REPUBLIC OF KENYA

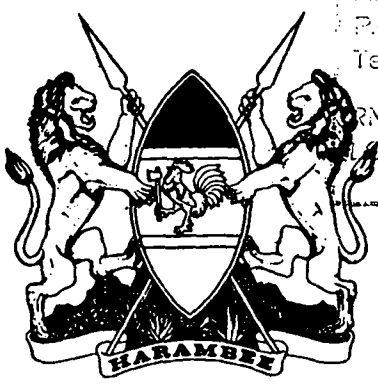
MINISTRY OF AGRICULTURE AND LIVESTOCK DEVELOPMENT

IRRIGATION AND DRAINAGE BRANCH

METHODS OF WATER SUPPLY AND IRRIGATION

FOR FARMERS - OPERATED SCHEMES

1986



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SUMMARY

Smallholder irrigation schemes, operated by farmers

This paper restricts itself mainly to a description of technical, economical and organizational aspects of those irrigation schemes that are operated and maintained by the farmers themselves. In such a scheme farmers will in general be organized in a water association and choose their own scheme committee. Outside advise may be given through normal extension services.

In general, smallholder schemes will not surpass 100-150 ha. Clusters of smallholder schemes may reach sizeable areas and could surpass 1,000 ha. Such a cluster may make use of a water undertaker to operate and maintain the main canal system, while farmers will operate and maintain their own scheme.

Irrigation in smallholder schemes means that farmers are dependent on each other. They have to co-operate to form a scheme committee in order to be able to run the scheme by themselves. For a scheme to have a chance to be successful, it should be possible for the farmers to operate and maintain their scheme with labour only or to be able to raise the cash required. Constraints may be expected if large cash contribution are required.

Irrigation as the introduction of an innovation

The introduction of a new irrigation scheme or the upgrading of an existing one can be seen as bringing an innovation to farmers. Not every farmer will make full use of the possibilities for increased production, even if, as a group, they were consulted intensively and did participate in the preparation and implementation of the scheme. This is experienced all over the world when innovations are introduced in agriculture.

There will be severe problems if the projected economic performance of a scheme is calculated on the basis of expected increases in income of the average farmer. A lot of farmers in the scheme will perform below average and may not be able to meet the costs of the scheme.

Water supply to an irrigation scheme

The amount of water needed for irrigation is very high and has no comparison with the requirements for human and livestock consumption. Storing water for irrigation requires large reservoirs and dams and the cost will in general be beyond the scope of smallholder irrigation schemes which are operated by the farmers themselves.

Irrigation schemes to be operated by groups of farmers have to be based on gravity water supply with earthen canals for conveyance. Lining of canals is to be considered only if in-field water management by the farmers is efficient, and water losses in the canals are exceptionally high. Pipes for water distribution may be required where the terrain does not allow for canal construction and is not generally recommended for larger groups of smallholders as investment and maintenance costs are high.

Irrigation with diesel pumps can only be made financially attractive for a group of farmers if it is permanently subsidized. Up to now, no Government backed or initiated smallholder scheme using pumped water and having more than 10 members has survived without subsidies.

At the moment there is no low-cost alternative to diesel pumps. Solar and wind energy as alternative power sources for driving pumps are at the moment not recommended for smallholder schemes.

Field irrigation systems

Basin irrigation, with small-to-medium sized basins, is most suitable and common for smallholder irrigation schemes. Small- or medium-sized basins positioned with their long side along the contour require almost no levelling and water efficiency can be high.

Furrow irrigation requires heavy mechanized land levelling, and even with skilled labour water losses may be high. In smallholder schemes this method has to lead to bad performances (eg. Yatta canal) and when changed to basin irrigation results were favourable (eg. Turkana, Isiolo Clusters).

Wild flooding, as an improvement on flood-fed agriculture or water harvesting from surface run-off, may be suitable in some cases. Both require skilled construction of levees and other related structures as the risk of erosion is high.

Sprinkler irrigation systems (certainly if pump-fed) require intensive maintenance, while operational costs as well as the organizational aspects are even more problematic than they are with gravity water supply. Low-pressure sprinklers fed by gravity from open canals may sometimes be suitable on sloping land if the equipment is bought by individuals.

C O N T E N T S

1. INTRODUCTION

This paper discusses technical, economic and organizational aspects of smallholder irrigation projects planned for farmers who are to operate and maintain the scheme themselves. It may be seen as a follow-up on the extension paper on "Guidelines for Smallholder Irrigation Projects for Rural Development".

Groups of smallholder farmers consist of individuals with different degrees of skill and sometimes have no experience with irrigation. If irrigation is introduced, it will be one of the many activities of the household. Irrigation may be introduced to safeguard food crops or to obtain some cash income.

Sprinkler irrigation (gravity-fed or pump) may seem a very attractive proposition to a group of smallholders. Decision makers may regard such a request as appropriate to promote agricultural production and to raise the standard of living of the farmers. However, the need to raise a considerable amount of money for operation and maintenance has in general proved too large a burden for many farmers in such a group.

It is necessary to choose realistic irrigation development options, for which operation and maintenance costs are low. This paper discusses the technical, economic and institutional requirements for the different options. Surface irrigation methods, which allow farmers to gradually improve their profits from irrigation, are emphasized.

Clusters of smallholder schemes may be quite large (tentatively over 1000 ha) and could make use of a water undertaker to operate and maintain the main canal system. Farmers will in this case operate and maintain their own scheme and will have to contribute in cash towards the maintenance and operation of the main system.

2 IRRIGATION AS THE INTRODUCTION OF AN INNOVATION

2.1 Innovations and their adoption by farmers

In agricultural extension, results from research institutes are translated into messages for farmers. These messages may be simple (e.g. distances and depths for planting maize seeds), or more complex (e.g. the introduction of a new crop variety or hybrid combined with husbandry factors such as fertilizer application and crop protection). All these messages involve the introduction of an innovation in farming techniques.

The adoption of these innovations by farmers depends on decisions made by individuals. Each farmer decides if and when he is going to apply these innovations on his own farm. He may be influenced by agricultural staff, by other farmers, and by results he notices on other farms, but in the end his own decision will be implemented independently of his colleagues or neighbours.

The process of diffusion and adoption of innovations by farmers is well known, and follows the same pattern in widely different agricultural communities all over the world. An ourstanding feature is the different rate of adoption which occurs within any group or community of farmers. There will be early adopters at one end of the scale and farmers who are slow to adopt innovations (laggards) at the other end.

2.2 Irrigation as an innovation

The introduction of irrigation or the rehabilitation of an existing scheme is an innovation to farmers. In schemes operated by the farmers themselves, the individual farmer is free in his production methods and crop choice. Only in rice schemes will the crop choice be a token. The utilization of new possibilities for agriculture production depends on the rate of adoption by individual farmers.

