes of the Aberdare Mountains and Mount Kenya and has a total length of approximately 1,000 km. In the lower part of the catchment area (downstream of Garissa) the river meanders in an alluvial floodplain, finally embouching in an extensive delta between the coastal towns of Malindi and Lamu (Figure 1).

The non-regulated flow of the river at Garsen is perennial and shows a bi-modal pattern, with peaks occuring from April to June and November to December. Long term averages (32 years) of mean monthly non-regulated flow vary from about 60 m³/sec in September to about 350 m³/sec in May. The 10 percent low mean monthly flow is in the order of 25 m³/sec, whereas the lowest mean daily flow ever recordered was about 8 m³/sec (October, 1960).

1.5 Demographic Situation and Present Land Use

The project area is at present scarcely inhabited by two major ethnic groups. The most numerous group are the Pokomo, who are predominantly agriculturalists. About 50 ha of land in the project area is permanently cultivated, the main crops being maize, bananas and rice. Agricultural production is extremely low, mostly still at a subsistance level.
The second important group are the pastoral Orma people, who herd their cattle in the project area on a transmigratory basis.

2 The Irrigation Project

2.1 The Objectives

In accordance with the objectives of the National Food Policy, the Government of Kenya has called for accelerated development of potential irrigation areas, ultimately aiming at self sufficiency in food production within a relatively short period. In particular, the National Food Policy emphasizes the necessity to promote the production of acceptable substitutes for maize, Kenya's principle staple food.
Responding to the Government's efforts to meet the increasing food demand, the Tana Tana and Athi Rivers Development Authority plans to develop the potential irrigable land in the lower Tana Delta area, with special reference to mechanized rice production. The total net irrigable land of the proposed Tana Delta Irrigation Project (Phase I) is provisionally limited to approximately 10,000 ha, comprising a 9,000 ha nucleus rice estate and an outgrower scheme of about 1,000 ha.

2.2 General Design Considerations

The optimal development plan and design of a large scale mechanized rice estate is to a great extent determined by the following general considerations :

a. Seasonal flooding of the alluvial flood plain (River Basin Land). Though lowland irrigated rice can withstand a certain degree of flooding, maximum production is only achieved under optimal water management conditions, complete submergence being avoided to the maximum. Moreover, major floods will cause considerable damage to the physical infrastructure as well and can be a serious threat to human beings and animals.

b. Soils should be suitable for mechanized rice cultivation, preferably double cropped. The main criteria are low permeability, level topography, no salinity in the rootzone and no alkalinity or sodicity.

c. A gravity fed irrigation system capable of supplying good quality water to the proposed project area and maintaining the desired waterdepth in the ricefields.
Level and graded plots as well as adequate drainage facilities are pre-requisites to proper watermanagement in ricefields.

d. River morphological aspects. As the Tana River in the Delta area is strongly meandering and unstable, possible changes of the river course are to be expected and should be taken into account.

e. Large scale mechanized estate farming requires a number of essential supporting activities and infrastructural facilities. Access road network, estate compound, residential areas and related agro-industry should all be considered in the development plan.

f. The project as a whole should be profitable and feasible both from the point of view of the national economy and the investor ('bankable'). The future income level of estate workers and outgrowers should be to acceptable or pre-defined standards.

g. The environmental impact of the project. The changing hydrologic regime, pre-emption of habitat, ecological effects and wildlife danger are all factors to be considered.

2.3 Design Criteria

2.3.1 Irrigation Requirements

Because of the favourable bi-modal rainfall pattern a double rice cropping pattern is proposed, whereby harvesting and land preparation can be carried out during the relatively dry seasons. The first crop (100%

cropping) is sown at the end of October and harvested towards the end of February, whereas the optimal growing season for the second crop (75% cropping) extends from early May to September. The estimated potential evapotranspiration of the rice crop (consumptive use) is derived from calculated open water evaporation (Penman). Average field application efficiency is assumed to be 0.58, whereas distribution and conveyance losses are estimated at 20 percent. Total (gross) water requirements of the first and second crop amount to some 1,200 mm and 1,350 mm respectively, including 300 mm for pre-saturation and wet tillage and assuming that all rainfall is effective under average conditions.

Estimated water availability of the Tana River at Garsen and downstream water rights are not conflicting with total diversion requirements for the proposed net irrigation area of 10,000 ha.

2.3.2 Drainage Requirements

Adequate and efficient drainage facilities in an irrigated rice scheme are required to remove and evacuate all excess or undesired water in the rice field that may possibly jeopardize crop production. Three major reasons for excess water can be distinguished :

1) operational and seepage losses;
2) crop husbandry and watermanagement requirements (periodic field drainage);
3) excess rainfall.

