DEVELOPMENT OF FLOOD-RECESSION CROPPING IN THE MOLAPO'S 0F THE OKAVANGO DELTA, BOTSWANA

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1. The Okavango Delta in a Nutshell

1.1 Geography

The inland Okavango Delta in north-west Botswana is hand-shaped, with the fingers spread (Figure 1). The Okavango River, which originates in Angola, enters the delta at its apex. On the average, the river carries about 10 000 million m^3 of water a year into the delta. The flow rate is high in the months of March and April (about 1000 m^3/s on the average, but varying from year to year between 500 to 1500 m^3/s) and low in November (100 to 200 m^3/s).

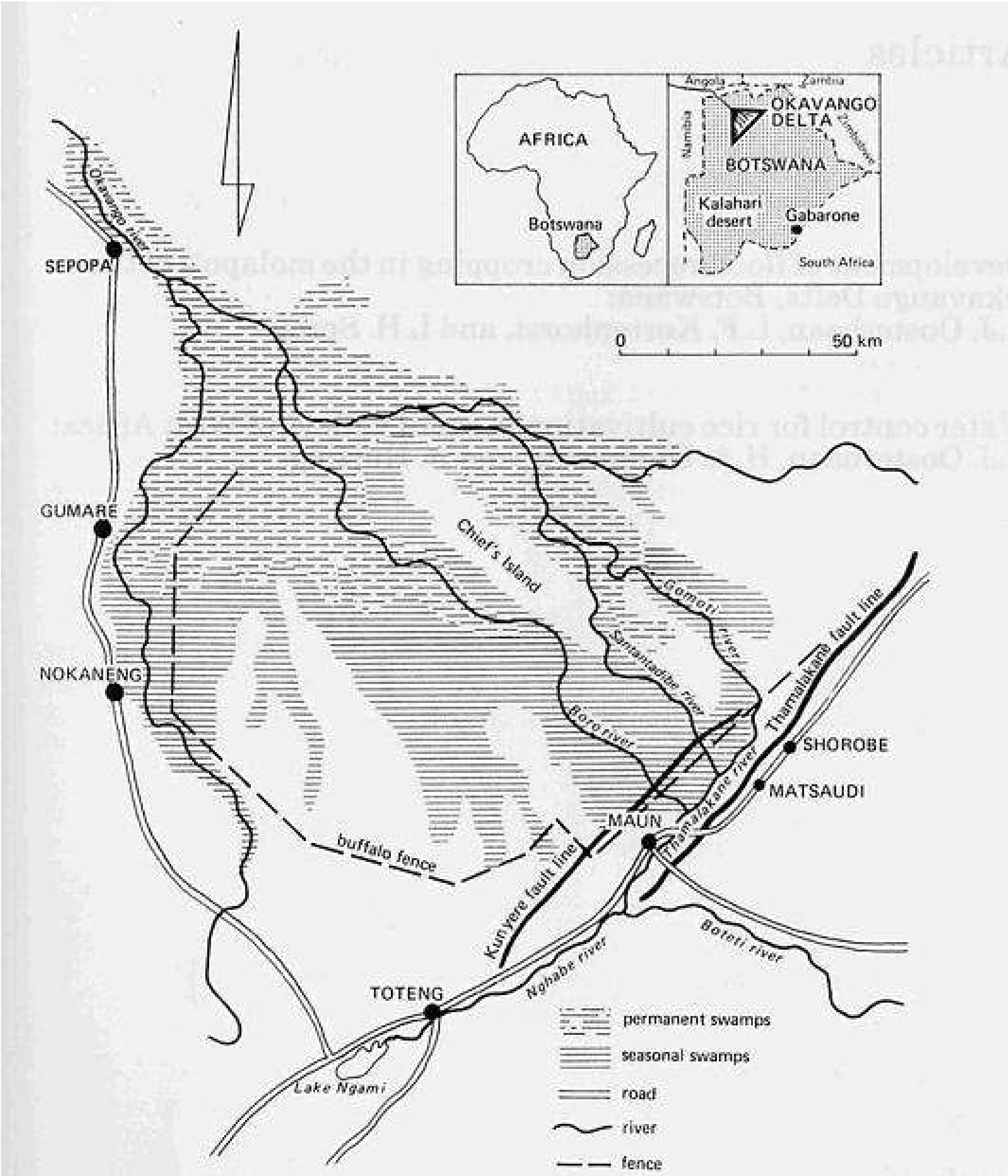

Figure 1. Map of the Okavango Delta

The large volume of water spreading over the delta is almost fully absorbed in permanent and seasonal swamps (the latter are called *molapo's*) before is slowly infiltrates or evaporates. There is a rich swamp vegetation, which creates an ideal environment for numerous kinds of animals. The rich fauna finds its habitat on and between the thousands of islands between the swamps (Photo 1).

