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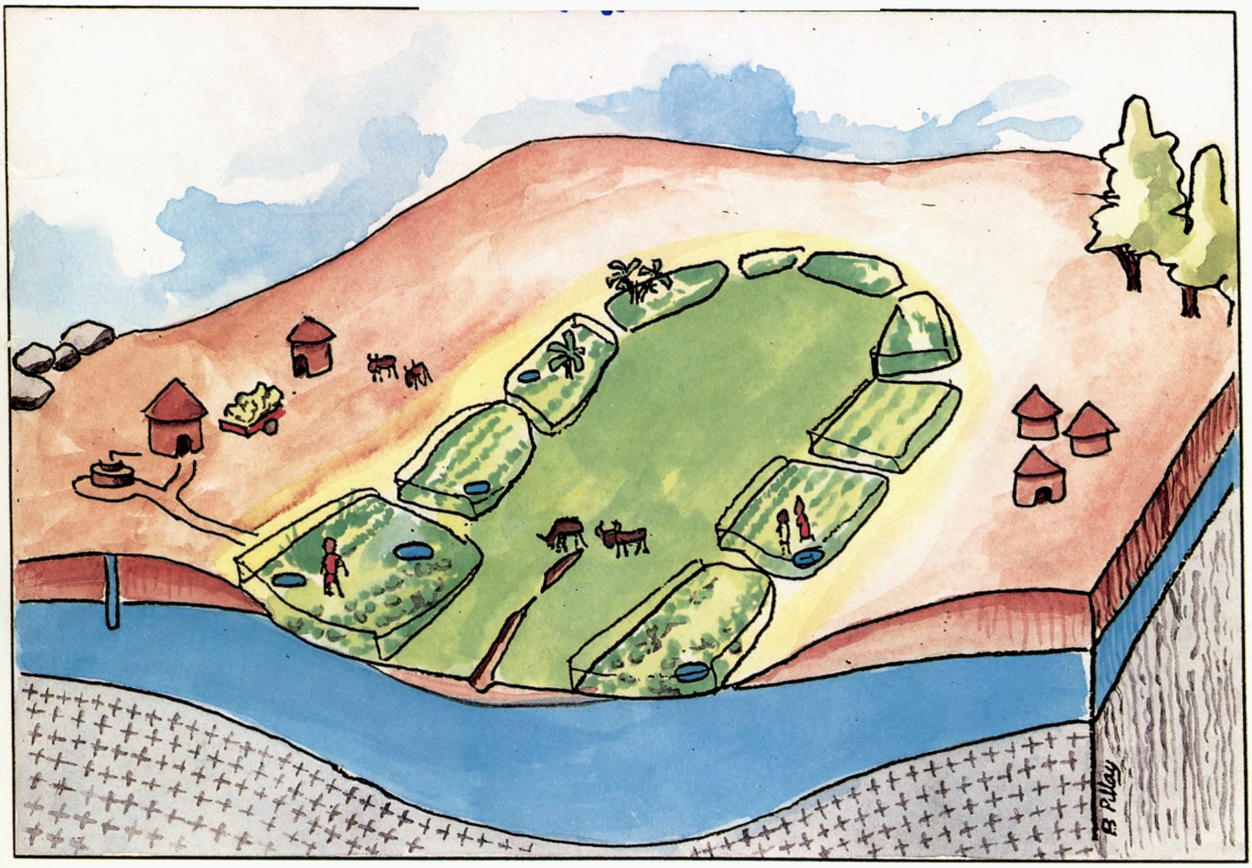

Water Management, Cropping and Soil Potentials for Smallholder Farming in the Wetlands

