Smallholder irrigation technology: prospects for sub-Saharan Africa
SMALLHOLDER IRRIGATION TECHNOLOGY:
PROSPECTS FOR SUB-SAHARAN AFRICA

Melvyn Kay
FAO/IPTRID Consultant
The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Food and Agriculture Organization of the United Nations (FAO) or the International Programme for Technology and Research in Irrigation and Drainage (IPTRID). Mention of specific companies, their products or brand names does not imply any endorsement by FAO or IPTRID.

The designations employed and the presentation of material in this information product do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations or the International Programme for Technology and Research in Irrigation and Drainage (IPTRID) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

All rights reserved. Reproduction and dissemination of material in this information product for educational or other non-commercial purposes are authorized without any prior written permission from the copyright holders provided the source is fully acknowledged. Reproduction of material in this information product for resale or other commercial purposes is prohibited without written permission of the copyright holders. Applications for such permission should be addressed to the Chief, Publishing and Multimedia Service, Information Division, FAO, Viale delle Terme di Caracalla, 00100 Rome, Italy or by e-mail to copyright@fao.org

© FAO 2001
Summary

This report is a review of irrigation technologies for smallholders in the context of improving rural livelihoods, especially in regard to the prospects for sub-Saharan Africa. The role of traditional technologies is evaluated and modern water distribution technologies, such as sprinkler and trickle irrigation, are reviewed. Low-cost irrigation systems, including such innovations as the use of treadle pumps and drip-kits are then examined. The most appropriate technology to use varies from place to place depending on a wide range of circumstances. A broad classification has been made based on climate and the traditional agricultural background of the local people, which links technology options to specific places – to agricultural regions and to countries. Some ideas are presented on the direction that might be taken by governments, aid donors, NGOs and the private sector to support future development, with a special emphasis on the need to support a wide range of education and training programmes.

The Case for Smallholder Irrigation

Irrigation has long been seen as an option for improving rural livelihoods by increasing crop production, but massive investments throughout the 1970s and 1980s in sub-Saharan Africa have not borne fruit. Food production targets were not met, development costs were extremely high in relation to returns and there were many technical and management problems that remain unsolved. The decrease in real terms of world cereal prices over the past decade has made it difficult to invest in and maintain irrigated agriculture for basic grain crops.

Much of this criticism was directed at the more formally structured irrigation schemes usually under the control of a government body. Because of this, attention turned in the 1980s to the informal sector, small-scale or smallholder irrigation, which is described as the ‘bottom-up’ or ‘grass-roots’ approach to development. There are many smallholder success stories, particularly where farmers have made the investments themselves.

However, all has not gone smoothly where donors have tried to stimulate development. Donors, funding agencies and national governments, wishing to accelerate the development process, still tend to use a ‘top down’ approach where only lip service is paid to farmer participation. The pace is forced to meet investment targets and market forces have been ignored.

Available Technologies

Experience in sub-Saharan Africa has shown that successful smallholders generally use simple technologies and have secure water supplies over which they have full control. The most successful technologies are those that improve existing farming systems rather than those that introduce radically new ideas.

Traditional technologies

A wide range of well-established traditional technology options is available for use by smallholders including of water harvesting, swamp irrigation, spate irrigation, flood plain irrigation using seasonal water and shallow aquifers, hill irrigation, and groundwater irrigation. There is still, however, considerable room to improve and adapt these traditional technologies to different circumstances.

Modern technologies

In recent years there has been a growing interest in new technologies to carry and apply water. These usually cost much more than traditional methods and rely very much on external specialist support from
suppliers and distributors. Distribution technologies such as trickle and sprinkle irrigation and piped supplies for the more traditional surface methods, can help farmers to manage their water better as well as reducing wastage. All these technologies have the potential to raise the productivity of water and labour. But they are really only accessible to those farmers who can afford to buy them and who are growing cash crops such as vegetables, fruits and flowers. They are unlikely to be taken up by poor farmers.