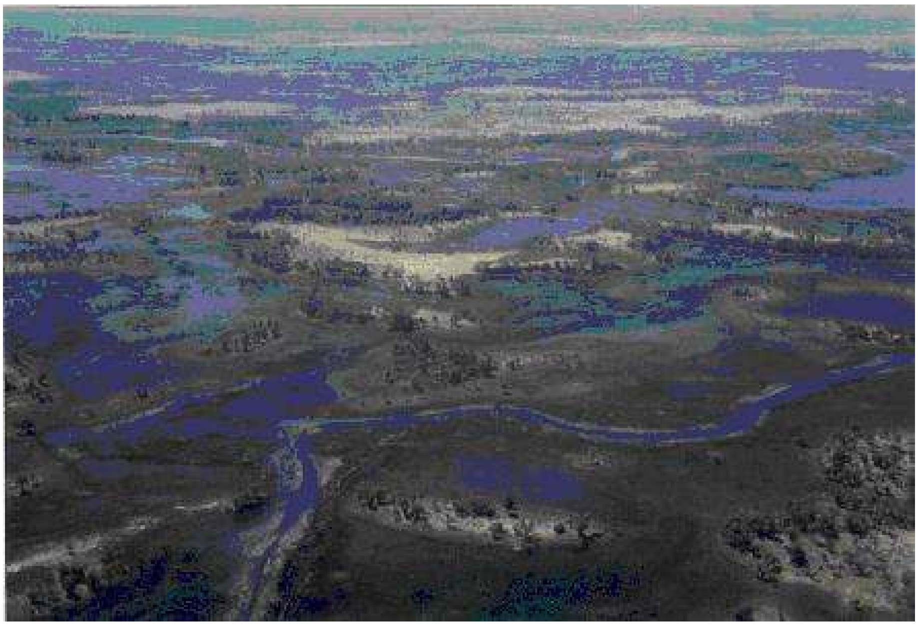

Photo 1. Islands and permanent swamps in the Okavango Delta

The little water that exceeds the retention capacity of the marshy wilderness drains from July to November through the fingers of the giant hand. Hence, it takes almost six months before the peak discharge of the Okavango River manifests itself at the base of the delta. Here, the water meets a barrier: the Thamalakane Fault Line, beyond which the Kalahari sands rise up 10 m. At the foot of the fault, the Thamalakane River collects the water (which is not more than 5% of the total inflow) and carries it almost without gradient to the Boteti River, which flows through a breach in the fault line. Eventually, the remaining waters evaporate in the Makgadikgadi Pans, more than 200 km to the east.

Although the annual rainfall is relatively low (an average of 500 mm, the greater part of which falls from December to March), it contributes a volume of water to the Delta equaling half of the Okavango inflow. The annual rainfall and its yearly distribution are equally erratic as the regime of the river.

The Okavango River transports a large amount of sands and other sediments into the delta. Their mass is about 2 million tons a year. Salts also enter the Delta, but they do so in a dissolved form. The salt concentration of the water is some 200 mg/l, which is very low. The total weight of incoming salts is thus about 2 million tons per year.

The sediments and the salts imported by the Okavango River settle in the delta. Together with the vegetation the sediments build up resistances to surface-water flow. As a result, the main watercourses have in the past swayed from thumb to little finger to and fro, as is common in alluvial fans. Tectonic movements have also contributed to this phenomenon. At present the middle finger, from which the Boro River stems, provides the major thoroughfare.

Many of the islands in the delta have a garland of riparian trees along their borders, but in the middle they are bare: symptoms of salt accumulation (Photo 1).

The Kalahari Desert cooperates with the Okavango River to form the predominantly sandy soils of the delta. The desert uses the vector wind to deposit its share of fine sand. The arable *molapo's* in the south-eastern fringes of the delta often have a sandy topsoil. In depressions, the topsoil may be thin or missing altogether, exposing a heavy clay soil.

The geophysical characteristics of the Okavango Delta have led to a low population density, so that the natural situation has scarcely been disrupted by mankind.

1.2 The people and the **molapo** *cropping system*

Various Bantu tribes live on the western and south-eastern fringes of the delta. The most numerous are the *baYei*. The second largest group – but politically, culturally and economically the most important – is the *baTswana*.

Livestock rearing is the main income-generating activity (Photo 2) and, as in most livestock-based farming systems in Africa, the people attach great socio-cultural values to it. Livestock also plays an essential role in people's strategy of risk avoidance. Activities of minor importance in the farming system are crop production, palm-wine tapping, fishing, hunting and basket weaving (Photo's 3 and 4). The relative importance of the different income generating activities depends on the specific environmental conditions: they may therefore change from one year to the other.

Photo 2. Livestock rearing is, a major component in local farming systems.

The land-use rights are vested with title-holders who are often the direct descendents of the original settlers or long-ago conquerors. The title-holders often control large areas; too large to be cultivated by their own households alone. Landless people can borrow land if they want to cultivate. This creates obligations towards the title-holder, which the landless sometimes repay by assisting the owners with some of their agricultural activities. It also happens that this debt is called in at another time. Although long-term leases exist, most of the land is borrowed for one season at a time. The borrowers often change fields from year to year. As a rule, therefore,

	Photo 4. Tapping palm juice for wine

Photo 5.

Fish, an important contribution to the diet.

farmers cultivating borrowed land will not invest in any structural improvement, such as erecting cattle fences. Possible, this has also to do with the authority of the title-holders, who may not agree to borrowers acquiring a kind of moral right to occupy by fencing the land they borrow. On the other hand, this system of changing fields may be a flexible response to the annual changes in flooding regime. Insight into these socio-economic relations is yet incomplete.

Farmers prepare their land in different ways, depending on the wealth of the family. The very poor use the hand hoe, the poor use donkeys, and the relatively wealthy use oxen-traction and a moldboard plow. Many farmers who do not own draught animals may borrow a span of oxen and the required equipment to till their land, in exchange for money or a labor contribution to the agricultural activities of the owner. As a rule, these farmers will be late with planting since the owner of the oxen will prepare his own fields first and sometimes call in the labor contribution of the borrower before providing the oxen.

For yet unknown reasons, the spans of oxen number six to ten animals, an exceptional feature in Africa. Is it a matter of status? Or do the oxen need better training or better care?

Crops (mainly maize, sorghum, and millet) are produced on both the sandy soils of the uplands (*santvelts*) and the arable flood plains (*molapo's*). Sowing is done broadcasting a mixture of crop seed, followed by a light plowing. Thefields – those of the *santvelts* fenced with thorn-bush to keep out cattle and wildlife – are scattered along the delta fringes. On the *santvelts* the yields are low because of the Sahelian-like rainfall and because the soil fertility is poor, whilst weeds compete with the crops for the scarce water and nutrients, and insects and birds take their toll.