Editors: Richard Owen, Katherine Verbeek, John Jackson and Tammo Steenhuis

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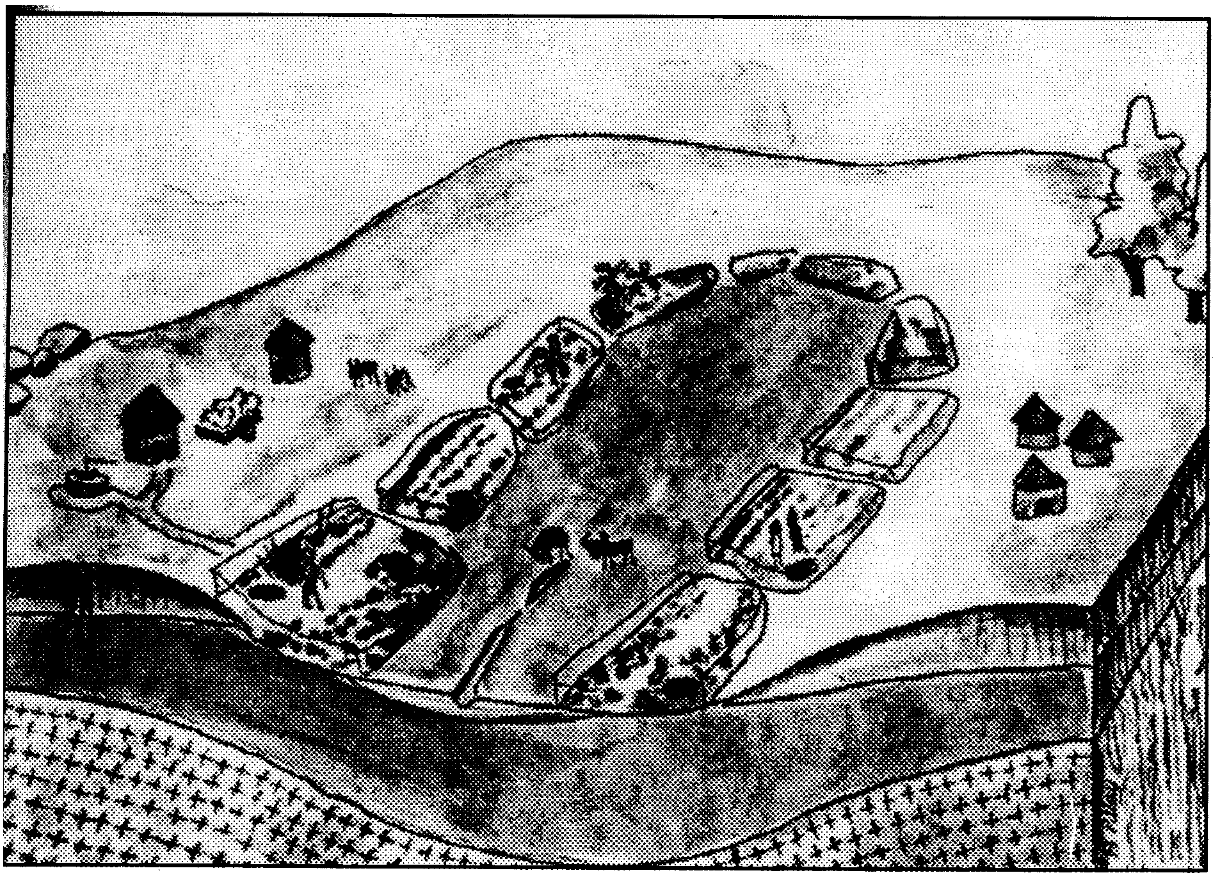
Section I

Water Management



Improving Water Use Efficiency in Garden Irrigation:

Experiences from the Lowveld Research Station, Southeast Zimbabwe

M. Murata[1], C. J. Lovell[2] and C. H. Batchelor[2]

Introduction

In dry regions, access to irrigation systems is the principle factor effecting garden size and success. In rural areas, efficient irrigation can allow more families to benefit from a particular water source and can improve crop production. In urban areas, where water must also be paid for, it can improve the economic returns made from gardening.

Thousands of small gardens in Zimbabwe are laboriously irrigated to produce extra food for families. Surface irrigation of small beds is the common practice, but this traditional irrigation method is not efficient in water use. With each irrigation, some water applied to the soil surface is lost as soil evaporation. With increasing human pressure on limited water supplies, and the possibility of climatic change, it is vital that more efficient methods of irrigation be developed and adopted.

Soil evaporation can be reduced, and efficiency of irrigation improved, if water is applied beneath the soil surface (via homemade clay pipes or porous clay pots), applied to a limited area of the soil surface (by drip irrigation), or applied beneath a surface mulch. Experiments to develop these alternative methods of garden irrigation are being conducted at the Lowveld Research Station (LVRS) in southeast Zimbabwe.