Even if the group of farmers has been consulted intensively and if the farmers really have participated in the preparation and implementation of the scheme, not all farmers will take advantage of the possibilities to increase their production immediately. Early adopters will start using higher inputs as certified seeds, fertilizers and chemicals and use cash crops to increase their profits. Others will grow subsistence crops without any increased inputs. Some farmers may take as long as 10 to 15 years to change their crops and production methods.

It has been observed in small irrigation schemes where vegetables are grown for marketing that it may take some years before the whole area is cultivated, even when the area concerned is very small (say 5 ha) and the number of farmers is as many as 50 - 80.

Efforts to promote accelerated adoption by the farmers lagging behind through increased extension efforts, usually give extremely poor results. A basic extension service will be required, giving attention to those farmers who are ready to make increased use of the possibilities. Moreover, the extension should reach those farmers who are involved in the actual field activities, which in some areas may be mainly women.

Given a basic extension service, adoption will take care of itself and cannot be forced upon farmers. The consequences are that, for any scheme, it will take considerable time before all the farmers will use all the possibilities.

.3 Farmers' contributions

Contrary to other innovations, irrigation in smallholder schemes means that farmers are dependent on each other. This dependency occurs in several ways, as in smallholder schemes farmers have to co-operate to form a scheme committee, develop bye laws etc. They will also have to contribute, at least in harambee labour, towards the implementation and maintenance of the scheme.

If the farmers really see irrigation as an improvement of their farming conditions they will be willing to participate and contribute. They may need guidance from extension and irrigation staff. Depending on their cash income from agriculture or other activities, they may also provide some cash as an initial payment towards implementation or towards recurrent maintenance and operation costs.

For a scheme to have a chance to be successful, it should be possible for the farmers to raise the cash required independent of their estimated increased income from irrigation. There will be a major constraint if larger cash contributions are required to operate and maintain the scheme.

Large cash contributions will be required when pumps are used or equipment (as sprinklers) with high maintenance and replacement costs. Not all farmers will be able to meet the required costs, as their production will not have increased sufficiently.

Gravity-fed irrigation requires much less operation costs, while maintenance of earth canals only requires harambee labour.

2.4 The non-existence of the "average" farmer

Economic calculations for the period after implementation of an irrigation scheme take in general an increase of production into account. It is assumed, that such an increase will be small at first and that full production will be obtained after some years. Calculations are thus based on average yields to predict total production figures for a scheme. However, the "average" farmer does not exist. As long as the economic calculations are focused on the rate of return of the invested money they may be valid. If they involve individual farmers, such calculations are invalid.

A large number of farmers will not increase their net profits for some time and will not be able to raise sufficient cash for their contribution to the operation costs. As all members have to share, the scheme will face financial problems as the early adopters are not willing to pay the share of the farmers which remain behind. The resulting problems will be unsolvable, as eviction of farmers who have contributed towards project implementation but cannot meet their obligations, is an impossible task for a scheme committee.

It is not surprising that most pump-fed government or donor implemented irrigation schemes have collapsed within a very short time. These schemes, may collapse due to lack of money for diesel, because of major pump repairs, or because market prices have been lower than expected. This will be aggravated when a large number of farmers do not meet their commitments.

It is not said, that pump-fed irrigation cannot be feasible. Pump-fed irrigation may well be profitable for an individual farmer, and for small groups consisting of some (say 2-5) progressive farmers. Government funding will not be required to cover the investment cost in these cases.

2.5 Comparisons with centrally managed schemes

In centrally-managed schemes the crops grown and production methods can be decided by the management. Farmers are often tenants and have to be supervised. Also a central organization for providing inputs (seeds, fertilizers and chemicals) and operations (land preparation, spraying) is required. The result is an organization which incurs expenses for outside management and is thus outside the scope of government promotion of smallholder schemes.

Although the pressure to repay investment costs by accelerated increase of production may favour centrally-managed schemes on the short term, such schemes tend to be low in efficiency. Schemes managed by farmers themselves may be more cost effective in the long run.

3.6 The concept of smallholder irrigation on large schemes

The concept of smallholder schemes managed by farmers themselves does not have to be restricted to small scheme areas. A scheme may consist of clusters of small areas which are, in turn, consigned to large schemes. In scheme areas in the range of 10-100 ha the farmers can manage the scheme themselves.

However, it may be necessary to subdivide larger areas in sub-areas each with their own committee. An independent body (water undertaker) to supervise the water distribution and maintenance of major irrigations works can be set up. Such a body may consist of representatives of the scheme committees, or may be totally independent. In the latter case close co-operation with the sub-area scheme committees is essential.

For a water undertaker to be able to work without subsidy, the farmers will have to contribute cash. The costs of operation and maintenance should not be based on supposed increased income from individual smallholders. Maintenance within the small areas should as much as possible depend on harambee labour. Cash contributions may however be required for maintenance of the main irrigation works, but should be limited (see also section 3.3).