When the crops have to depend entirely on the scarce and erratic rainfall – especially in the *santvelts*, but also in the *molapo's* that are not reached by the floods in a particular year – they may be sown between December and February. More favorable conditions exist in the *molapo's* when, after adequate floods, the water withdraws by October. The crops can then be sown early, germinating on the residual soil moisture. (Unfortunately, this situation does not occur every year). If all goes well, the rains set in before the soil gets too dry. In this way, the growing season is prolonged and the available water for plant consumption is increased by about 100 mm. Yield may locally exceed 1.5 ton/ha when rainfall and its distribution are also favorable.

Early floods, caused by local rainstorms in the delta and preceding the flos from the Okavango River, may damage standing crops. In the past, people have constructed bunds to protect the fields against such unwanted inundations.

Molapo cropping is a risky farm activity. This explains the great flexibility in the farming system, with its escape possibilities to family activities that are better suited to the subsistence opportunities of a particular year. In dry years, for instance, crop production is of hardly any importance to most farmers; they may even leave their homeland for some time, to concentrate on extensive livestock activities, or on palm-wine tapping, or to find a temporary job, but it is not quite clear how this subsistence strategy works.

2. Molapo Developments

In 1978/79, after four years of high and prolonged floods had made *molapo* farming impossible, a sever drought coincided with an outbreak of foot-and-mouth disease, leaving the local population in a state of emergency. This resulted in two important undertakings.

The first took place from 1979 to 1981 when, as part of a drought-relief program (Food for Work), FAO organized labor-intensive works to rehabilitate the bunds that the local population had built to protect their crops against inundations from rainstorms. Some new bunds were also built.

The second was the construction of the "Buffalo-fence" (Figure 1), which separates the outré fringes of the delta from its interior to prevent the spread of cattle diseases – especially foot-and-mouth. Completed in 1983, this fence has increased the importance of the *molapo's* outside it, and for the following reasons.

Especially in the years when rains start late, the new grass flush in the *molapo's* after flood-recession presents about the only source of fodder in the region, also for the herds in the wide surroundings of the delta. With the *molapo's* inside the fence closed to cattle grazing, the grazing intensity in the *molapo's* outside the fence has increased.

The people who have an old title to the *molapo* land wich is now inside the Buffalo Fence can no longer cultivate those family lands because draught cattle have not been allowed in there since 1983. They have thus been forced to join the category of landless farmers in the outer *molapo's*.

2.1 On-going agricultural projects and programs

Although the mainstay of the people living in and around the Okavango Delta is fishing, hunting, and cattle rearing, the government of Botswana attaches great value to the development of agriculture, because the country is not self-sufficient in food (except beef) and therefore imports large quantities of cereals and vegetables. As part of a national program to study the possibilities of enlarging the country's domestic agricultural production, the Department of Agricultural Research (DAR) has started a farming-systems research project in the delta's northwestern *molapo* areas. There are also various farm-subsidy programs designed to stimulate agriculture in the area. These are:

1. – The Drought Relief Program (DRP): all farmers without adequate animal traction are eligible for a grant (the equivalent of 150 kg cereals) to hire additional oxen draught-power or a tractor to plow a maximum of 3 ha. (For comparison: the yield expectation of the *santvelts* when rainfall is sufficient is not more than 400 kg/ha.) The farmers may apply every year again.

The DRP is also creating temporary employment opportunities. For instance, the labor force for labor-intensive infrastructural works (including flood-protection bunding and group-fencing against crop damage by stray cattle) is being financed at a rate of the equivalent of 6.5 kg cereals per man-day.

The program also provides free food-rations to all children under 10, all pregnant and nursing women, as well as the old, the destitute, and the disabled. Since people living in remote areas are also entitled to free food rations, only a minority of the population is excluded from the food assistance.

2. –The Accelerated Rain-Fed Arable Program (ARAP): all farmers can qualify for premiums on land-preparation and crop-cultivating operations, although only once and with a certain hectare ceiling. For instance, without counting free seed and fertilizer, the total premium for land clearing, plowing, row planting and weeding a field of 1.5 ha corresponds to the value of about 550 kg of maize, enough to feed a small family for a year.

3. – The Arable Lands Development Program (ALDEP): all farmers with less than 40 head of cattle, and who have cleared 1 ha and are willing to follow the extension advice, are eligible for the ALDEP-subsidized loan scheme to purchase draught animals and farm implements. The government provides a grant of 85% of the costs, except for the draught oxen, for which the grant is 60%. In future, farmers without any cattle will receive 100% grants.

A point of concern is whether the many subsidy programs will not demotivate the people from engaging in self-help and from accepting full responsibility for operation and maintenance and ordinary farm management. Another point of concern is whether any possibilities and incentives for continued *molapo* development will remain after the generous subsidies cease.

2.2 The molapo development program (MDP)

The Molapo Development Projects (MDP) became operational in December 1983. It is supported by the *Gesellschaft für Technische Zusammenarbeit* (GTZ), West Germany.

The original project aimed at increasing crop production in pilot areas by protecting those areas against prolonged high floods. This was a response to the high and prolonged flooding in the years 1974-1978, when molapo cropping was largely impossible. In more recent years, however, inadequate floods appeared to present an equally severe constraint to satisfactory crop production. It was therefore decided to focus also on improved, more stable crop production under fully rain-dependent conditions.