Irrigation Methods

Subsurface irrigation

Soil evaporation can be reduced by maintaining a dry soil surface during irrigation and applying the water directly to the root zone. Subsurface irrigation could be employed in Zimbabwe by utilizing homemade clay pipes and porous clay pots. Both methods are low-cost and can be manufactured locally. Both are suitable for irrigating small plots, and both can be operated using water from a simple delivery system or using water carried in buckets.

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Clay Pipes Homemade clay pipes can be manufactured using a simple mold and fired in a shallow bark-filled pit. Further details are given by Lovell *et al.* (1990). Briefly, the pipes made at LVRS are 24 cm long, have an inside diameter of 7.5 cm and are 4 cm thick. They are placed along the centre line of beds, simply laid end to end in a level trench then backfilled with soil. The pipes are placed with 10-20 cm of soil above them, depending upon soil type and the crop to be grown. To allow pipes to fill with water, an inlet is formed at one end of the bed by tilting the first pipe section, the lower end of which is angled during manufacture to join smoothly with the second, level pipe section. At the other end of the bed, which is normally 3 to 6 m in length, the subsurface pipe system is blocked with a large stone. During irrigation, water is poured into the pipe and seeps directly into the root zone via the joints between individual pipe sections. Perforated bamboo or PVC pipes can also be used as an alternative to clay pipes.

Porous clay pots Subsurface irrigation using unglazed porous clay pots is an ancient method still practised today in several countries, notably India, Iran and Brazil (Power, 1985; Yadav, 1983; Monda, 1974; Anon., 1978 and 1983). At LVRS, the locally made pots are buried neck-deep in the soil next to the plants or between plant rows at intervals of 0.3 m. When filled, water seeps from each pot through pores in the pot wall and forms a wetted zone similar to that formed by a subsurface drip source. The amount of water that can be applied at any one time is limited by the volume of the pots. Different amounts are achieved by varying the frequency of filling but this is limited by the size and porosity of the pot.

Drip irrigation

Drip irrigation can improve water use efficiency by enabling the required depth of water per plant to be applied to a limited area of the soil surface rather than to the entire soil surface, thereby reducing the area of wet soil from which soil evaporation can occur while maintaining a favourable moisture status close to the plants. At LVRS, a low-head drip irrigation system operating under pressures of between 5-20 kPa (0.5-2 m head of water) has been developed by using a raised 200 l drum as a water source, locally available plastic piping as the conveyance system, and homemade "drippers". Further details are given by Batchelor *et al.* (1990).