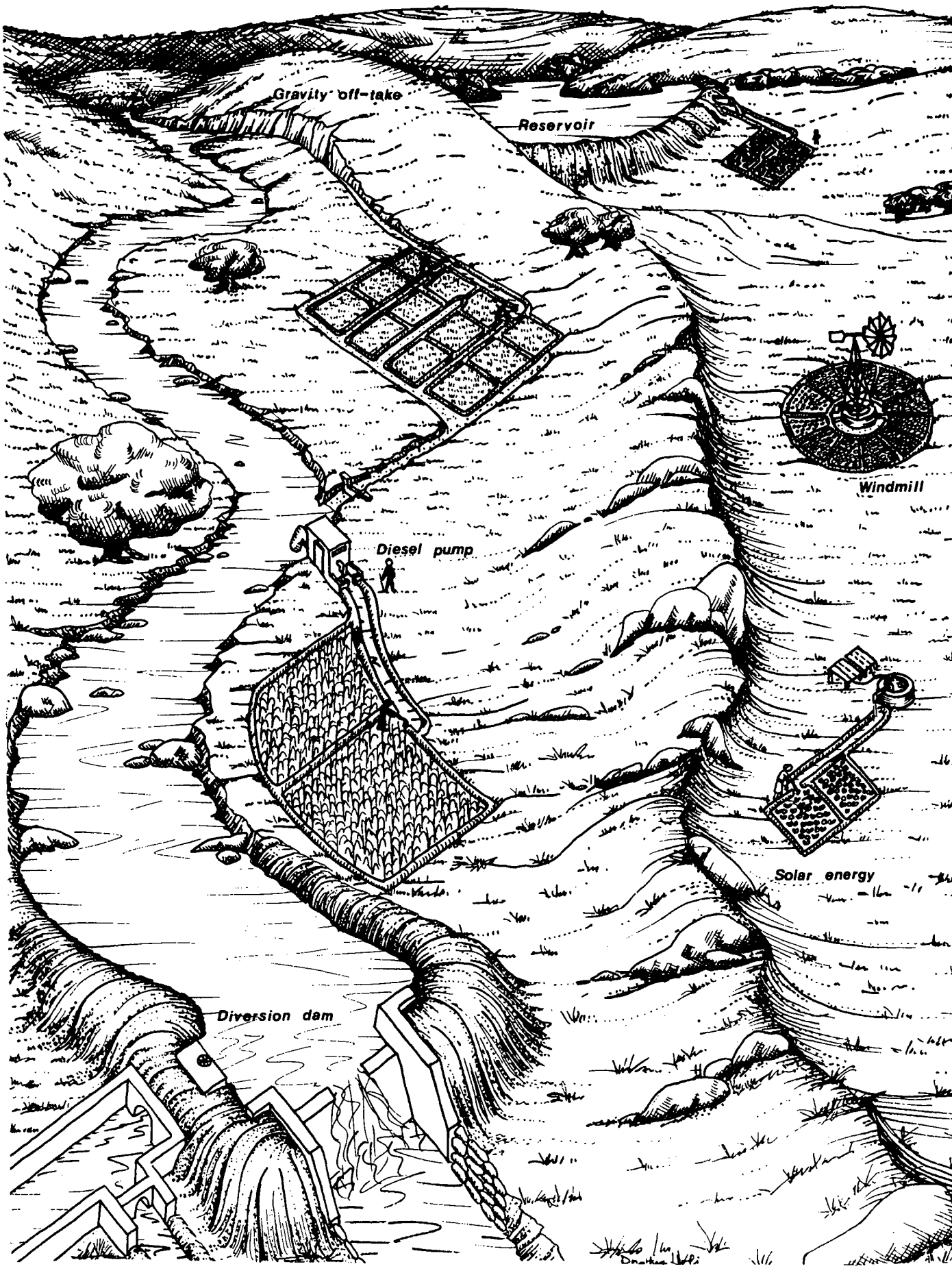

Fig. 1: Sources of water supply for irrigation

3. WATER SUPPLY TO IRRIGATION SCHEMES

3.1 The amounts of water involved

Two points about the amount of water involved in irrigation which are often the cause of misunderstandings are important to consider:

- The amount of water required for irrigation is not usually compatible with rural water supply methods and sources;

- Raising the water level in a river by use of a dam does not increase the amount of water available.

Storage of water in a reservoir for irrigation purposes, requires large dams and reservoirs. Only on few sites will it be technically possible to construct dams. Investment costs are too high for medium to small size schemes, while rivers carrying sediments may fill a reservoir in a few years. Reservoir dams, are therefore beyond the scope of district smallholder irrigation schemes. Possible sources for irrigation have been presented in figure 1.

Given the large quantities of water required for irrigation it is important to find out whether enough water is available to irrigate the required acreage of the proposed irrigation scheme.

3.2 Water permits

The Ministry of Water Development has flow data on many rivers and streams, and these may be used to obtain an indication of the available flow. It is important to be aware of the period in which the flow was measured. The flow rate in the proposed cropping period in the scheme, usually the dry season, generally determines whether irrigation should be possible.

In Kenya anybody who wishes to use water for irrigation has to apply for a water permit from the Water Apportionment Board of the Ministry of Water Development through the District Water Bailiff. If a water permit has not been issued, works for implementation of a scheme should not start, because it is possible that there is insufficient water left for the proposed scheme.

The fact that at the proposed scheme location there is sufficient water in the river is not relevant as the water may be needed downstream for irrigation, urban water supply projects or for a base flow in the river.

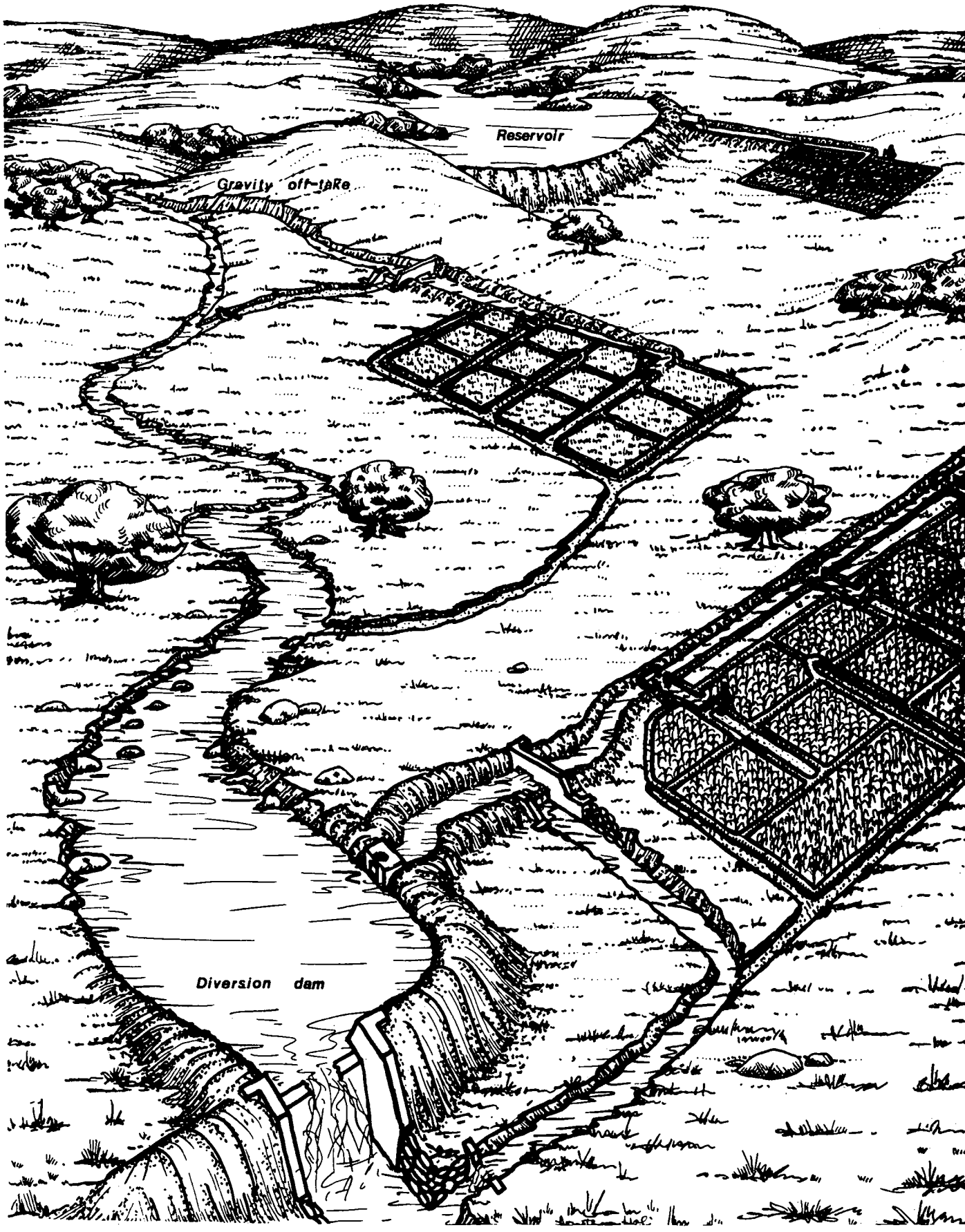

Fig. 2: Gravity water supply from a river and reservoir

The farmers involved in the scheme should organize themselves and choose a committee, so that on application for a permit they can register themselves as a water association.