The project is about to complete the flood-control works (Photo's 5 and 6) in two pilot areas: Xhwaa (830 ha cultivable) and Shorobe (670 ha cultivable). A third pilot area (Mazanga, 100 ha) had already been protected by FAO. For their locations, see Figure 2. The required length of the bunds per ha (and hence the cost per ha) ranges between 1 and 2 m. This is a small value, thanks to the presence of the many islands and hills.

Photo 5. Molapo area with new bund between adjoining islands

Figure 3 shows that crop production has not been possible in 60% of the hitherto recorded years because of the prolonged high floods. This figure refers to molapo's under the flooding regime of the Boro River and may need some adjustments because the flood levels in the Project area are somewhat different from those along the Boro.

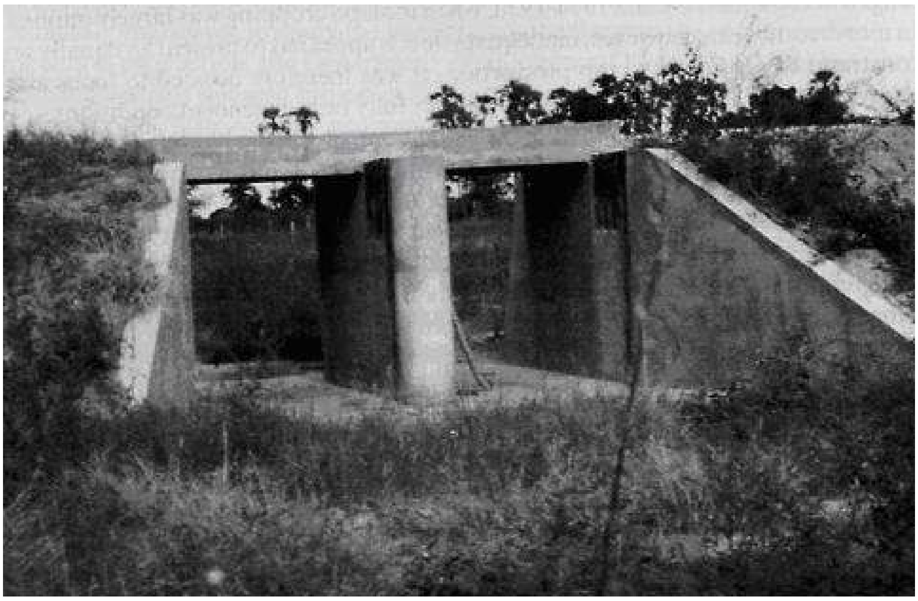

Photo 6. Close up of the sluice gate of the bund in Photo 5.