Flood irrigation beneath mulch

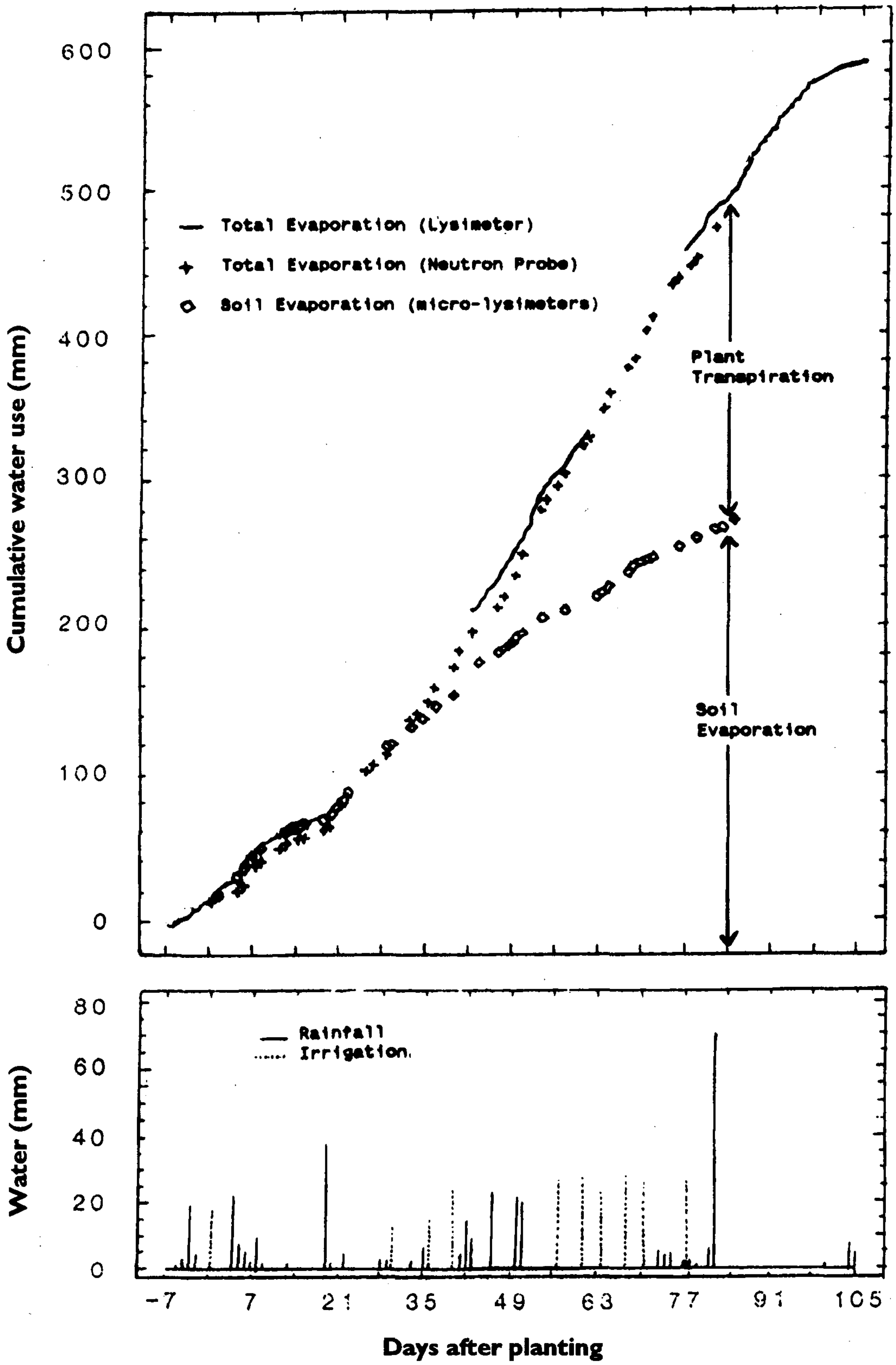
Surface mulches are recognised worldwide to reduce soil evaporation, and are used for this purpose in some modern, large-scale commercial farming systems (e.g. Unger and Parker, 1976). At LVRS, native grasses (*Eragrostis sp.* and *Heteropogon sp.*), maize stover, rice straw and leaves of the neem tree (*Azadirachta indica*) have been used to provide a surface mulch during irrigation experiments. Other locally available materials that can also be used include leaf-litter, sand and even flat stones.

Potential for Saving Water in Garden Irrigation

During the 1990-91 wet season, micro-lysimeters and a large weighing lysimeter were used at LVRS to measure soil evaporation under maize grown in small beds and irrigated by supplementary flood irrigation. One objective of this work was to quantify the partition of total water use to soil evaporation, plant transpiration and drainage beneath the root zone during the life of the crop. The soil type at LVRS is a reddish-brown sandy clay loam.

Figure 1, taken from Lovell *et al.* (1992), illustrates the partition of water use recorded during the season. Plant transpiration accounted for only 46% of total water use. Soil evaporation accounted for 54%, and was the dominant process until about day 42. Of the rainfall and irrigation received on bare soil prior to plant emergence, 79% was subsequently lost as soil evaporation. Drainage below 0.9 m did not occur during this experiment. These results highlight the potential that exists to improve water use efficiency in garden irrigation by reducing soil evaporation.