**Low-cost technologies**

This phrase refers to modern technologies that have been developed or modified in some way to bring down their cost. An excellent example is the treadle pump, which was developed specially as a low-cost pump for smallholders and continues to be adapted for particular local needs and markets in the region. Low-cost systems of water conveyance and distribution have not been comprehensively tested and evaluated in the region, with the exception of treadle pumps. The adoption by smallholders of treadle pumps to replace the onerous task of lifting and carrying water and the way in which the support services have developed offers lessons for the promotion of other irrigation technologies.

**Technology uptake**

Low-cost, modern technologies can help smallholders move from subsistence farming into growing cash crops. Success will be determined more by the capacity of smallholders to take risks and adopt new technologies in situations where services are erratic, costs are high and markets are unpredictable. Factors influencing technology uptake are the existence of a market-driven demand for agricultural produce; a well-designed technology that is both appropriate and affordable for the local farming and manufacturing systems; a local private sector capable of mass production of reliable equipment; effective private sector distribution networks for agricultural inputs and equipment including transport, infrastructure and retailers.

**How fast can irrigation develop?**

The average rate of irrigation development for the sub-Saharan Africa region (40 countries) over the past 12 years is 43 600 ha/year – an average of 1 150 ha/year for each country. Some countries have average rates of development over 2 000 ha/year (e.g. Tanzania, Nigeria, Niger, Zimbabwe and South Africa).

If the current rate continues over the next 25 years then an extra one million ha of irrigation could be brought into production – increasing the total area presently under irrigation by 50 percent. Even at the most optimistic rate, the contribution that irrigation can make to increase food production in the region will be modest unless some of the key constraints are removed.

Speeding up development does not necessarily mean building irrigation schemes faster but building many more of them. An important lesson learned over the past 20 years is that smallholder schemes develop through a slow incremental process of improvement, usually in response to farmer demand. Unfortunately this is at odds with the way in which most donor and government agencies work to specific time schedules.

**A dearth of experience**

For irrigation to succeed, experienced and knowledgeable staff will be needed. Labour studies can assess the demand and supply of trained people. Demand is based on the expected growth rates in irrigation and the supply of trained people at all levels is based on the output from both the institutional and in-service training arrangements. Support will undoubtedly be required in order to establish appropriate institutional and in-service training programmes that properly equip people for the jobs they must do to address the fundamental issues related to the improvement and adoption of appropriate irrigation technologies in sub-Saharan Africa.
Contents

SUMMARY ...................................................................................................................................................... III

ACKNOWLEDGEMENTS .................................................................................................................................... VI

INTRODUCTION ................................................................................................................................................ 1
  The case for smallholder irrigation ........................................................................................................... 1
  Too many reviews? ................................................................................................................................. 2
  Technology – at the heart of irrigation ...................................................................................................... 2
  The nature of smallholder irrigation ......................................................................................................... 3

TRADITIONAL TECHNOLOGIES .......................................................................................................................... 5
  Water harvesting ......................................................................................................................................... 6
  Communal scheme experiences .............................................................................................................. 9
  Role of traditional technologies in sub-Saharan Africa ......................................................................... 11

MODERN TECHNOLOGIES .................................................................................................................................. 13
  Sprinkle irrigation ..................................................................................................................................... 14
  Trickle irrigation ....................................................................................................................................... 17
  Improving traditional methods ................................................................................................................... 18
  A role for modern technologies in sub-Saharan Africa? ......................................................................... 19

LOW-COST TECHNOLOGIES .................................................................................................................................. 21
  A new philosophy ...................................................................................................................................... 21
  Irrigation kits ........................................................................................................................................... 21
  Treadle pumps .......................................................................................................................................... 24
  Prerequisites for uptake ............................................................................................................................ 25
  A role for low-cost technologies in sub-Saharan Africa? ......................................................................... 25

MATCHING TECHNOLOGIES TO AGRICULTURAL REGIONS ................................................................................. 27
  Desert and semi-desert .............................................................................................................................. 27
  Dry savannah agriculture .......................................................................................................................... 27
  Humid savannah agriculture .................................................................................................................... 29
  Humid tropical forest agriculture ............................................................................................................. 29
  High tropical and subtropical plateau agriculture .................................................................................... 29

