Garden irrigation: Alternative techniques and techonology diffusion in dry regions

Monica Murata and Chris Lovell

A number of simple, low-cost irrigation techniques have been developed that improve both yields and water use efficiency. So why has the technology diffusion process had such a chequered history among farmers in Zimbabwe's dryland areas?

In semi-arid environments, water scarcity has led to the search for irrigation methods that use water efficiently. Development and assessment of water-saving irrigation techniques began at the Lowveld Research Stations (LVRS) in Zimbabwe in 1985. The objective was to compare low-cost methods of irrigation that improved water-use efficiency in community gardens by reducing loss of water evaporation from the soil. Methods tested included sub-surface irrigation (applying water beneath the soil surface through either home-made clay pipes or porous clay pots), home-made drip irrigation (applying water to a limited area of the soil surface) and improved flood irrigation (applying water beneath a surface mulch). Each method was found to improve water-use efficiency (yield per cubic metre of water used) — when compared to traditional flood irrigation of bare soil, but take-up by farmers in Zimbabwe's communally managed dryland areas has been, in general, disappointing, for a number of important reasons.

1. Rutenberg, G. (1971). 'Trickle Irrigation Literature Survey', Israel Centre of Waterworks Appliances Publications: International Expert Panel on Irrigation.

2. Anon. (1979). 'Kuzeh pot irrigation'. *Irrinews* No. 11.

3. Power, G. (1985). 'Porous pots help crops in north-east Brazil' *World Water*, July pp.21-23.

The use of porous clay pipes for sub-surface irrigation dates back to 1896.

Charles Batchelor

About the concepts

Sub-surface irrigation by pipes dates back to 1896 when a German system known as *Kuchluhn* used sub-surface concrete pipes, the upper part of which were porous. In 1923, Kornev in Russia developed an irrigation network composed of porous clay pipes joined with rubber joints and buried at a depth of between 0.2 and 0.3m at intervals of 1m, the lines connected to a container placed at the highest point. Later research led to the use of clay pipes which were 27 per cent porous.[1] Pitcher irrigation is traditional in the Punjab, in Iran where it is called *kuzeh* pot irrigation and, more recently, has been used in Sahelian Nigeria, Argentina, Brazil, Bolivia and Chile.[2,3] Surface mulches are known to reduce soil evaporation by increasing the relatively non-turbulent layer of air above the soil, and by offering increased resistance to water-vapour flow from the soil surface to the atmosphere. Various mulches ranging from organic residues to polyethylene films and petroleum emulsions have been used to modify the hydrothermal régime to better suit the crop, and many studies have shown that mulching can help in moisture conservation.

Technology development at LVRS

Sub-surface irrigation

Porous clay pots or unglazed earthenware pitchers, common to rural areas, come in a range of sizes and shapes. At LVRS, the pots have 0.08 to 0.1m-long, 0.02 to 0.04m-diameter necks, with a capacity ranging from 0.5 to 2.5 litres. They provide a simple irrigation system. Staff bury the pots neck-deep in the soil next to plants, or between rows at intervals of 0.3m. When filled, water seeps from each pot via pores in the wall, forming a wetted zone similar to that formed by a sub-surface drip-irrigation source. The amount of water that can be applied is controlled by the pot volume. Different irrigation régimes can be achieved by varying the frequency of filling. Where available, gourds pierced with small holes offer an alternative to the clay pots.

Flood irrigation beneath mulch

At LVRS, native grasses (*Eragrostis sp.* and *Heteropogon sp.*), maize stover, rice straw, and neem tree leaves were used to provide surface mulches during irrigation trials. Other suitable materials include leaf-litter, coarse sand, and even flat stones.

Irrigation Method	*Advantages*	*Disadvantages*
Traditional flood irrigation	Traditional, well-known method. Easy to perform. Good crop establishment. Minimum additional inputs.	Not efficient in water use. No inherent control against over-irrigation. Labour intensive.
Low-head drip irrigation	Improved water-use efficiency. Good uniformity of wetting. Reduced drudgery and effort of carrying water.	Cost and availability of materials. Degree of management skill required. Water filtration required. No inherent control against over-irrigation.
Sub-surface pipe irrigation	Improved water-use efficiency. Pipes made locally. Robust method. Low labour requirement. Some inherent control against over-irrigation. Good uniformity of wetting. Low-cost, simple, easy to learn. Once installed, pipes good for several years.	Initial labour and skill required for pipe manufacture and installation. Crop establishment can be poor if initial irrigation only via pipes.
Pitcher irrigation	Improved water-use efficiency. Inherent control against over-irrigation. Can be positioned next to individual plants or in very small plots or undulating land.	Initial skill and labour required for manufacture and installation. Less robust than clay pipes. More labour-intensive: pots have to be filled individually. Porosity of pots decreases with time. Difficult to cope with heavy water requirements.
Improved flood irrigation (mulch)	Improved water-use efficiency. Low skill requirements and easy to carry out. Good crop establishment. Protects fruit from damp soil. Prevents soil capping and reduces soil erosion.	Potential for pest and disease increase. Material suitable for mulching not always readily available.