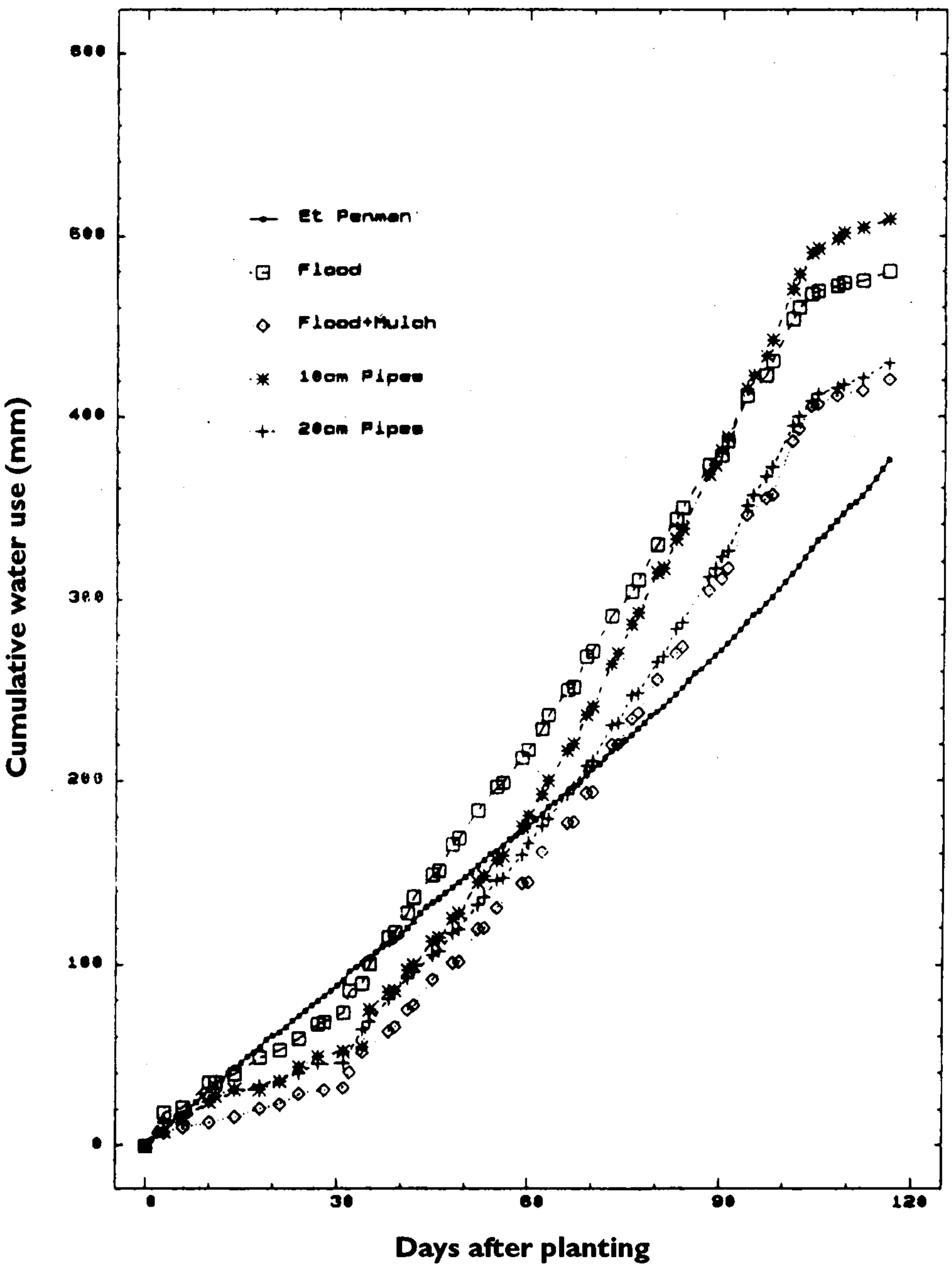
Figure 1. The partition of total water use to plant transpiration and to soil evaporation for maize grown in small beds and irrigated by supplementary flood irrigation during the wet season in Zimbabwe (from Lovell et *al.*, 1992)



Savings in water and improved values of water use efficiency (kg of crop produced per cubic meter of total water used) have been achieved under a variety of crops in a number of replicated trials conducted at LVRS in which crop yield and water use of alternative methods of irrigation have been compared to those of traditional flood irrigation. Figure 2 provides an example, and shows the temporal pattern of water use measured beneath sugar beans irrigated during winter by traditional flood irrigation, flood irrigation beneath a surface mulch of rice straw, and subsurface irrigation via clay pipes placed at two different depths.