HOW FAST CAN SMALLHOLDER IRRIGATION DEVELOP? ..................................................................................... 31
  Review of experience from sub-Saharan Africa ....................................................................................... 31
  Existing situation ...................................................................................................................................... 34
  Future potential ......................................................................................................................................... 36

THE RIGHT DIRECTION: PROSPECTS FOR SUB-SAHARAN AFRICA .................................................................... 39
  Developing human resources .................................................................................................................... 39

REFERENCES .................................................................................................................................................... 41
Acknowledgements

The author would like to acknowledge and thank the following people for their valuable assistance during the preparation of this report:

• Tom Brabben, Audrey Nepveu de Villemarceau, and Arumugam Kandiah, IPTRID, Land and Water Development Division, FAO, Rome

• Officers of the Water Resources Development and Management Service, FAO, Rome, particularly Reto Florin, Martin Smith and Nico VanLeeuwen

• Michael Fitzpatrick, Amadou Soumaila and Abdul Kobakiwal, FAO, Rome

• Jean Payen, Irrigation Adviser, IFAD, Rome

• Ed Perry, Enterprise Works Worldwide, Washington DC, USA

• Peter Raymond, INPIM, Washington DC, USA

• Fernando Gonzalez, Geert Diemer and Itaru Minami of the Rural Development Department, World Bank, Washington DC, USA

• Jaap van de Pol and Volker Branscheid, World Bank, Washington DC, USA

• Richard Carter, Cranfield University, UK

• Gez Cornish, HR Wallingford, UK

This paper was prepared in response to a request from Fernando Gonzalez, Senior Irrigation Adviser in the World Bank. IPTRID gratefully acknowledges the financial support provided by the World Bank.
Introduction

Irrigation has long been seen as an option to improve and sustain rural livelihoods by increasing crop production. It can reduce dependency on rainfed agriculture in drought prone areas and increase cropping intensities in humid and tropical zones by ‘extending’ the wet season and introducing effective means of water control. In the 1970s and 1980s international agencies and national governments invested heavily in irrigation to intensify agriculture and reap the benefits of the high yield potential of irrigated agriculture. The nature of donor-sponsored development favoured large-scale projects rather than small ones and the majority of funding went into large-scale irrigation schemes. It is now widely accepted that this massive investment has not borne fruit. Food production targets were not met, development costs were extremely high, and there were many technical and management problems that remain unsolved. Over the past decade low world cereal prices have not helped this situation making it more difficult to maintain and invest in expensive irrigated agriculture for basic food crops.

Much of this criticism of irrigation has been directed at the more formally structured irrigation schemes usually under the control of a government body. Because schemes were large, the approach was almost exclusively ‘top-down’. Project management, to all intents and purposes, treated smallholders as labourers, and attempts were made to carry out all major agricultural operations on a large scale as a subsidized service. Dissatisfaction arose as a result of the inability of scheme managers to provide promised services such as cultivations, land grading, and harvesting on time.

The case for smallholder irrigation

Because of the criticism, attention turned in the 1980s to the informal sector. This was a significant shift from engineering led irrigation solutions towards an interactive approach in which the financial, cultural and social circumstances of the beneficiaries were to be taken into account. This was irrigation practised by individual farmers or smallholders, usually farming on a small scale (a few hectares) under their own responsibility; usually at low-cost with little or no government support and using technology they could understand and manage easily themselves. It is often described as the ‘bottom-up’ or ‘grass-roots’ approach to development. Surprisingly, up to that point this kind of development had received very little attention from the main aid donors in spite of the fact that this type of irrigation was already playing a significant role in several countries.

Over the past 20 years this approach has been the main focus of attention. Ideas about how to increase food production have been adjusted to take into account some of the physical realities of land and water use and resource allocation. For example, only five percent of the cultivated area in sub-Saharan Africa is irrigated and the rural poor are more likely to be found on marginal land in non-irrigated and often non-irrigable agriculture. There has been an increased emphasis on poverty reduction and a renewed interest in alternatives to the more traditional ways of irrigating using surface or groundwater such as water harvesting.