3.3 Gravity water supply

In a gravity irrigation scheme, water is conveyed by gravity from a river (Fig. 2), spring or swamp (Fig. 3) to the fields. For gravity flow a difference in level is required to transport water. The water level at the source (e.g. low water level in the river) has to be above the ground level in the scheme. Sometimes the water level in the river can be raised some 0.5-2.0 metres by a diversion weir.

Investment

Local conditions determine the structures and the length of canals needed, and therefore the investment costs. As a guide for district smallholder irrigation schemes, the costs should not exceed Shs. 10,000-15,000/ha.

The main structures are in general made of brickwork or concrete. They comprise the intake, sometimes a weir, distribution and drainage works, flood/erosion and run-off inflow prevention works.

The cost of structures alone for a scheme covering an area of 20-60 ha will be in the range of Shs 100,000-175,000. Lined canals or water conveyance through pipes increase the total costs of a scheme by a factor of 5 - 20. In addition, topographical conditions may require road crossings, gulley crossings and erosion prevention.

The main canal and in-scheme distribution feeders may be made by the farmers themselves. Excavations for structures may also be done by the farmers, and they may agree to provide harambee labour for an agreed amount of work. If more work is required, casual labour may be used, while machinary may be used if the amount of work required is excessive.

Irrigation staff of the M.O.L.D. have to investigate (e.g. surveying) and to supervise the implementation. The costs of the transport and allowances involved may not have been provided for in the recurrent budget.

Operation

A gravity irrigation scheme should be designed to make a simple operation of the distribution system possible.

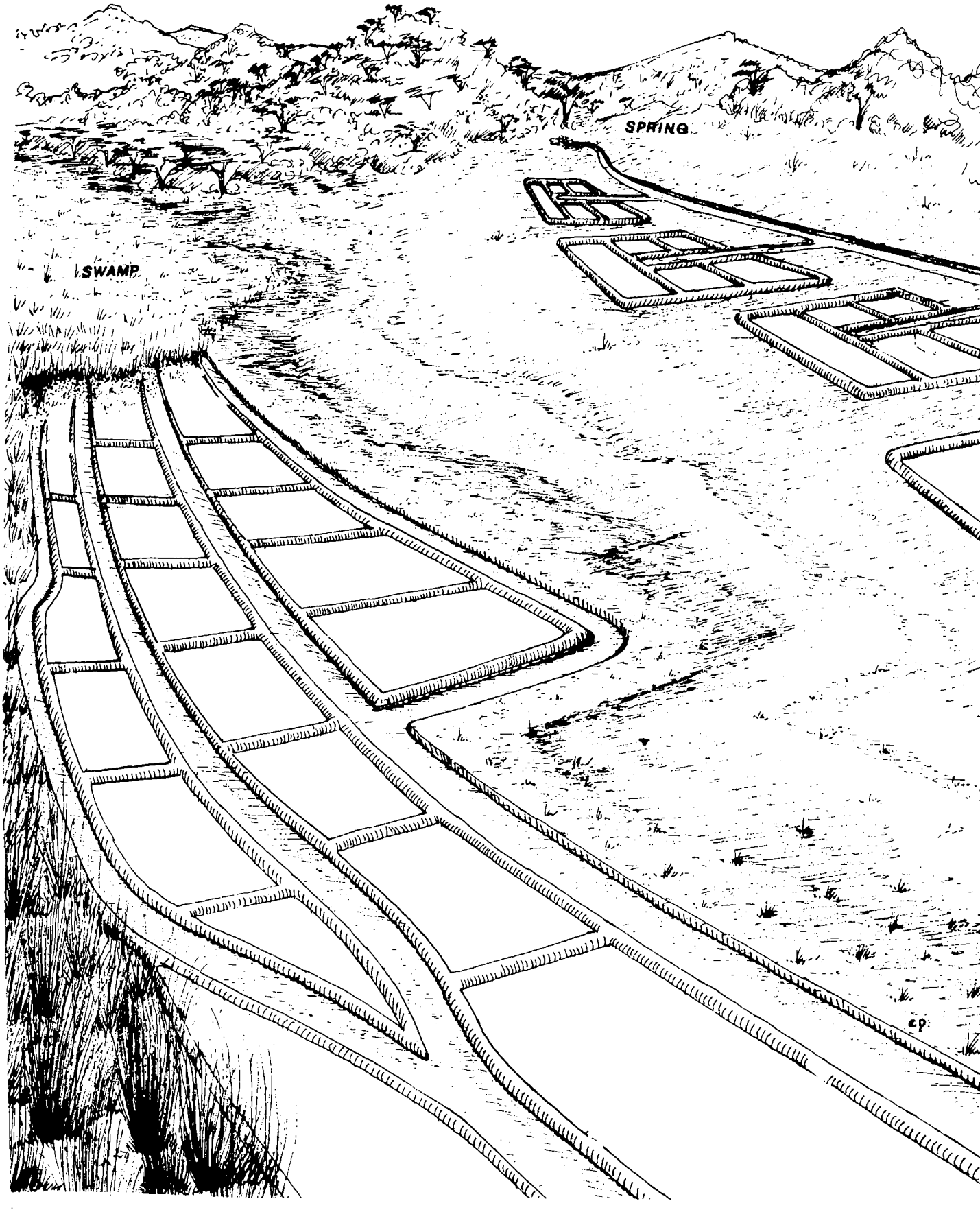

Fig. 3: Water supply from swamps and springs

Maintenance

In a gravity irrigation system, most of the maintenance can be done by manual labour. Maintenance consists of cleaning the canals, intake, distribution boxes, culverts etc.. It is up to the farmers to decide whether to do their jobs themselves or to hire casual labour.

Even when the farmers provide all the labour required for the maintenance of the scheme, some repairs still require specialized skills (e.g. repair of structures) and materials which have to be paid for. The cash involved should preferably not be more than Shs 100/- per farmer per year.

With a more complex or larger irrigation canal network a water undertaker may be needed, charging the farmers for water rights to meet the costs of maintenance in the range of Shs 75 - 150 per farmer per growing season. A water undertaker will thus only be able to operate well, if the area is rather large. Tentatively the minimum area to be considered is set at a minimum of 1,000 ha.