The first two reasons result in a continuous drainage discharge during the irrigation seasons, which has been estimated at some 580 mm for both crop seasons.

The design capacity of the drainage system, however, is determined by the permissible depth and duration of excess rainwater. Assuming a maximum storage capacity of 50 mm in addition to the desirable waterdepth and a maximum permissible submergence period of 2 days, the design drainage module amounts to 45 mm/day or 5.2 l/sec/ha for a 1 in 5 year design storm of 166 mm in 5 days.

2.3.3 Flood Protection

Flood protection measures (embankments and flood diversion channels) are designed for a peak flood with a 50 year return period.
The 1 in 50 year flood discharge at Garsen is derived from flood frequency analysis at Garissa, taking into account the attenuation effect between these two sites (flood routing according to Muskungum method) and is estimated at approximately 2,000 m^3/sec.
As the maximum discharge of the main river bed at Garsen has been estimated at 500 m^3/sec, flood protection measures will have to be provided for a flow of 1,500 m^3/sec in a flood plain which will considerably be reduced by the irrigation project.

2.3.4 Field Units

Large field or tertiary units are desirable from the point of view of mechanized farming and mechanical land levelling. However, the cost of land levelling and water control in the fields are adversely affected by too large units. Taking into account these conflicting requirements, the optimal size of a field unit has been retained at 12 ha (200 x 600 m), surrounded by 30 cm high bunds. Each unit is bordered by a distribution canal at the upper side and a field drain at the lower end of the field.

2.4 The Design

2.4.1 The Basic Concept

The flood hazard and impeded natural drainage in the proposed project area are strongly determinant for the basic concepts of the design, i.e. complete protection of the 10,000 ha net irrigation area against flooding and adequate internal drainage of agricultural land. As such a design represents some major characteristics of "impoldering", it may be refered to as the polder concept.

2.4.2 The Lay-out

The basic lay-out of the irrigation project is mainly determined by soil suitability, topography, flood protection requirements and the existing natural drainage system.

Most of the deep and non-saline soils of the River Basin Land are classified as highly to moderately suitable for mechanized rice farming when adequate flood protection and drainage measures are provided. Some of the soils of the Levee Land are classified as highly suitable as well. A total area of some 24,000 ha has tentatively been classified as highly suitable (reconnaissance soil survey).

Since the irrigation system is to be gravity fed, the lay-out of the scheme is limited by topographical features related to site and elevation of the diversion structure on the river.

In order to reduce the costs of flood protection and main drainage canals, maximum use will be made of the existing network of natural drains and old river courses. The irrigation area is therefore limited to both the east and the west by the course of a natural drainage channel. The resulting lay-out is shown in Figure 2. The total net irrigation area of 10,000 ha is sub-divided in three separate polders for the following reasons :

- the existing course of the natural drainage channel in between polder 1 and 2;
- the construction of polder 2 and 3 will not interfere with cultivation in the completed polder 1;
- independant drainage and flood protection measures for each of the three polders will reduce the risk of complete crop failure and damage in case of severe floods or extreme rainfall;
- the space between the polders can be used to advantage as a corridor for the seasonal movement of cattle and game.

2.4.3 Flood Protection Measures

Major flood protection is achieved through the following measures :

- a flood embankment around each of the three polders;
- flood diversion channels around the polders and mostly parallel to the flood embankment;
- two river bank spillways, the first one just upstream of the intake structure and a second one a few km upstream of Garsen, in order to divert flood waters into the east and west flood diversion channels during periods of high discharges (Figure 2).