In a review of a published report on smallholder irrigation for a journal it was stated that:

‘An outsider to African smallholder irrigation with farming experience, would be amazed at the way irrigated agriculture has been approached in the region in recent decades. The manner in which farmers are given restricted and limited tenancies, told what to grow, charged for doubtful services and offered derisory prices for their produce would be laughable to European farmers. The fact that this and many other documents make such obvious statements shows how widely the existing paradigm of development has been accepted.

‘The authors’ message is two-fold. First, governments and others should allow farmers to control their own decisions and activities and help them to produce effectively. Second, the authors stress that most African smallholders are preoccupied with minimizing risk, and survival. If farming is too risky, then farmers may give priority to other means of survival and income generation.

There are major obstacles to change that lie in the enormous vested interests of those other than farmers who promote smallholder irrigation.’
There are many smallholder success stories but all has not gone smoothly. Too many international agencies and national governments wishing to accelerate the development process still tend to use a ‘top-down’ approach. Some have grouped many independent smallholders together into a ‘project’ for administrative convenience and created large-scale projects with their attendant problems. There have been too many instances of paying lip service to farmer participation, forcing the pace to meet investment targets and ignoring market forces. The much-used term of ‘low-cost engineering’ has become a euphemism for poor engineering design and construction.

**Too Many Reviews?**

It is well established that the potential for irrigation in terms of land and water resources in the region is significant. These resources do not constrain development although many other factors do. The reality is that smallholder irrigation does not mean it is simple.

Over the past 20 years a great deal has been written about what has or has not been done for smallholder irrigation. The literature available is comprehensive, covering topics that include appraisals of various technologies and socio-economic and anthropological studies. Much has been published, but there is still much that is not in the public domain, which may be of considerable benefit to others and resides as ‘grey’ literature in the archives of various organizations. Indeed, there is a fear that a great deal of knowledge and experience is ‘lost’ simply through changes in international agency and government staff, thus reducing ‘corporate memory’ to little more than a decade.

Unfortunately very little of this experience seems to have found its way into current development practice. The question remains as to how this potential, in terms of the available natural resources, can be realized. Some argue that market forces will drive development if the price of food crops is enough to encourage farmers to increase production. The rewards for meeting market demands can be high but so too can be the risks of failure. Others suggest that development can be driven by aid support, particularly for subsistence farmers who are more concerned with securing their basic livelihoods than producing crops to sell. The reality is that both approaches play important roles. The challenge is to encourage more subsistence farmers to move towards the market economy, through reduction of risk to their basic livelihoods, so that they may be prepared to take the risks and rewards that the market offers.

If progress is to be made in smallholder development there is an urgent need to continually review and update what is known and to put this information before decision-makers in a way that provides them with the information to develop cohesive strategies to support future development.

**Technology – at the heart of irrigation**

It is well known and accepted that technology alone does not determine success and it is essential to assess its usefulness within a social and economic context for any intervention to have meaning. It is for the individual farmer in each village, in each country to assess the appropriateness of the technology within their own complex socio-economic circumstances. Technology provides a useful framework on which to build a strategy for development. Technology comes early in any irrigation development and is always at the heart of any irrigation scheme, large and small, and without it there is no irrigation scheme. Technology can significantly reduce the drudgery of lifting and applying water and can help solve water management problems faced by small-scale farmers making it easier and simpler to apply the right amount of water to their crops at the right place at the right time. The technology must be right for the situation if irrigation is to have a chance of success. Putting in the wrong technology can mean that the seeds of failure are already well established before a scheme has even had a chance to grow.

A wide range of well-established and well-documented traditional technology options is available for use by smallholders including water harvesting, swamp irrigation, spate irrigation, flood plain irrigation using seasonal water and shallow aquifers, hill irrigation and groundwater irrigation. There is still, however, considerable room for improvement and adaptation of these traditional
irrigation technologies so as to fit different circumstances.