Organization

In order to ensure that they will get a water permit and be able to manage the operation and maintenance, farmers will have to organize themselves. For a gravity system, such organization can be simple. Within the scheme, sub-groups of farmers receiving a continuous flow can divide the water between themselves according to a schedule requiring no scheme management for daily operation. A scheme committee will deal with the organization of maintenance and special situations, and enforce bye-laws agreed upon by the members.

3.4 The distribution network

Water can be conveyed through canals or through pipes.

Canals

The simplest and cheapest field canal for smallholder irrigation projects can be constructed by farmers themselves, and is simply excavated and unlined. The excavated soil is used for bank construction.

Lined canals will carry about twice as much water on the same grades as earth ditches and seepage losses are greatly reduced. However, investment costs are high. Although maintenance/repair costs are acceptable, the tasks involved are not easy for the farmers to carry out. They probably need to hire skilled labour, while materials such as sand and cement have to be bought. The required funds have to be budgetted for, which needs additional organization.

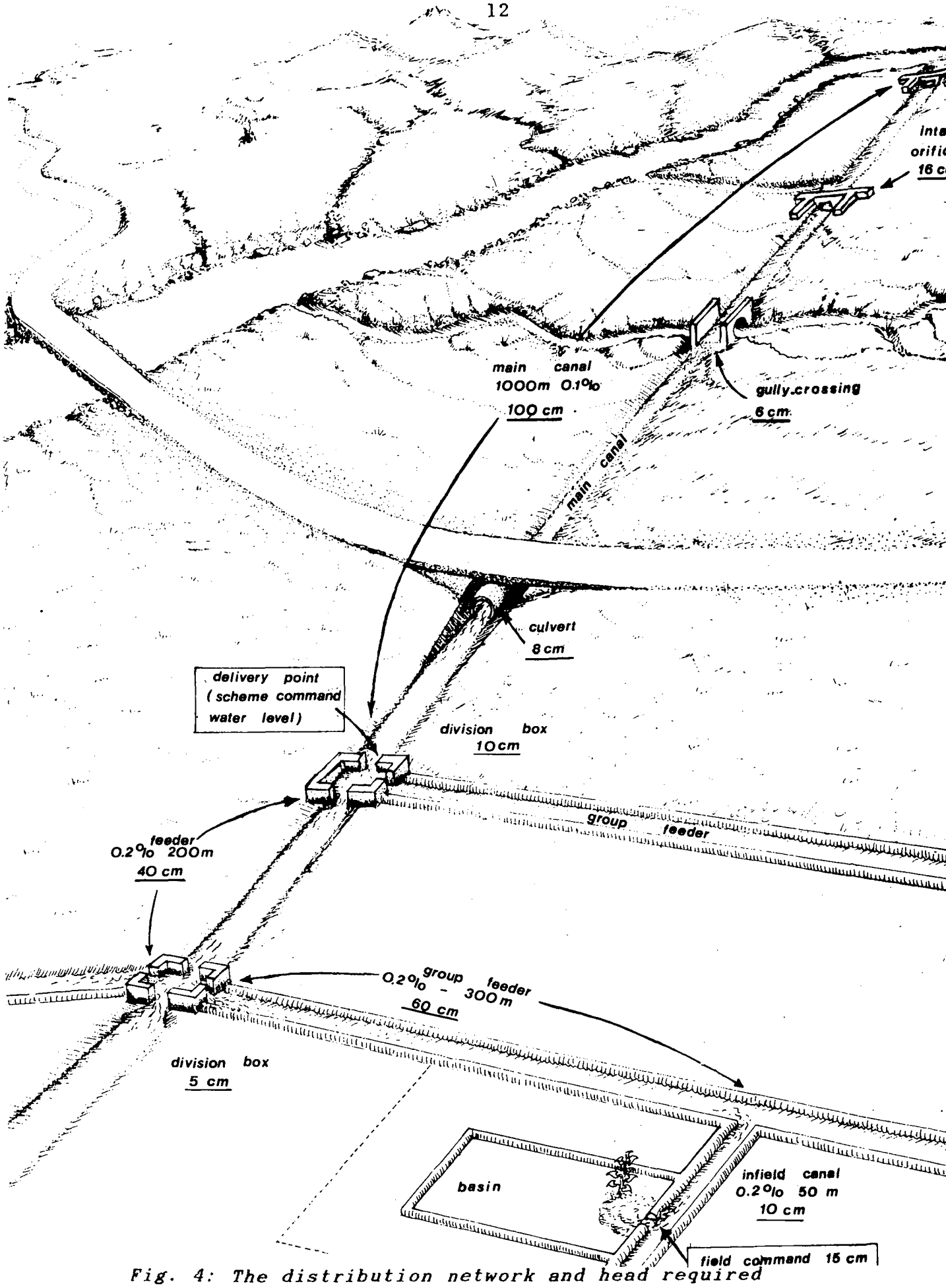

Fig. 4: The distribution network and head required

Only when water losses are exceptionally high, lining of canals can be considered. At the same time water losses in the farmers' fields should be low, otherwise water gained by lining the canals is largely lost again in the farmers fields, through inefficient water management.

Pipes

Piped distribution systems bring a scheme to a higher level of technology. There is a high initial cost component. Maintenance costs for the pipes are low, but parts such as valves have to be replaced regularly. It may, therefore, be necessary for farmers to hire skilled labour while materials have to be ordered and paid for.

Pipes may be used in different parts of the conveyance network:

From distribution canal (feeder) to field:

Water transport from distribution canals (feeders) within the scheme to farmers' plots through pipes may be suitable when steep slopes (over 5%) are irrigated. In such situations surface irrigation is not suitable and if there is sufficient head, low-pressure sprinklers (15 m) could be used as for example in Highland Scheme in Nyeri District.

From river to scheme:

Water is conveyed to the scheme, but within the scheme, water is conveyed through canals. Investment costs are high and only advisable in those areas where topography does not allow the construction of canals.

From river to field:

Pressure (available head) in the pipe makes sprinkler irrigation possible. Pressure regulators may be required to compensate for the changing pressures in the pipeline.

Investment and maintenance costs are high and this method is not recommended for smallholder schemes operated by farmers.

3.5 Fuel-driven pumps

When water cannot be diverted from a river or lake by gravity because the level of the surrounding land is too high, the water has to be lifted by pumps. The introduction of pumps adds a new dimension to the costs of an irrigation scheme. A diesel powered pump set is technically complicated and vulnerable. It requires considerable organizational skill to keep pumps operational all the time, which is essential for an irrigation scheme. Pumped irrigation is only feasible when the following aspects are well organized.

Investment

The investment in a pumped scheme (gravity in-field system), is often somewhat less than for a gravity scheme. The in-field structures are about the same, but the intake and feeder canal are replaced by a pump station, which is generally equal in cost or somewhat cheaper. Therefore, from this point of view, there are no objections to pumped irrigation.