Table 1. Advantages and disadvantages of simple micro-irrigation methods.

The research process

Over eight years, LVRS conducted a great number of replicated irrigation trials to measure and compare crop yields and water-use efficiency with those of traditional flood irrigation.[4,5,6] The crops included maize, tomatoes, rape, okra, cabbage, beans, carrots and onions. Some of the practical findings of the trials are summarized in Table 1.

In general, gardeners did not have problems with pipe installation; one quick demonstration was sufficient. But people did have reservations about whether seedlings could extract water applied 0.1 to 0.2m underground; how fertilizers (especially manure) should be applied; and whether only two rows of plants per bed could be grown with sub-surface irrigation instead of the three rows traditionally grown on flood-irrigated gardens. Studies found that sub-surface irrigation can be used successfully with three rows per bed, the third row being placed directly above the pipes; simple mulches, particularly of manure, can improve germination and seedling establishment above clay pipes; and liquid fertilizer can be applied successfully through the pipes by first dissolving manure (or inorganic fertilizer) in irrigation water for a day or two before irrigation.

Technology diffusion

Sadly, the technology-diffusion process, which started in about 1990, has had a chequered history. Initially, agricultural extension staff were invited to LVRS to see the alternative irrigation techniques. Despite expressions of interest made at the field days, there was little evidence of technology transfer through these staff to local communities.

In contrast, Intermediate Technology (ITDG), which was then an NGO involved in a Food Security Project in Chivi District, brought a group of local farmers to LVRS to see a range of research ideas. The group — 90 per cent women, was particularly interested in the idea of sub-surface irrigation. As the women were already skilled potters, they felt capable of making their own pots and pipes. Pipe-making demonstrations were conducted at Chiredzi and in Chivi. The women experimented with the system in 14 group gardens, where they discovered that the technique reduced both the amount of watering required, and the time needed to tend their gardens.[7]

In another initiative at this time, the urban community around a Kellog-funded garden in Chiredzi town were introduced to sub-surface irrigation by Mr Mharapara, a KILP fellow. Three project members were trained to make pipes and they in turn instructed others. Similarly, Hippo Valley, a local sugar estate, expressed interest in adopting the method for use by employees in their backyard gardens; other NGOs such as Friedrich Ebert Stiftung introduced the method to establish hedges and gardens in their projects; and agricultural extension staff

4. Batchelor, C.H., Lovell, C.J. and Murata, M. (1996). 'Simple micro-irrigation techniques for improving irrigation efficiency on vegetable gardens', *Agricultural Water Management*, 32, 37-48.

5. Lovell, C.J., *et al* (1992). 'Development of small-scale irrigation using limited groundwater resources: Third Interim Report'. Report ODA/92/4, Institute of Hydrology, Wallingford, UK.

6. Murata, M., *et al* (1995). 'Development of small-scale irrigation using limited groundwater resources: Fourth Interim Report'. Report ODA 95/5, Institute of Hydrology, Wallingford, UK. 104pp.

7. Murwira, K. (1995). 'Freedom to change: the Chivi experience', *Waterlines*, Vol. 13, No. 4.

began promoting the ideas through demonstration plots at regional shows.

Why such low adoption?

Despite much initial interest, uptake of the research has been disappointing. Although the alternative irrigation methods are simple and low-cost, undoubtedly save water, and improve yields under research-station conditions, some five years later these methods are not widely used. We have not been able to conduct an ex-post evaluation. This would be a useful exercise and relevant to other agricultural research projects. However, we can suggest why uptake of this research has been poor to date:

- Research findings — in the form of pamphlets, etc. written in the local languages have not been disseminated adequately. Communities need access to information about irrigation scheduling, crop rotations, marketing strategies, and pest and disease control, if they are to derive the maximum benefits from the new technologies.
- Inadequate opportunities for local communities to see new ideas, through exposure visits and to learn by doing. Finding out via extension staff, or by being presented with results at research stations is not ideal. Research and extension staff must help facilitate visits and encourage local farmers to carry out their own experiments based on what they have seen.
- Very few demonstrations were conducted with farmers under local conditions, so other factors, such as production aims, labour constraints, and access to materials, could not be considered properly during the development phase. Also, the LVRS trials were on a single soil type, a sandy clay loam, and insufficient attention was paid to planting arrangements that could conserve water and improve pest and disease control — a second key constraint facing local farmers.
- *Improved water supply*. The irrigation trials and initial interest in water-saving coincided with an unprecedented dry cycle, culminating in the severe drought of 1991-2. Since then, above-average rainfall has replenished ground- and surface-water supplies, so interest in water-saving methods has declined — this interest should be reactivated when the next dry cycle commences.[8]
- Water in Zimbabwe's communally managed dryland areas is a common-property resource. This, combined with a poor local understanding of groundwater behaviour, places serious limitations on both the incentive and responsibility felt by individuals to conserve the resource.[9]
- Finally, from the woman farmers' perspective, the benefit or advantages of these improved irrigation techniques do not outweigh the disadvantages.