In recent years there has been a growing interest in modern technologies. These usually cost much more than traditional methods and rely very much on external specialist support from suppliers and distributors. Small motor-driven pumps, for example, can greatly reduce the drudgery of lifting water. Distribution technologies such as trickle, sprinkle irrigation and piped supplies for the more traditional surface methods, can help farmers manage water better as well as reduce wastage, which in turn reduces the amount of water that needs lifting. Modern technologies have gained favour with farmers in the developed world allowing them to apply water more accurately and adequately and to increase yields and crop quality. Engineers and planners often favour the use of these technologies because water savings by some farmers means that more is available for others. As one irrigation specialist stated; “Trickle irrigation can improve crop yields, which is what farmers are interested in, and significantly reduce water wastage, which is what engineers are interested in”. A win-win situation for people and the environment.

Low-cost technologies are being examined and evaluated. Most of the traditional technologies are low-cost. However, the term ‘low-cost’ is usually reserved for modern technologies that have been developed or modified to bring down the cost. An excellent example is the treadle pump, which was developed specially as a low-cost pump for smallholders. It has been particularly successful in Asia in replacing the manual lifting and carrying of water. Its uptake in sub-Saharan Africa in recent years is very encouraging.

Are these modern technologies as good as people say, or are they just another quick fix promoted by those who have a vested interest in selling the equipment? How successful have they been in the developing world as opposed to the more sophisticated social and economic environments of the developed world? Are the traditional technologies being ignored simply because it is psychologically easier to invest in sprinkler and trickle irrigation that are regarded as ‘efficient and modern’ whereas traditional methods are regarded as ‘old and inefficient’?

THE NATURE OF SMALLHOLDER IRRIGATION

The term smallholder requires some clarification as it means different things to different people. For some, the large irrigation schemes in Egypt and the Sudan are smallholder schemes. These schemes are large in terms of area but they are made up of many small farms (often less than 2 ha). They are designed and constructed by government agencies that then take over the responsibility for managing the water supply system. They are often described as formal or large-scale irrigation schemes and have borne the brunt of much of the criticism of irrigation development in sub-Saharan Africa in the 1970s. Government management characterizes formal irrigation rather than size. For example, a 50 ha irrigation scheme with 500 smallholders each with 0.1 ha where the water supply is managed by a government agency might be thought of as a smallholder scheme. However, it would have all the characteristics of a ‘formal’ or ‘large’ irrigation scheme because of the way in which water and other key agricultural services are organized independently of the farmers.

For others, smallholder is synonymous with ‘small-scale’ or ‘informal’ irrigation – small farms (often considerably less than 2 ha), privately owned and under the complete control of the farmer with little or no input from external government resources. Such private farms have developed where farmers use their own initiative and respond either to their family’s food needs or to the market place. Farmers usually have direct access to surface water or groundwater and make their own decisions about how and when they will irrigate and how much water to apply. They practise a mix of commercial and subsistence farming where the family provides the majority of the labour and the farm provides the principal source of income. This sector includes small commercial enterprises growing high value crops such as cut flowers and produce for export.

Smallholders usually work on their own, but, because of the investment needed to gain access to water they sometimes need to work in groups. An example would be a scheme requiring a reservoir or a large pumping station on a river that one farmer alone could not afford. A 50 ha irrigation scheme having 500 smallholders each with 0.1 ha managed by the farmers themselves without government support could equally be called a smallholder scheme. It would have quite different characteristics to the similar sized scheme described above. The farmers themselves might manage such a scheme or commission a professional irrigation manager to do the job for them. The essential difference is that managers are responsible to the farmers for their performance and should they fail to perform
properly the farmers have the ultimate power to dismiss the manager and to hire an alternative. This is not usually the case when the government runs the scheme.

The term smallholder is used in preference to small-scale as the latter is often confused with size as well as management style. Smallholder is also a term now widely used by international agencies and includes individual farms as well as groups where the farmers themselves or their representatives have taken on the responsibility for managing the distribution of water among the members of their group.