Water use was lowest beneath the mulch. A considerable saving in water was achieved by this method, but occurred only during the first

Figure 2. The temporal pattern of total water use measured for sugar beans irrigated by traditional flood irrigation, by flood irrigation beneath a surface mulch, and by subsurface irrigation using clay pipes placed at two different depths



30 days. During this critical period, prior to plant canopy closure, evaporation from the moist soil exposed by traditional flood irrigation was high (initially equal to the potential rate of evaporation shown). Placing water beneath the mulch reduced this loss of water and, during this initial period, this method used only 43% of the water used by the traditional method. Thereafter, as the plant canopy closed, the rate of water use became virtually identical under all methods of irrigation. The savings in water achieved by using the mulch was 12% over the course of the season.

Variability in Water Savings Achieved to Date

During other replicated trials and under other vegetable crops, savings in water achieved by use of the alternative methods of irrigation have varied from 11% up to 28% of the water used by traditional flood irrigation, the higher savings in water generally being recorded during the dry winter seasons. The variation reflects some of the complexities encountered during experiments designed to compare different irrigation methods.

The performance of different irrigation methods can vary in response to the choice of experimental design and the method by which irrigation requirements are determined. In the sugar bean trial illustrated in Figure 2, different amounts of irrigation water were applied to each treatment in order to match water use measured individually using a neutron probe. This approach was successful in highlighting the initial savings in water possible using surface mulch, but a similar initial savings in water achieved using shallow subsurface pipes was subsequently lost as the plants on this treatment flourished more than on other treatments and water use increased. Though yield was higher and significantly larger bean seeds were grown, the water use efficiency achieved by this method in this experiment was similar to that achieved by traditional flood irrigation.

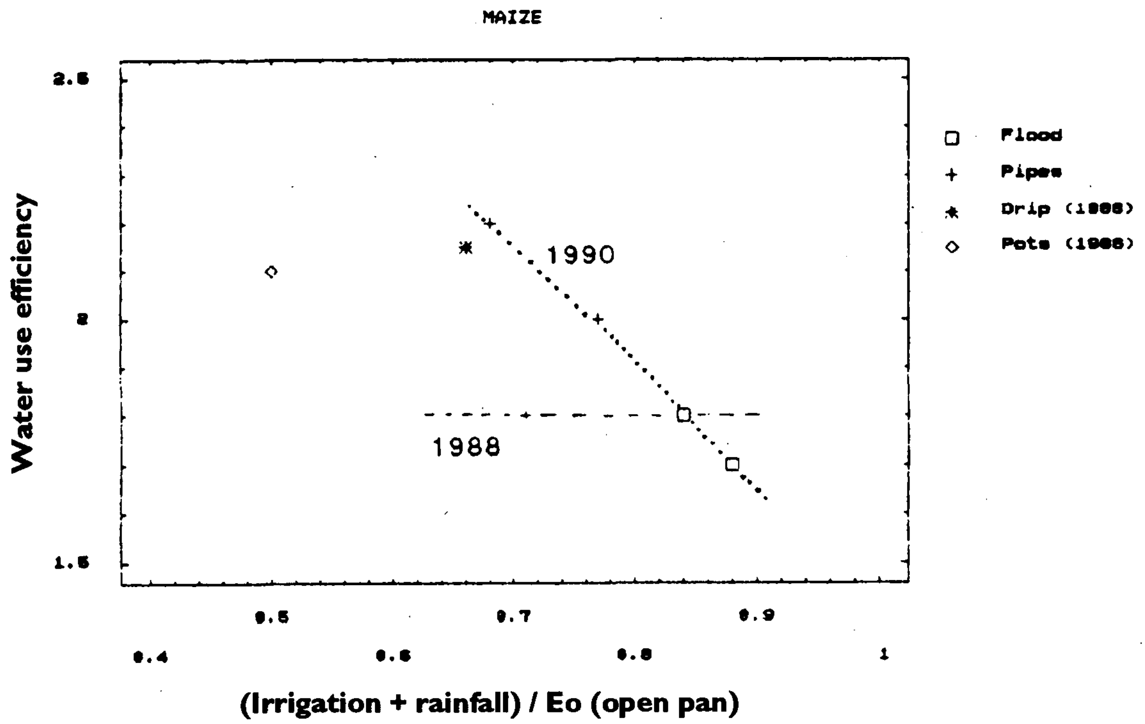
Plant transpiration accounted for 46% and soil evaporation accounted for 54% of total water use. Of the rainfall and irrigation received on bare soil prior to plant emergence, 79% was lost as soil evaporation