A pump set for 20 ha with a water lift of 5 m costs around Shs 100,000 and a shelter has to be constructed to protect the pump from the weather (and thieves). The shelter and pipes required cost around Shs 30,000.

The installation of pumps and pipes requires specialized skills. A relatively small canal to the scheme and the lay-out of the fields can be done by hand.

Operation

The operation of a pumped irrigation scheme, however, is the bottleneck, in both its organizational and financial aspects.

Money, to be contributed by the farmers in advance, is required to buy fuel and to pay for operational costs and repairs. Furthermore funds have to be put aside (saving) to be able to buy a new pump and motor when the existing one has worn out. For a group of smallholders comprising both intensive farmers who make money out of their irrigation and others who have no money available, this is not an easy task. Almost all Government-funded pumped irrigation schemes have either collapsed or require continuous subsidizing from Government funds.

Maintenance

To maintain the scheme in good working order probably requires less work than to maintain a gravity irrigation system because there is no feeder canal. The necessary works consist of cleaning of the canals, while the costs involved are only for minor repairs of the field structures.

The pump and motor need to be maintained regularly during the irrigation season. The pump attendant (group of farmers) or the individual farmer himself will look after it. Repairs in the case of breakdown may require a mechanic and the availability of spare parts.

The cash flow involved for maintenance as well as operation will be large. Spare parts and repair costs will require cash on the spot, for otherwise crops, invested money and labour will all be wasted.

Replacement

Pumps, pipes and shelter do not last for ever. After some time they have to be replaced. The initial investment costs may be provided through DDC funds but thereafter schemes should be self-sufficient. Provisions has therefore, to be made for cash to be available for replacement.

A pump lasts for approximately 10 years when used for only one crop per year. Thereafter the scrap value of the pump is around Sh 5,000. The average annual loss in value of the pump is therefore around Sh 9,500, or Shs 475/ha. The shelter and pipes are estimated to last for 15 years, after which the residual value can be considered as negligible. Annual loss in value of the shelter and pipes is Sh 2,000, or Shs 100/ha.

The total annual loss in value is, therefore, Shs 575/ha. To raise these contributions from the farmers may be difficult in the first years after implementation as the urgency may not be evident. This may amount to higher contributions later on. Moreover, although the average pump life may be 10 years, the actual life may be much shorter, certainly if maintenance has been neglected.

Organisation

The organization of fuel-driven pump-fed irrigation schemes is complex in comparison to a gravity fed scheme.

Fuel: Sufficient supplies of fuel must be kept in stock. In remote areas the fuel stock should be large enough to keep the pump going in the event of a temporary shortage, or the roads to the scheme being impassable. Planning ahead and cash availability are essential. When the fuel supply runs low, new fuel must be ordered so that the pumps continue to operate.

Operation: The pumps cannot be operated by all the farmers together as this would lead to increased wear and tear of the pumps. Pump attendants need to be trained and employed during the irrigation season. These can be farmers, but they need not necessarily be from that particular scheme.

These attendants operate the pumps, starting them in the morning, monitor the pump operation, and undertake some of the routine maintenance (changing oils, etc.).

Maintenance: Much of the pump maintenance cannot be carried out by the farmers themselves, but depends on outsiders. In remote areas it may be impossible to arrange for a technician to come frequently to carry out regular maintenance. As a result, the farmers will often wait until something breaks down. This will lead to shortening of the lifespan of the pump.

Reservations: Right from the beginning of the life of the pump, the farmers will have to start putting money aside for the fuel, maintenance, repair and replacement of the pump. This does not occur to the farmers when they see a brand new pump. Consequently, insufficient money may be available, at the time the pump needs to be replaced and the entire investment in the irrigation scheme is then questionable.

Cash contributions: The average farmer may be able to pro vide cash towards the operation and maintenance costs of the scheme and the scheme committee may easily collect the cash required from those farmers whose performance is above average. But the farmers performing below average will give the scheme committee great problems as the net income from their irrigated plots will not cover the required contributions.

Enforcement is difficult; denying water to such farmers or evicting them from their plots is an almost impossible task as they may form a substantial proportion of the membership - about one third - and moreover they may very well have contributed towards the implementation of the scheme by providing harambee labour or cash contributions.

3.6 Wind and solar-driven pumps

Alternative power sources for driving pumps can be considered. At the moment there are two sources which could be promising in future.

Wind energy

Windmills are able to lift sufficient water for irrigation only in those areas where the wind is regular and wind speed is high enough (Coast and Lower Tana). In other areas windmills may be successful only in producing water for human consumption or cattle. The command area depends on the windspeed, but is in any case limited to a few hectares per windmill. Thus windmills are at present more suited for individual farmers than for irrigation schemes.

In addition, very little experience has been gained with windmill irrigation in Kenya, while the available experience has been quite negative. Therefore it is at present too risky to have an entire scheme depend on such a water lifting device.

Solar energy

Pumps of small capacity with a command area of about 2ha can be powered by solar energy. Most locations have enough sunlight to be suitable for solar pumps. At the moment, solar pumps are still too expensive to be considered for irrigation projects.

4. FIELD IRRIGATION SYSTEMS

Irrigation water may be applied to the soil by several methods. In surface irrigation, the land is ponded in basin irrigation or covered by a moving sheet of water in border irrigation and wild flooding. In furrow irrigation, water is guided over the land between ridges and only part of the land is flooded.

With sprinkler irrigation the soil is wetted as with rainfall. In drip irrigation water is conveyed to individual plants and most of the land remains dry.

4.1 Surface Irrigation

Basin irrigation

The basin method of irrigation is most widely used and is easiest to operate. Most of the rice in the world is grown in basins. Many other crops such as cotton, grain, maize, groundnuts and vegetables are suited to basin irrigation, as well as fruit trees and bananas.

The method involves dividing a field into units so that each has a nearly level surface. Small banks of earth constructed around the level area allow the basin to be filled with water. The ponded or dead water infiltrates into the soil.

Basins of different types (Fig. 5) may be used according to the crop preference (flat or ridged) and the slope of the land (contour furrows).

In irrigation schemes such as Kimana and Sandai, very small basins with a size of 5 - 15 square metres are in use. Water application is simple and the skill required for good irrigation is relatively low. Labour requirements, however, are high as constant supervision is needed. Larger basins of the order of 25 - 50 sq m may be constructed to reduce work, but whether this is advisable depends on the topography and the farmer's preference.

In large basins, such as those used at the Mwea rice scheme, for example, land levelling requires earth moving machinery. Although supervision of the irrigation is reduced in such areas, the initial cost of preparation is in general quite high.

For smallholder projects it is better to vary the plot size with the topography, as is done by rice farmers in the Kano plains. In this area, basins range from very small to large.