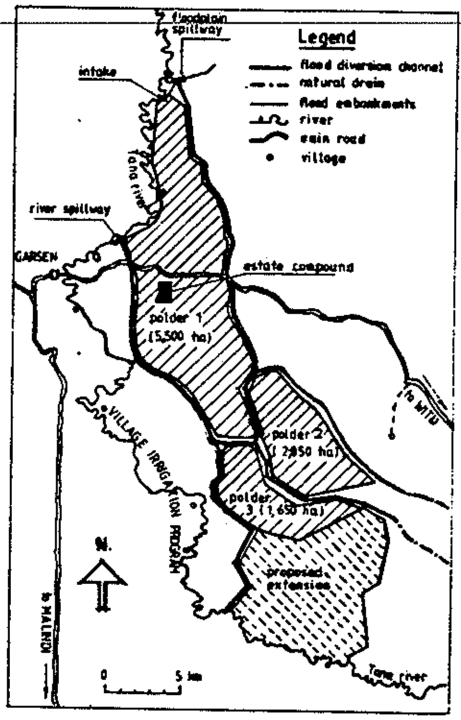


Figure 2 Lay-out of rice polders

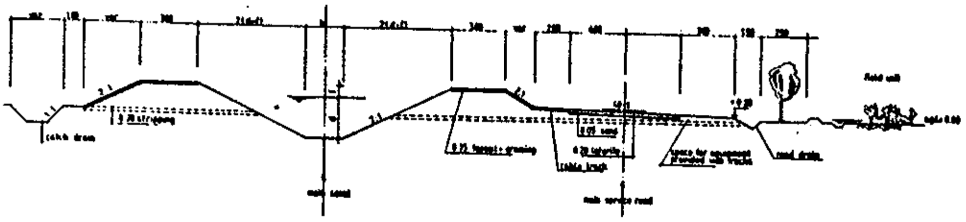
The 1 in 50 year flood levels are estimated by means of a hydraulic flood routing model for non-uniform flow in the flood plain and diversion channels, assuming that the maximum discharge capacity of the latter is 250 m³/sec.

A typical cross-section of a flood embankment is shown in Figure 3.

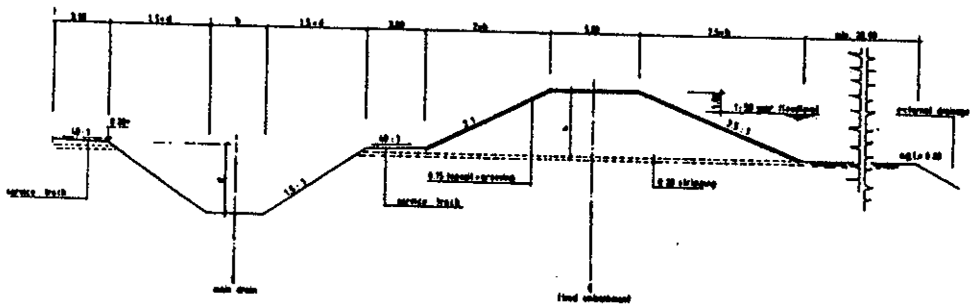
2.4.4 Irrigation and Drainage System

For river morphological reasons mainly the river intake is proposed in a cut of a river bend, some 20 km upstream of Garsen. The intake works consists of a concrete diversion weir across the river with a radial gated scouring sluice way and a radial gated oblique intake structure.

Since the sediment load of the river is high, especially during floods, a desilting device has been proposed in the supply canal just downstream of the intake. The intake structure and supply canal are designed for a discharge of 18.2 m³/sec.



Typical section main canal



Typical section main drain + flood embankment

Figure 3 Typical Cross-Sections

The main and secondary irrigation system consists of open earth canals, partly constructed in fill. At places where high seepage rates are expected, an impervious blanket of clay will be provided at the bottom of the canal. The main features of the canals are shown in Figure 3.
The drainage system consist of open channels, which discharge by gravity into the flood diversion channels or directly into the natural drains. Free drainage is impeded at times of extreme floods and drain outlets are therefore provided with flap valves and emergency sliding gates (also because of tidal influence at the lower end of the project area).

2.4.5 Infrastructure

Service and transport roads are provided for along main and secondary canals. Because of heavy traffic during harvest time paved or gravel surfaces are proposed, at least along the main transport roads.
The proposed estate compound comprises a residential area, public and community facilities, as well as an industrial area for agro-processing purposes (rice mill, stores, farm facilities, work shop and office blocks). An airstrip for crop spraying, basic power and water supply as well as communications have been included in the design.

2.5 Implementation

Actual implementation of the development proposal is scheduled to start in 1984 and should be completed by the end 1989. The annual development rate will gradually increase from 1,000 ha in 1985 to 3,000 ha in 1989. A 7 year implementation schedule has been considered as well in order to analyse the effect of a slower development rate on the economic viability.

2.6 Organization and Management

The 9,000 ha nucleus rice estate will primarily be managed on a commercial basis, in order to achieve maximum yields at the least costs. It will be state owned and a subsidiary of the Tana and Athi Rivers Development Authority.
As the project has in principle no settlement objectives, outgrowers and estate workers will basically be recruited locally.
The estate management authority will be responsible for operation and maintenance of the nucleus estate and will be self sufficient in manpower, agricultural inputs and equipment.

3 Economic Evaluation[1]

3.1 Cost Estimates

The cost estimates for capital goods and civil engineering works are based on early 1982 unit prices. A summary of investment and annual running costs is presented in Table 1.