The term irrigation needs clarification. Irrigation includes any practice that stores, directs or exploits water such as water harvesting, use of low-lying wetlands and groundwater as well as the more traditional techniques of diverting or lifting water for distribution using surface, sprinkle or trickle irrigation methods.
Some technologies are referred to as ‘traditional’ because farmers have used them for many years, in some cases for centuries. Underhill (1984) first suggested a classification of traditional technologies, which is used here with some modifications, Table 1. Brown et al. (1995) attempted to show how these technologies were linked to farmer control, i.e. the level of control that a farmer would have over the design and investment decisions and over water management, Figure 1.

### Table 1. A physical classification of traditional smallholder irrigation

<table>
<thead>
<tr>
<th>Classification</th>
<th>Description</th>
<th>Some examples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water harvesting involves making better use of natural run-off. Many approaches. Collecting run-off from a catchment and concentrating water in a smaller cultivated area. Large schemes – several hectares of catchment, small schemes may involve individual plants. Success depends on having right ratio of catchment to cropped area. New developments applying chemicals, plastics to catchment to increase run-off.</td>
<td></td>
</tr>
<tr>
<td>Swamp irrigation</td>
<td>Fresh water swamps protected from saline seawater by bunds/dykes. Used for growing rice. Also tidal swamps planted after rains leach soil. Inland valley swamps – small valleys (1–100 ha) where season/perennial streams can be used/controlled for paddy rice cultivation. Boilands and dambos – depressions in swamp grasslands. Lake swamps – large areas of flat plain flooded as lake level rises.</td>
<td>Gambia River, Gambia. Sierra Leone, Burundi Rokel River, Sierra Leone, Guinea, Mali, Burkina Faso, Côte d’Ivoire, Ghana, Malawi and Zambia. Lake Victoria, Tanzania</td>
</tr>
<tr>
<td>Spate irrigation</td>
<td>Water spreading – spreading floodwater in rivers and wadis across cultivated land in a controlled manner.</td>
<td>Lower Omo Valley, Ethiopia, food and fodder crops.</td>
</tr>
<tr>
<td></td>
<td>Dry season Recessional irrigation. Impounding receding floodwaters with earth bunds. Residual moisture. Similar to recessional, water is stored in soil rather than on the surface. Pumped irrigation. Large areas of flood plain where surface water storage and shallow ground water can be exploited using lifting devices, often for vegetables. Shadufs – traditional technique of lifting small quantities of water using the ‘lever principle’. Usually low lift 1–2 m.</td>
<td>Rice cultivation along most large rivers in West Africa. Dry season cultivation of dambos or vleis in Malawi, Zambia, and Zimbabwe. Increasingly common in Nigeria also along most large river flood plains. River Omo, Ethiopia Most large river flood plains in West Africa, Niger, Bani Senegal, common along Nile, Tana River, Kenya. Traditional cultivation by the Chagga tribe on the slopes of Mount Kilimanjaro, Tanzania, Malawi, Ethiopia Exploited for small gardens, e.g. Burkina Faso, Niger, Togo, Benin, Zimbabwe, Botswana.</td>
</tr>
</tbody>
</table>
WATER HARVESTING

Water harvesting is a method that has been around for centuries but is not widely exploited in sub-Saharan Africa. It is ideally suited to arid and semi-arid areas where rain-fed crops cannot be grown with any certainty because the rainfall is both unreliable and highly variable (FAO 1994). The rainy season is often short with no assurance of when it will start and finish and there may be frequent long dry spells. Rainfall is collected from surrounding areas and channelled as run-off onto farms to add to the rain that falls directly onto the crops. Interestingly, no one doubts the critical importance of rainfall, although few policy-makers recognize the importance of run-off, which is the inevitable product of excessive rain. It is a curious paradox that farmers recognize and exploit the natural concentration of rainwater in valley bottoms and local depressions, yet the overriding perception driving policy is that run-off is a hazard. This view is fuelled by the prominence given to the concerns about soil erosion, which is one product of run-off and has been the focus of research and extension efforts to curb it since the 1930s. Water harvesting recognizes the potential value of run-off as a resource and aims to control the process in order to mitigate the hazard.