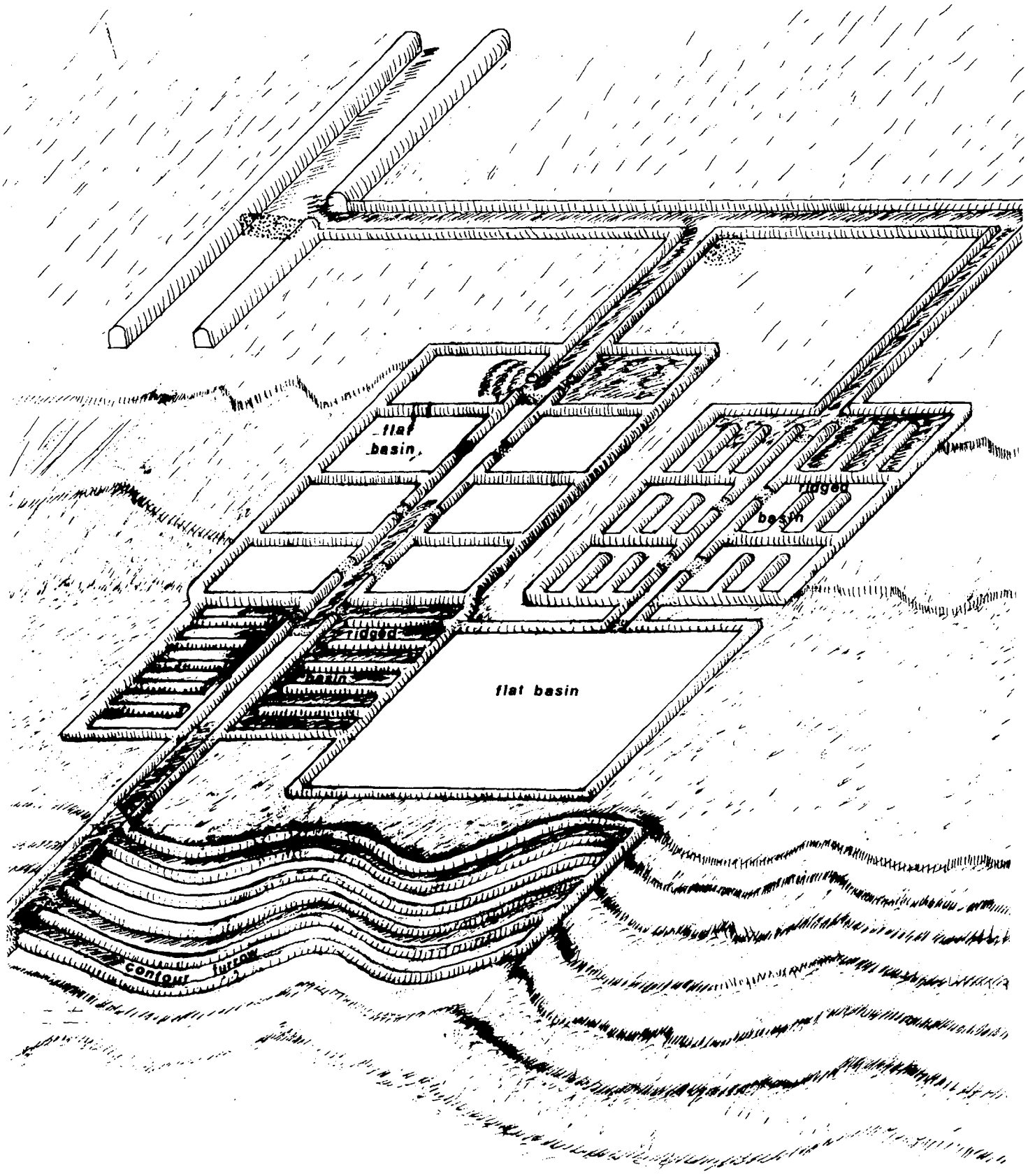

Fig. 5: Different types of basin irrigation

Uniform water application with surface irrigation is most easily achieved by basin irrigation, as it reduces water losses and the percolation of water (with nutrients) out of the root zone. Basin irrigation is strongly recommended for smallholder irrigation schemes.

Furrow Irrigation

In the furrow method of irrigation, water is carried down the slope of the land to wet the soil. Crops are grown on ridges between the furrows. The method is suited for crops grown in rows such as vegetables, tomatoes, cotton, maize, potatoes and sugarcane. In contrast to basin irrigation, furrow irrigation requires considerable skill. The method is best suited to deep, moderately permeable soils, with uniform, relatively flat slopes - preferably not over 2%. Land levelling requires earthmoving machinary and initial costs are therefore high.

Generally several furrows receive water at the same time and close supervision is necessary to avoid unequal flow to each furrow and to minimize soil erosion. It requires skill and understanding to achieve a uniform water application and to minimize run-off waste water. A non-uniform application may result in high percolation losses. This water will carry nutrients and may possibly raise the groundwater table.

It is recommended to use checks in the head ditch and gates, and pipes or siphons to distribute water to the furrows. The level of technology and cost of the system increases even further if a light metal-gated pipe is used to control the water. The method is best suited to longer runs, and some form of mechanization is preferable. The furrow method is not recommended for smallholder schemes.

In some smallholder irrigation projects (eg. Turkana Cluster) a furrow irrigation system has been changed to the much simpler and less expensive basin irrigation system.

Border irrigation

In border irrigation a large field is divided into a series of borders (which are still quite large), by low flat dykes or levees constructed in the direction of the prevailing slope. Water is turned into the upper end of each border and moves to the lower end guided by the levees. Cross slopes within the borders must be eliminated by grading or levelling. Construction and maintenance costs are high and machinery is generally needed to prepare the land.

Skilled labour is required to obtain uniform water application and to minimize run-off and soil erosion. Border irrigation suits irrigation on large farm, where it reduces labour requirements.

Due to the relatively large-flow streams required per border it is not advisable to use earth dams in the head ditches or to cut through the ditch bank for control. Permanent checks or canvas dams and outlet gates are recommended, but these increase the cost of the system and the operation and maintenance requirements.

Thus the border method is not recommended for smallholder irrigation projects with small farms and plots, due to the high investment costs and required skill in irrigation.

Uncontrolled or wild flooding

In uncontrolled or wild flooding, water is applied from field ditches to the field, but there are no levees to guide the flow of water over the field. This method is best suited for rather smooth and flat lands. The outstanding feature is the low initial cost of preparing the land for irrigation. Water-losses are high due to the low appplication efficiency. The method can only be used when water is in abundance.

It may be possible to use such a method in the lower Tana area as an improvement on flood-fed agriculture. Water harvesting from surface run-off on wadis is based on the same method. High flow rates make such areas highly susceptible to erosion. The method may be suitable for small areas provided it is preceded by skilled construction of levees and other structures.

With very low flows a form of controlled border flooding is used in small plots for overnight irrigation in West Pokot and Elgeyo Marakwet. Water losses are high, however, and erosion occurs on steeper slopes.