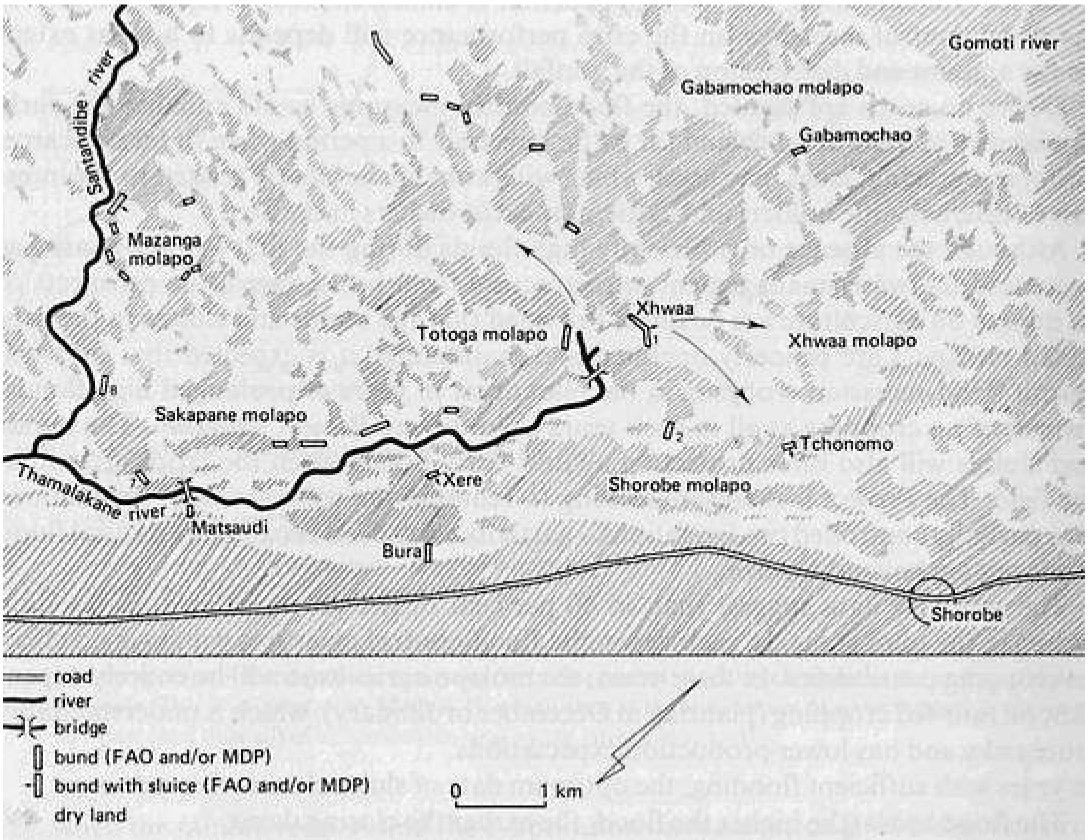

Figure 2.The area of the Molapo Development Project

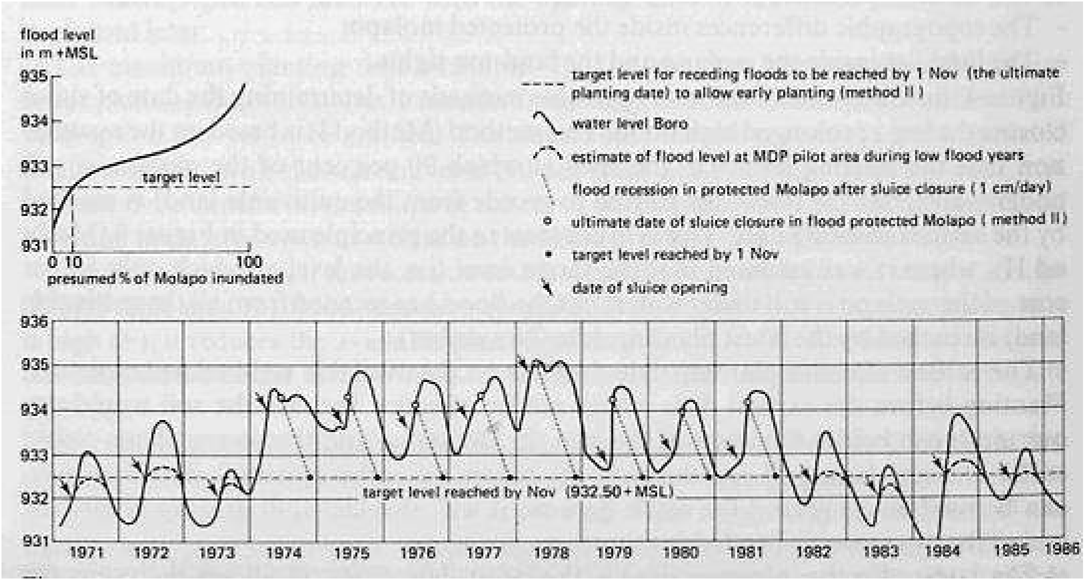

Figure 3. Hydrographs of the flood level of the Boro river, wit an indication of the years in which the timely closure of the sluice gates would facilitate flood-recession cropping in the molapo's

Figure 3 also shows how flood-control measures can bring about a timely recession of the water level in the molapo. After the flood has been permitted to enter the bunded molapo, the sluice gates are closed. Recession of the water in the bunded molapo then begins under the influence of evaporation and infiltration, and allows a timely planting of the crop (in October or November). The crops use the residual soil moisture (about 100 mm) till the onset of the rainy season at the end of November or the beginning of December. Thus the growing season is prolonged, the moisture availability is increased, and crop production is enhanced. However, the success of the flood-control measures on the crop performance still depends to a great extent on the amount and distribution of the rainfall.

Where no crops are planted, the flood recession would enhance the early availability of natural rangeland for cattle, precisely in a period when fodder is scarce. Cropping versus grazing issues may arise, which will probably be closely related to the interests of the title versus non-title holders and cattle versus non-cattle holders.

Although the absence of sufficiently high floods during the first project phase has prevented the water-management infrastructure from being tested, the prospects of its impacts on agriculture are positive. Provided that the bunds and sluices in the protected molapo's are properly operated and maintained, it is expected that they will permit flood-recession cropping in the pilot areas in years of prolonged high floods, instead of no cropping at all in such years as in the pre-project situation. The bunds and sluices will also offer protection against early floods when the crops are still in the field. The project is therefore seeking to remold the wild, seasonal, inundations into partially-controlled pre-irrigations – partially controlled beu=cause the natural flood levels still remain beyond control.

The available data suggest that in 40% of the years little or no flooding occurs in the pilot areas. In such years, the flood-control measures will have no effect on cropping possibilities. In these years, the molapo agriculture will be entirely

dependent on rain-fed cropping (planting in December or January), which is understandably more risky and has lower production expectations.
In years with sufficient flooding, the optimum date of sluice closure depends on:
1. - The flood levels (the higher the flood, the earlier the closing date);
2. - The rate of recession of the water level in the molapo after sluice closure (the faster the rate, the later the closing date);
3. – The earliest and latest possible planting dates (which have yet to be verified);
4. – The topographic differences inside the protected molapo;
5. – The land use inside the molapo and the land-use rights

Figure 4 illustrates one of the many possible methods of determining the date of sluice closure during a prolonged high flood. This method (Method I) is based on the assumption that the starting level (i.e. the level at which 90% of the molapo is still under water, but the flood has started to recede from the cultivable land) is reached by the earliest planting date. This is in contrast to the principle used in Figure 3 (Method II), where it was assumed that the target level (i.e. the level at which only 10% of the molapo is still under water, but the flood has receded from all the cultivable land) is reached by the latest planting date (November).

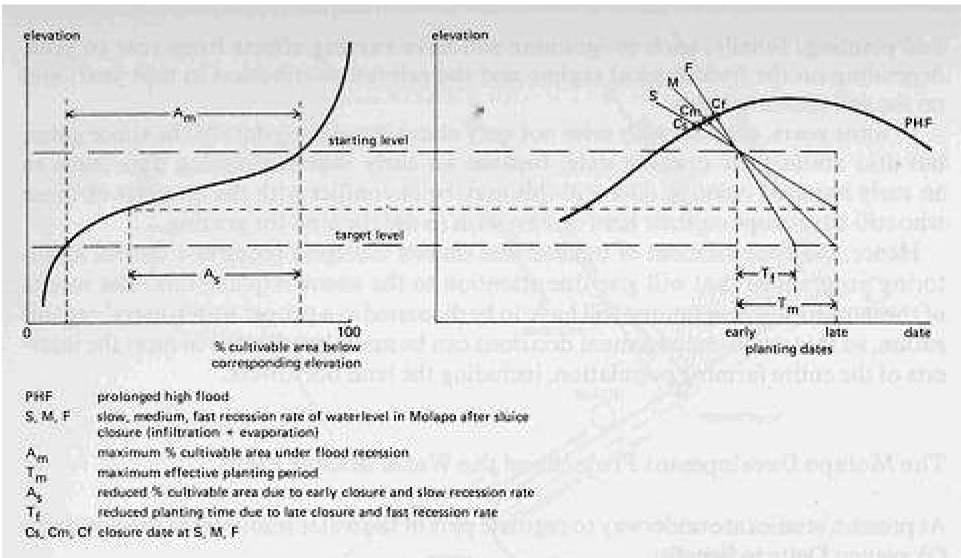

Figure 4. Method I of determining the opening date of the sluice gate during a prolonged high flood in the molapo's: flood recession starts in the higher part of the cultivable land at the earliest planting date. This is in contrast to Method II, which aims at the elimination of the water-logging in the lower part (and thus all) of the cultivable land by the latest planting date.