Water-resource management and the uptake of water-saving irrigation methods in communally managed dryland areas is complex, relying on a mix of physical, social and economic factors. As Lovell describes on page 5 of this issue, recent work in Zimbabwe has highlighted the many benefits of productive groundwater development. The big question remains: can the income generated from productive waterpoints provide the incentive for community-based actions that contribute to improved water-use efficiency and resource management at the catchment scale? Farmer-participatory research has an important role to play, but will not always be easy. Experience to date shows that it will depend on farmers gaining improved access to information, and on the willingness of researchers, extension staff and farmers to learn together. ■

8. Moriarty, P.B. and Lovell, C.J. (1988). 'Groundwater resource development in the context of farming systems intensification and changing rainfall régimes: a case study from south-east Zimbabwe'. AgREN Network Paper 81, ODI, London.

9. Waughray, D.K., *et al* (1997). 'Community resource management and livelihood strategies'. Final Report to ODA. Report 97/1, Institute of Hydrology, Wallingford, UK.

Acknowledgements
The authors would like to thank those who gave support and advice during the research endeavours and during preparation of this manuscript. Financial support for part of the research described was provided by the DFID Engineering Division, London.

about the authors

Monica Murata works at the Agronomy Institute, Box CY550, Causeway, Harare, Zimbabwe.

Dr Chris Lovell is a Principal Scientific Officer with the Institute of Hydrology, Wallingford, Oxfordshire, UK.

Monica Murata

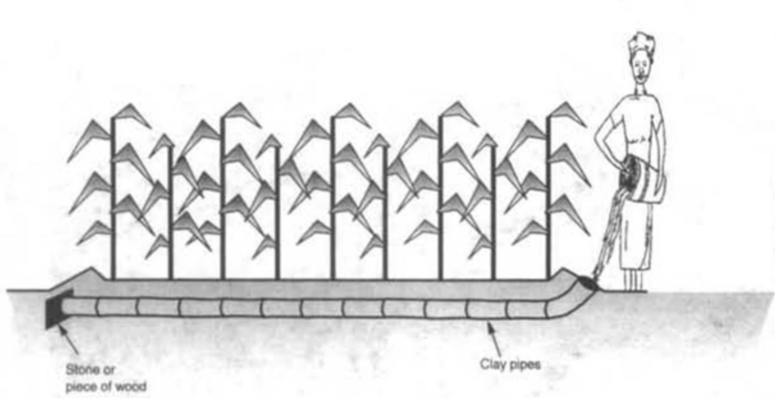
Research at LVRS found women to be particularly interested in sub-surface irrigation; many are already skilled potters.

How to make clay pipes

- With your hands, crush what should be reasonably heavy clay soil; leave it to soak overnight until pliable. Remove stones and roots and mix the clay 'paste' thoroughly by throwing it repeatedly against a hard surface.
- Place a rectangular wooden frame, with an internal length, width and depth of 0.3, 0.25 and 0.016m respectively, on a sheet of plastic of the same size, and fill completely with soil paste. Take care to remove trapped air. Level the clay using a straight edge (pulled along the sides of the frame), and make it smooth by sprinkling water at the same time.
- At either end, form grooves allowing a joint of constant wall thickness to be formed when the sheet of clay is wrapped around a 0.36m-long, 0.073m-wide wooden rolling pin. Form a strong joint by kneading the two ends of the clay sheet together, and insert the rolling pin plus clay into an outer mould, constructed of a 0.25m length of '125mm'-diameter PVC pipe cut along one side, with simple handles attached to allow the pipe to be opened slightly to accept the rolling pin and clay.
- Close the PVC pipe by squeezing the handles together, rotating the rolling pin several times so that the pipe has a smooth inner surface. Similarly, smooth the outer surface (by rotating the outer mould) and remove excess clay with a knife. Then remove the wooden cylinder and place the outer mould plus clay end-up on the ground. Remove the outer mould and plastic sheet and there is your finished five-minute clay pipe.
- It is important to maintain slow uniform drying of the pipes before firing. After moulding, stand the wet clay pipes on end for three to four hours in the open shade. Lay them side by side for two days — rolling them occasionally — and, finally, place them in direct sunlight for a day before putting them in a shallow, bark-filled pit. The pit should hold approximately 50 pipes per firing. Place a layer of tree bark on the bottom, followed by the pipes, tilted at a slight angle. Place bark inside each pipe, and over the pipes. Light the fire and allow it to burn overnight until only ashes remain. The pipes are ready for use as soon as they have cooled down.

The finished pipe should be 0.24m long, with an inner diameter of 0.075m and outer diameter of 0.115m. Place them along the centre line of garden-beds, laid end to end in a level trench; then backfill with 0.1 to 0.2m of soil above the pipes depending on the soil type and crop to be grown. So that they fill with water, form an inlet at one end by tilting the first pipe section, having angled the lower end during manufacture to join smoothly with the second, level pipe. At the other end of the bed, normally 3 to 6m long, block the pipe with a large stone. To irrigate, pour water into the pipe, either from a bucket or hose-pipe; this will seep directly into the root zone via the joints between pipe sections.*

* Where available, perforated-bamboo or PVC pipes offer an alternative to clay pipes.



Sub-surface irrigation.