4.2 Overhead irrigation

Watering-can or bucket

The simplest method of overhead irrigation is watering with a can or bucket. This method is limited to small plots with an easily accessible source of water, e.g. along the shores of fresh water lakes (Lake Victoria), rivers, canals or shallow wells. One person could manage a plot of about 500 square metres or one tenth of an acre with a plot adjacent to the water source. At 100 metres distance the person could manage only half this area, but it may be possible to dig a well at some distance from a lake or canal to reduce the distance between the irrigated land and the water source.

In the past some small schemes watered by cans and buckets were upgraded either by the use of diesel driven pumps or windmills. Experience has shown that due to high technology required and high operation or maintenance costs, this type of upgrading is almost sure to fail. Calculations show that the profit made from an upgraded scheme and a hand watered scheme are not much different.

Sprinkler irrigation

There are certain conditions under which sprinkler irrigation is favoured over surface irrigation. Common reasons given in textbooks are:

- Higher efficiencies are possible;
- Soils are porous or shallow;
- The land slope is excessive or the land is undulating;
- In case labour is inexperienced or unreliable;
- Frequent small applications are possible;
- The system can be designed and installed quickly which is an advantage if productivity is needed urgently.

In smallholder irrigation projects, where often only part of each farmer's land is irrigated, the irrigated plots are small and scattered. In such circumstances the field efficiency obtained with sprinkler irrigation is not necessarily higher than that obtained with small basins even with unskilled labour. In Kibirigwi, water application efficiencies did in general not surpass 50%.

In order to reduce the wear on sprinkler nozzles, only very little silt is allowed in the irrigation water. This requires extra money for desilting in tanks, if gravity-fed, which needs daily cleaning, or filtering if pumped, for which extra power and fuel are needed. In Garissa the original sprinkler irrigation schemes had to be changed to surface irrigation for this reason.

Although many of the factors favouring sprinkler irrigation do not hold for smallholder irrigation projects, farmers like sprinkler irrigation to be introduced. This is mainly because the field system is easy to handle and labour requirements are low. However, no thought is given to investment, maintenance and operation costs as well as to organizational aspects of replacement and maintenance which are already problematic in those cases where the sprinkler system works under gravity.

Low-pressure sprinklers fed through pipes of limited length (100-200m) from open canals may be suitable for smallholder schemes. With clean water, no desilting is required, and pipes and sprinklers are individually owned. This type of scheme occurs on the slopes of Mount Kenya, for example the Highland scheme in Nyeri District (see figure 6).

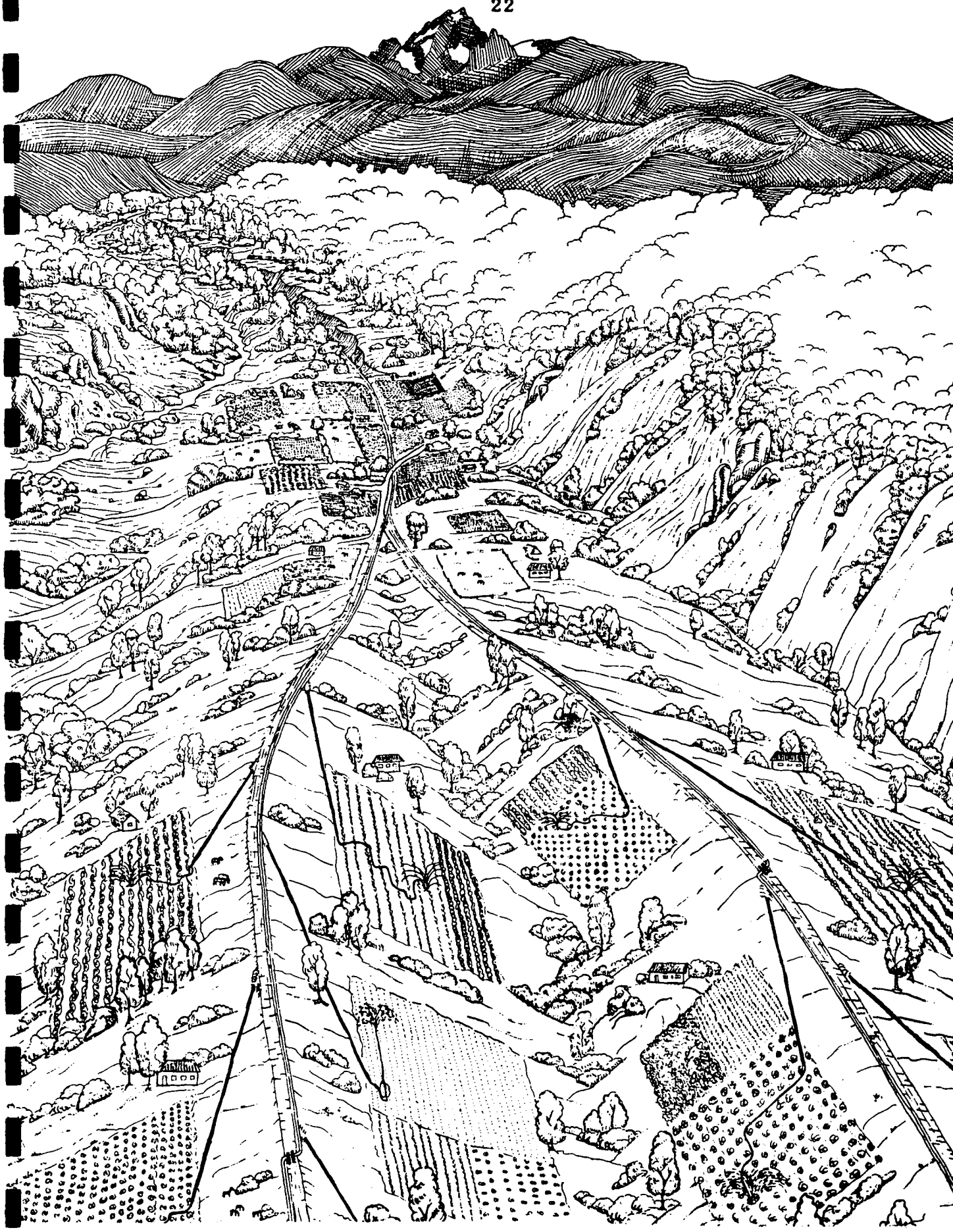

Fig. 6: Low pressure sprinklers fed from open canals

4.3 Drip irrigation

In drip irrigation water is carried by a piped system to distribution points (emitters) with very low flow rates. The water is put in the immediate vicinity of individual plants and most of the land remains dry.

No silt at all is allowed in the irrigation water, while some soluble components in the water may also block the emitters.

The same arguments given while discussing sprinkler irrigation can be used against drip irrigation. The costs are even higher than those for sprinkler irrigation, so that the use of drip irrigation becomes even more prohibitive for smallholders.