The earliest effective planting date depends on the available residual soil moisture. Planting before the earliest date would not be effective because the soil would dry out too much before the onset of the rains in December and the young plants would suffer drought damage. Land that falls dry before the earliest planting date, however, can be used as rangeland for cattle because it would provide fresh grazing before the end of the dry season when fodder shortages are acute,

The latest effective planting date is the latest date that still allows the crops the advantage of a longer growing season. The growing season virtually ends after

February, when the rainfall reduces and the evaporation increases strongly. Hence, any prolongation of the growing season should be sought in earlier planting, before December, rather than in counting on longer growth beyond February. Also, a crop stand lasting until March/April can interfere with the opening date of the sluice gates, as will be explained later.

The maximum planting time available, T_m (i.e. the time between the earliest and latest planting dates) is about 1 month: from early October to early November. This assumption has yet to be verified. The same holds for the percentages of inundated land with the starting level (90 percent) and the target level (10 percent), because these depend on the shape of the curve representing the relation between flood level and inundated area, as well as on the cultural practices and land-use rights.

Figure 4 shows that, if the recession rate is slow (S), Method I reduces the percentage of cultivable area for flood-recession cropping from A_m to A_s or, if the recession rate is fast (F), it reduces the available planting time from T_m to T_f. For Method II, these relations would be the inverse. Also for medium high floods, these relations are quite different.

The recession rate depends on infiltration and evaporation. Data on the infiltration capacity of the soils under flooded conditions, however, are fragmentary.

Each sluice-closure program affects the agro-hydrology of different parts of the molapo land in different ways, and consequently may cause disputes among land-users. Also, each program influences the possible cultural practices, for example: possible planting date, period of peak labour requirement, or land-use choice between grazing and planting. Finally, each program will have varying effects from year to year, depending on the hydrological regime and the rainfall distribution in that year, and the soil characteristics.

In some years, disputes may arise not only about the closing date of the sluice gates, but also about their opening date, because an early required closing date leads to an early required opening date and this may be in conflict with the interests of those who still have crops on their land or who wish to use the land for grazing.

Hence, the establishment of bunded and sluiced molapo's requires a careful monitoring program that will give due attention to the above implications. The results of the monitoring program will have to be discussed in a proper water user's organization, so that water management decisions can be made or adjusted to meet the interests of the entire farming population, including the land-borrowers.

2.3 Molapo Development Project and the Water Master Plan

At present, studies are underway to regulate part of the water resources in the Southern Okavango Delta to benefit:
1. – Molapo farming;
2. – Prospective commercial irrigation projects;
3. – The diamond mines;
4. – Other uses like drinking water, industry, fisheries.

Implementation of the Water Master Plan (WMP, officially called the Southern Okavango Integrated Water Development Master Plan) will change the hydrological conditions along the Thamalakane River, which is the main flood channel to the pilot areas of the MDP. Hydrologically the WMP aims at (Figure 5):