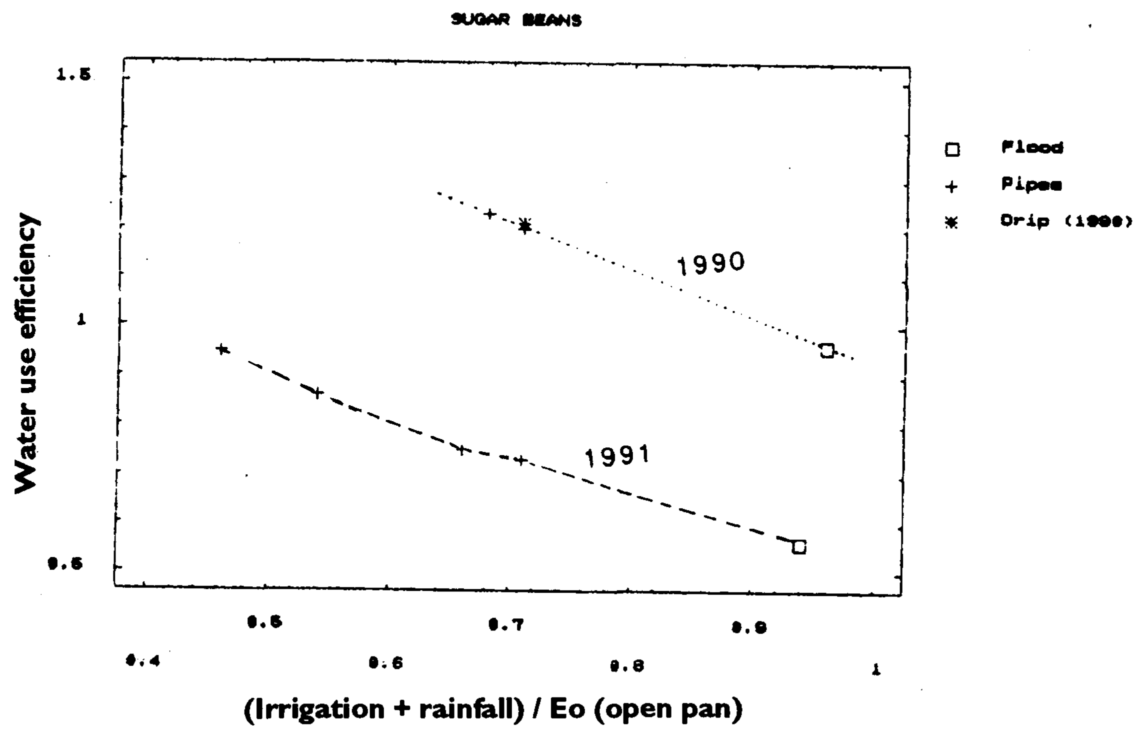
Figure 3 illustrates variations in water use efficiency as measured for particular irrigation methods and crops during different seasons and different years. The water use efficiency is here defined as the ratio of the amount of water applied and the amount of water evaporated by the plants. Variations in efficiency are due to many factors, including: differences in residual moisture content present in the soil profile prior to different experiments; the timeliness and pattern of rainfall received; general differences in weather patterns; and different incidence rates of pests. The variations measured from one year to the next remain clear although the data

Soil evaporation can be reduced, and efficiency of irrigation improved, if water is applied beneath the soil surface, applied to a limited area of the soil surface or applied beneath a surface mulch

in Figure 3 is normalised with respect to evaporation measured during each particular experiment. However, the trend toward greater water use efficiencies - by using alternative methods of irrigation - is consistent from year to year.