Run-off is collected from a large catchment area and channelled to increase the water available in a smaller growing area. There are micro-catchment systems, which are modest in size, where water is collected from land adjacent to the farm and channelled directly onto the fields. On an even smaller scale micro-catchments can be constructed around individual plants (often trees). There are macro-catchment systems that have large water collecting areas. These are often a considerable distance from the farming areas and can serve many farms. Substantial quantities of water can be collected from barren and fallow land and channelled into the cropped fields.

In sub-Saharan Africa, although there are examples of water harvesting, it occupies a neglected middle ground between soil and water conservation and irrigated agriculture. Both these extremes have received far greater attention.
Swamp irrigation

Swamps have been traditionally used for irrigation throughout the region. In mangroves and coastal swamps earth banks or bunds are built to exclude seawater and allow fresh water from inland to enter the cropped area, which is then planted with rice. The main areas for mangrove and coastal swamp irrigation stretch from The Gambia round to Liberia.

Inland valley swamps are naturally occurring swampy valley bottoms (up to 100 ha) used to grow rice. Small weirs and channels are constructed to divert natural drainage water around a swamp. The area is then divided into paddy fields, sluices are used to control the flow of water into the fields and a central drain allows excess water to escape back into the natural drainage (FAO 1984). This is very common in the humid parts of West Africa such as Sierra Leone and Liberia and in Burundi.

In the wet season many of the African lakes flood large areas of flat plains and these are used for rice cultivation. Examples of this type of irrigation exist in Tanzania beside Lake Victoria and Lake Malawi, in Malawi by Lake Chilwa and in the countries bordering Lake Chad. Also important are the traditional irrigation practices found in boîllands and dambos. These are low, saucer-shaped depressions in swamp grasslands such as those associated with the Rokel River in Sierra Leone. There are similar areas in Burkina Faso, Ghana, Guinea, Côte d’Ivoire, Mali, Malawi and Zambia.

Spate irrigation

This is a method of spreading water usually from flash floods in wadis (FAO 1987), which is a common practice in some arid countries such as Saudi Arabia and Yemen. It is not commonly practised in sub-Saharan Africa, although there are instances of its use in the Lower Omo Valley in Ethiopia for both food and fodder crops. The technology requirements need not be great though considerable skill is required to successfully divert and spread the water.

Flood plain irrigation

Flood plains are principally used for growing rice during the wet season. There are a variety of techniques involving different amounts of water control that overlap to a greater or lesser degree.

Some of the more distinct types of wet season irrigation include:

- Deep-water rice grown on the flood plains of the Niger and Bani rivers in Mali. Holdings are 1.5 ha with earth dykes constructed to prevent the fields being flooded while the rice plants are still immature. Problems arise if the floods arrive too late or too early or if they rise too fast and submerge the rice. Because of the high risk of failure, this technique tends to be secondary to rainfed subsistence crops cultivated above flood plain level.
• Flood irrigation involving the control of floodwaters to 50 mm/day for deep-water rice and 30 mm/day for paddy rice. Various levels of technology are possible from simple earth banks to dykes, canals and sluice gates.

In the dry season, shallow groundwater or open water left after the floods is used through a variety of gravity and water lifting techniques for:

• **Recessional irrigation.** Areas recently inundated by floods are used by impounding the receding water with small earth bunds. This type of irrigation is found in all the major flood plains in West Africa for rice irrigation and close to lakes (e.g. Lake Chad) for growing maize and sorghum.

• **Residual moisture.** This is similar to recessional irrigation but uses the water stored in the soil rather than water retained on the surface. It is a very common form of agriculture on all major flood plains. In East Africa it is found on many small dambos or vleis (seasonally wet areas in small catchments).

• **Pumped irrigation.** Pumping from rivers, streams and lakes is a simple activity and can usually be managed on an individual basis. The additional cost of pumping usually means that farmers are growing high value crops for sale in markets rather than low value subsistence crops.