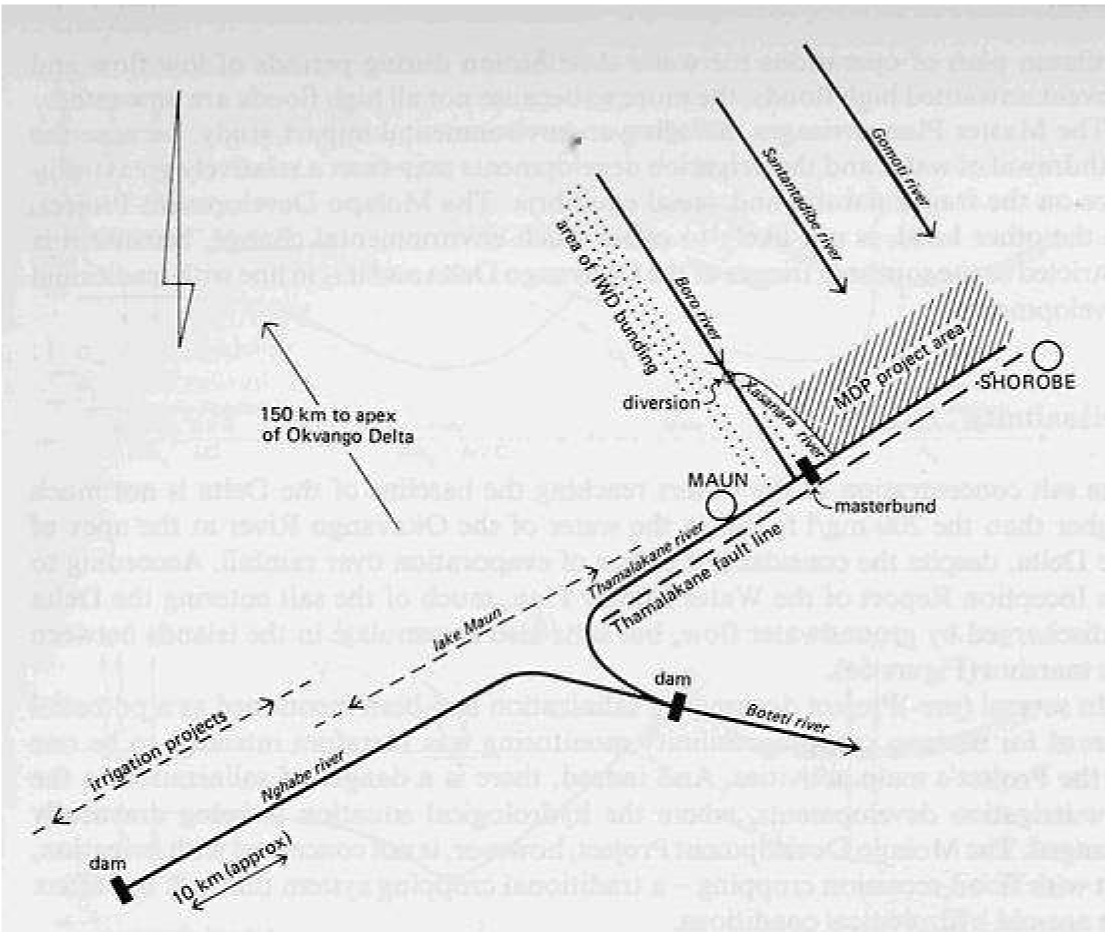

Figure 5. Sketch of the water-control works proposed in the Master Plan

1. – An increase of discharge through the Boro River (which is now the main tributary to the Thamalakane), especially during periods of low flow. This will be done by canalizing the lower Boro River and constructing dikes along it. These measures will reduce flooding from the Boro into adjacent swamps and molapo's, but will increase the incidence of higher peaked floods, which will call for additional flood-attenuation works.

2. – Storage of the Boro water in a reservoir (Lake Maun) by constructing a dam in the Boteti River, which will back up the water in the upper part of the Boteti and its tributaries (the Nghabe and Thamalakane Rivers) and in the Boro River, as well as in the adjoining low-lying areas and molapo's. There will also be secondary dams.

The WMP specifically states that molapo farming in the Boro-Shorobe area (which is the gross area of the MDP) is to benefit from the works by the prevention of unwanted high floods and the diversion of extra water to the Boro-Shorobe area during periods of low flow. For this purpose, a dam (known as the Master Bund) may be built across the Thamalakane River, between its confluence with the Boro River and the MDP project area. The Master Bund would retain the water of Lake Maun.

Upstream of its confluence with the Thamalakane River, part of the water in the Boro River can be diverted through a regulation structure into the Xasanare River, which is to be canalized. This distributary of the Boro will lead the water to the Thamalakane at a point between the Master Bund and the MDP project area. The Thamalakane has almost no bed gradient, so that the flow can pass in either direction.

Hence, the molapo's of the MDP project area can be supplied with water from Lake Maun - through the Master Bund – and from the Boro River, through the diversion structure.

Thus, during periods of low flow, the MDP project area might benefit from the implementation of the WMP, but this depends greatly on the present hydrology and on the operation programs of the regulating structures. Both factors have yet to be determined.

The variability of the Okavango's inflow into the delta, and of the hydrological behaviour of the delta itself (which retains more than 95% of the incoming water), together with the flatness of the Thamalakane River, the irregular shape of the inundatable molapos's, with intricately dispersed undulations, and – last but not least – the different interests vying for the water resources, will make it extremely difficult to design an effective network of hydraulic structures that would ensure an optimum plan of operation for water distribution during periods of low flow and prevent unwanted high floods, the more so because not all high floods are unwanted.

The WMP envisages to include an environmental impact study, because the withdrawal of water and the irrigation developments may exert a relatively great influence on the fragile natural and social equilibriums. The MDP, on the other hand, is not likely to cause much environmental change, because it is restricted to the southern fringes of the Okavango Delta and is in line with traditional developments.

2.4 Soil Salinity

The salt concentration of the waters reaching the baseline of the delta is not much higher than the 200 mg/l found in the water of the Okavango River at the apex of the delta, despite the considerable excess of evaporation over rainfall. According to the Inception Report of the WMP, much of the salt entering the delta discharged by groundwater flow, but salts also accumulate in the islands between the marshes (Figure 6A).

In several project documents, salinization has been mentioned as a potential hazard for molapo cropping. Salinity monitoring was therefore intended to be one the main project activities. And indeed, there is a danger of salinization in the new irrigation developments proposed in the WMP (Figure 5), where the hydrological situation is being drastically changed. The MDP project, however, is not concerned with irrigation, but with flood-recession cropping – a traditional cropping system that will not affect the age-old hydrological conditions.

In the regularly flooded molapo's of the Shorobe region, high water tables are normally not present. Sometimes groundwater is not even found at considerable depths (10 m or more). It is therefore probable that, during periods of high flood levels, the natural groundwater flow into and through the aquifers is sufficient to maintain a favourable salt balance in the molapo's (Figure 6B). The present mediocre soil fertility in the molapo's and the absence of salinity problems confirms this viewpoint: there is a net leaching of minerals. Hence it is unlikely the the area of the MDP project will face any serious threat of salt accumulation in the soils.

If, despite the observed features above, some salts accumulate at the soil surface at the end of the dry season, the following floods and/or the rainfall will be sufficient to wash them down to below the root zone. If, on the other hand, the floods and/or rainfall are insufficient to wash the salts down, there will be n overall shortage of water so that, in such a year, any crop failure will be primarily due to drought, not to salts.