Table 1 Summary of cost estimates for 10,000 ha net irrigation area

Description	Total costs		Cost per net ha
	K.Shsx10[6]	US$x10[6]	in US$
Irrigation, drainage, flood protection and roads.	550	52.4	5,240
Estate compound	80	7.6	760
Rice mill and silo storage.	70	6.7	670
TOTAL	700	66.7	6,670
Annual running costs at full development.	102	9.7	970

3.2 Benefits

Rice yields are assumed to gradually increase under optimal conditions of mechanized farming and direct seeding from 2,500 to about 4,000 kg/ha. Transplanted rice yields on outgrowers plots are assumed to range in between 3,600 and 4,000.

Assuming that outgrowers will sell their paddy to the estate for processing, total paddy production at full project development is estimated at some 68,000 tonnes, of which 64 percent will be marketable consumption rice. Compared with an anticipated rice demand in Kenya of 90,000 tonnes by 1989, the project will produce about half of the country's demand.

The average gross production value of the project is estimated at 21 million US$ per annum at full development level (from 1991 onwards).

The net production value per outgrower (1 ha) is estimated at about 750 US$ per annum, assuming a cropping pattern of rice in the main season and maize/sorghum as the second crop.

3.3 Economic Viability

The internal rate of return has been used as the parameter to examine the economic viability of the project.

Total project costs and benefits have been calculated on a cash flow basis over a period of 30 years. The project benefits are net values, i.e. adjusted for the expected benefits in a 'without' project situation. It is further assumed that the intake works will have to be reconstructed in 1999, due to drastic changes of the river course.

The resulting economic internal rates of return are presented below :

Implementation Rate	I.R.R. (%)
6 years	13.8
7 years	13.2

If the gross production value is reduced by 10% in all years, the I.R.R. will drop to 10.8 and 10.5% respectively. Increased construction costs by 10% will reduce the I.R.R. only slightly to 13.2 and 12.6% respectively.

In the context of the National Food Policy, the Tana Delta Irrigation Project will play a particularly important role. Not only will it contribute to the development of one of Kenya's least developed areas, it will considerably help to relieve the country's food shortage. At full development the project's rice production will satisfy the staple food requirements of a considerable proportion of the population while also allowing for exportation of the surplus.

Note

1 The figures given in this paragraph are at this stage still provisional.

Acknowledgements

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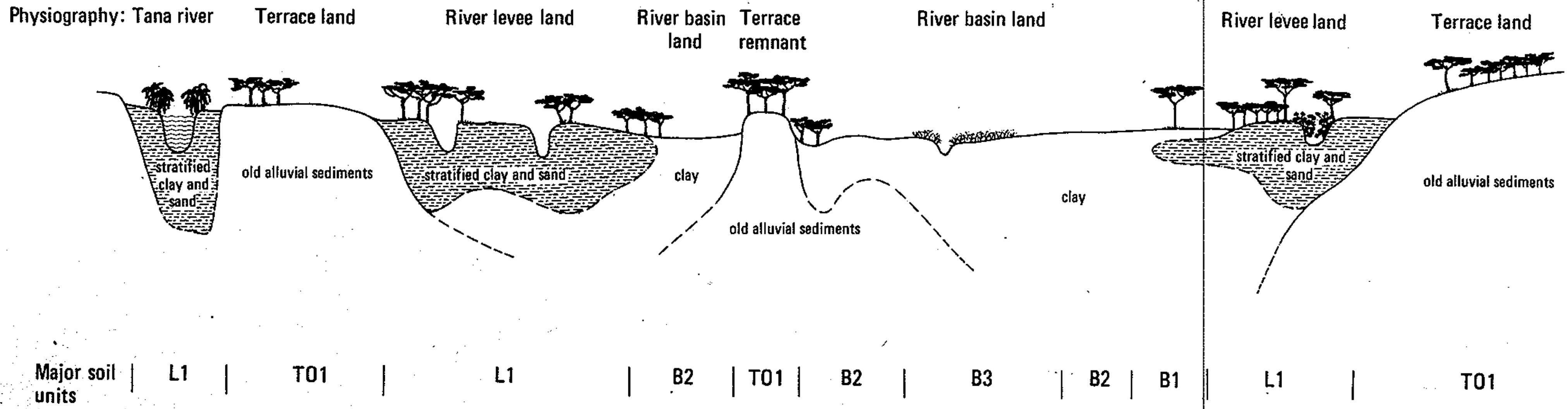

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