Figure 3. Variations in water use efficiency measured for maize and for sugar beans grown during summer and winter respectively during two different years using several methods of garden irrigation





Ongoing Work at the Lowveld Research Station

Of the several alternative irrigation methods studied at LVRS to date, subsurface irrigation via homemade clay pipes and surface irrigation beneath an organic mulch appear to be the two methods that hold most promise for use in irrigated gardens in this part of Zimbabwe. Ongoing experiments to further develop these two methods include:

1. Establishment of curves that define the relationship between water use and water use efficiency (yield) for the main vegetable crops grown, in order to determine the optimum area of land that should be irrigated per unit of water available.

2. Establishment of irrigation schedules that best utilise the water saving potential of these methods and which promote improved crop yields. The traditional irrigation schedule identified as that most often used in local rural areas (Murata, 1992) applies the same amount of irrigation from beginning to end of the vegetative cycle. Water use efficiency can

Table I. The advantages and disadvantages of each method were recorded during the experiments conducted at LVRS to compare and develop different methods of garden irrigation

Irrigation Method	Advantages	Disadvantages
Flood	Traditional, well-known method. Easy to perform. Good crop establishment. No additional inputs required. Application of manure on all soil surfaces possible.	Not efficient in water use. Impact of water can damage soil structure causing sealing. No inherent control against over irrigation. Labour intensive. Cycles of excess moisture and drought can be extreme. Weeds can be a problem.
Flood & Mulch	Improved water use efficiency. Excellent crop establishment in moist soil conserved at planting. Addition of organic matter can improve soil structure/infiltration. Protection of soil surface during heavy rain. Simple low-cost method.	Mulch may not be available. Incidence of pests and fungal diseases can be higher beneath mulch and in moist environment maintained at plant base.
Low-head Drip	Improved water use efficiency. Good uniformity of wetting. Reduced weed problem. Reduced drudgery of carrying water. Fertiliser can be applied with irrigation water.	Cost and availability of materials. Degree of management skill required. Clogging of emitters. Damage by rodents.
Clay Pipes	Improved water use efficiency. Can be made locally. Robust method. Low labour requirement. Some inherent control against over irrigation. Reduced weed problem. Good uniformity of wetting. Fertiliser can be applied with irrigation water. Low-cost, simple method, easy to learn. Once installed, pipes can be used for several seasons.	Initial labour required for manufacture and installation. Crop establishment can be poor. Root development in a limited volume of soil. Application of manure in liquid form is necessary.
Clay Pots	Improved water use efficiency. Can be made locally. Inherent control against over irrigation. Reduced weed problem. Can be positioned next to individual plants or in very small plots or on undulating land.	Less robust than clay pipes. More labour intensive, pots have to be filled individually. Porosity of pots decreases with time. Difficult to cope with high crop water requirements.

perhaps be improved if this irrigation schedule is varied to match more closely the development of the crop.

3. Improvement of crop establishment above subsurface clay pipes, in particular, by application of a surface layer of manure.

4. Studies of alternative planting arrangements and plant spacing designed to reduce soil evaporation by promoting complete and rapid canopy cover.

Ongoing Work In Southeast Zimbabwe

There has been much interest expressed in subsurface irrigation and an encouraging adoption of mulching using dry leaves by gardeners in some irrigated gardens of this area. These include established rural gardens, new collector well gardens (see Lovell *et al.*, this volume) and a recently developed urban irrigation project. Dissemination of ideas will continue at these and other gardens and feedback generated will be incorporated in the ongoing experimental programme at LVRS.

Summary

Water use efficiency in garden irrigation can be improved by using irrigation methods designed to reduce soil evaporation. Lysimetry experiments conducted at LVRS suggest that a potential saving in water of up to 50% may be achieved in this way, but this saving has not yet been realised in practice. Savings in water can be substantial, but vary from crop to crop and from season to season. It is possible to save water before a full crop canopy develops. Thereafter, soil evaporation is reduced by the plants that shade the soil surface. The mature plants require a specific amount of water irrespective of irrigation method, and little potential remains to save water. In summer, significant savings in water may occur only if rainfall is low and irrigation is necessary prior to plant canopy closure. Crops that provide poor shade of the soil surface should benefit most by use of the alternative methods of irrigation and provide greater opportunity to save water.

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