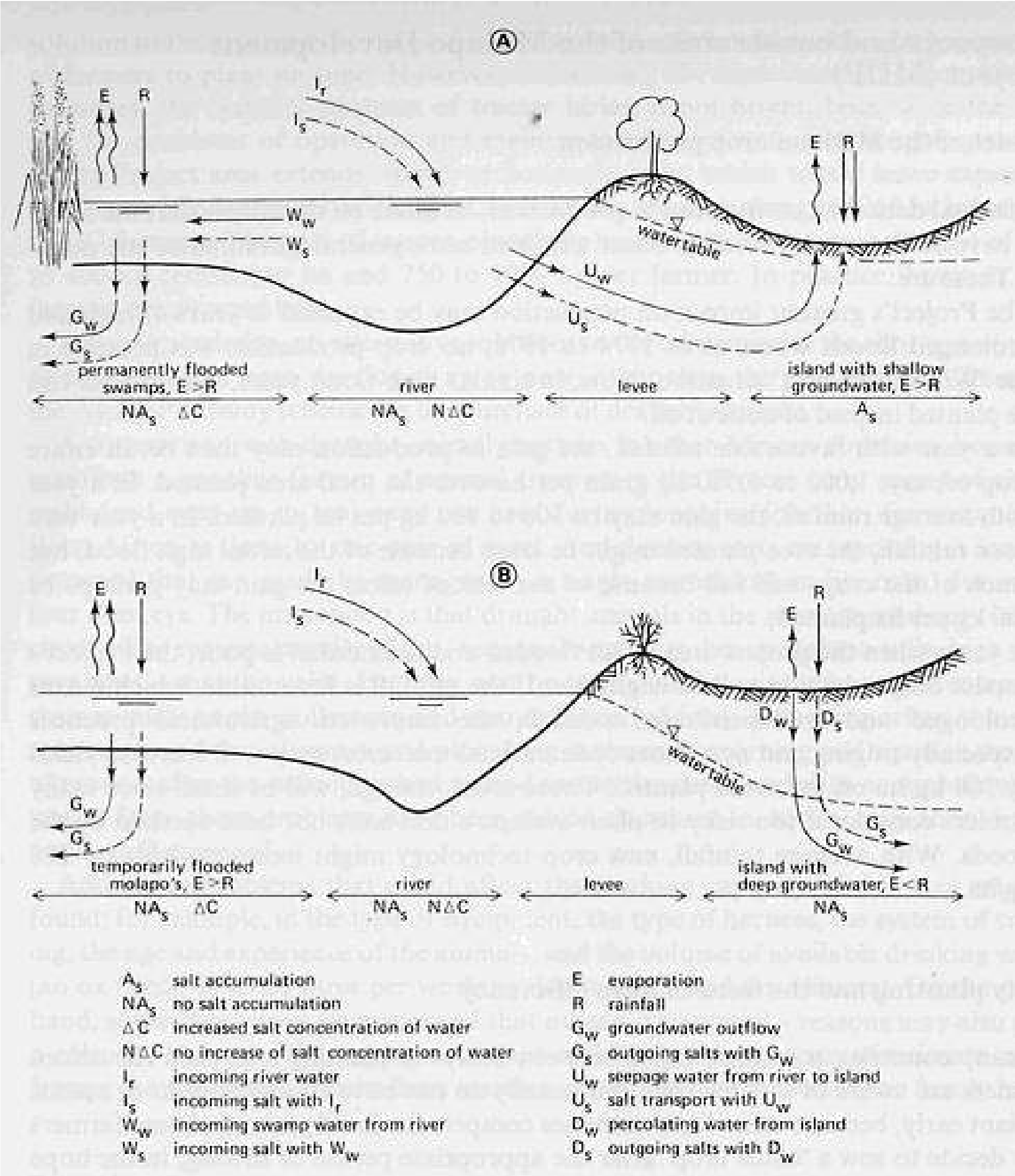

Figure 6. Sketch of water and salt movements in the Okavango Delta
A: Upper part of the delta with permanently flooded swamps
B: Lower part of the delta with temporary flooded molapo's

3. Agronomic Prospects and Constraints of the MDP project

To be completed . . . .

3.1 Impact of the MPD on crop production

3.2 Early planting and the issue of oxen efficiency

3.3 Row planting

3.4 Pest control

3.5 Training and extension

A girl gathering food in the delta

4. Conclusions

The Molapo Development Project (MPD) is studying and experimenting with water-management and agronomic innovations, as well as with rural extension programs. Yet, not many particulars are known about the farming communities. The answers to the following questions, for instance, are not known:
1. – What are people's socio-economic constraints and possibilities?
2. – Through whom, and by what methods, should the extension worker try to reach all the people, also the poorer ones?
3. – Which farmers are willing to try out an innovation, which are not, and for what reason?
4. – Which land and which crop is planted by the farmers in different years?
5. – What do the farmers do besides farming? What is their "farming system" as related to their yearly varying resource base?

If the project is to have any chance of success in obtaining a permanent increase in crop production, it needs to continue its activities in the present integrated way, with even stronger extension efforts, because an isolated action – say one with only a technical orientation – is not only likely to be in vain, but also likely to damage the social and environmental equilibrium.

For the local human population, the fringes of the Okavango delta offer both a beautiful ecological setting and a resource base. With careful planning, the natural resources can support more intensive agriculture, provided that the prospective developments aim at sustaining, not disrupting, the environmental and social structures.

5. Colour Pictures

5.1 The delta

Panorama

A buffalo herd in the delta

A gracious female lechwe, flying without wings

Hippo's with their big mouths

Saddle billed storks

5.2 The molapo's

Maize fields in a *molapo*

Maize field close-up


Old, abandoned traditional bund made to retain water in the *molapo* for flood-recession cropping


Corn crickets may affect the yield strongly