The shallow depth aquifers that are scattered over more than 100 000 ha of **Niger** as well as northern **Nigeria,** **Mali,** and other Sahelian countries, also provide possibilities for successful smallholder schemes. The aquifers must be rechargeable (as they are in **Niger** and **Nigeria**). An obvious limitation to the expansion of irrigation on this basis is the limited area where such aquifers exist, and the possibility of overtaxing the recharging capacity of these areas. A wide variety of water lifting methods are used covering a range of traditional types such as archimedian screws and the shaduf to the modern petrol and diesel driven pumps. There has been a growing interest in treadle pumps throughout sub-Saharan Africa since their introduction from **Bangladesh** and **India** (Kay and Brabben 2000). Generally motorized pumps are most common in the richer countries that have ready access to spare parts and fuel, e.g. **Nigeria.** In water-scarce areas there is also a growing interest in the use of modern distribution equipment such as trickle and sprinkle irrigation for cash cropping.

### Individual Pump Schemes in Nigeria

Farmers in northern Nigeria lost their traditional use of the fadamas along the rivers following the construction of dams to control the river floods for urban water supply and irrigation. As an alternative they turned to small-scale irrigation using shallow groundwater recharged by the river and lifting it by shaduf or calabash in the dry season to grow vegetables for local and city markets. In the early 1970s a few farmers, with help from relatives, bought small pumps from private traders. In 1982-83 an agricultural development programme based in Kano sold over 2 000 pumps for cash to individuals or small farmer groups. Engineers introduced low-cost well technologies from India, which reduced well construction by two thirds with a commensurate increased return on tubewell investment.

This has been one of the most successful irrigation developments in Nigeria with many thousands of pumps being used by private farmers. Maintenance is well established and so farmers have confidence in the technology. However, external monitoring was necessary to avoid depletion of the aquifer.

Interestingly in the 1980s some farmers started to grow wheat on the fadamas in response to the high wheat prices in the country. A useful example of the way in which private farmers can and will respond to the market if the price is right.

### Hill irrigation

There are many small, irrigated areas that are situated some distance from their water source and supplied by mainly open channels and low-pressure pipe systems. The water source may be a stream or a small dam supplying water by gravity or use of some type of simple lifting equipment. An individual farmer or a group of farmers working together to share the water resource can practise this type of irrigation. Such systems are common in the hilly areas of central **Ethiopia,** **Tanzania** and **Malawi.**

### Groundwater irrigation from medium to deep aquifers

Medium to deep aquifers (>30 m) can be exploited all year and usually require more sophisticated pumping than is commonly found in traditionally irrigated areas. Usually submersible pumps driven by electric motors or diesel engines are needed. There are numerous examples of this type of water lifting and the agriculture based upon it throughout
Africa and other parts of the world, notably Bangladesh, Pakistan and India. This type of irrigation is only feasible for cash cropping because of the high cost of well construction and pumping or when it is subsidized in some way.

COMMUNAL SCHEME EXPERIENCES

All the methods described above can be practised by individual farmers on their own or by several farmers working together and sharing a common water supply. Once farmers group together the management of the supply system needs to be re-examined. If the scheme is small enough, the farmers may choose to operate it themselves. As the size increases a manager may need to be hired full time to undertake management of the irrigation scheme. Either way there is a significant shift in the management of the irrigation from individuals who can irrigate as and when they please to a group who must work to an agreed schedule of sharing in terms of quantity and timing.

This communal approach is most favoured by aid agencies and national governments because it is seen as a way to help many farmers at the same time. Agencies often step in, with the best of intentions, to satisfy a need or to act as a catalyst for development. In so doing the aid agency or government brings its own set of rules, which may not be compatible with what is required on the ground. Agencies need to disperse funds in line with their targets and are often constrained by time. The temptation to speed the process of development is always present and, as a result, so is the risk of killing the very thing that the agency is trying to foster by pouring in too much support too quickly. If the community cannot absorb the funds fast enough and do not have the institutional framework, farmers may quickly lose any sense of ownership of the project as they rely on a culture of handouts and support from outside. In such situations the project has a high risk of failure. The challenge is to provide the correct amount of support over the right time period to foster successful development. Underhill (private communication) once said that if you ‘interfere’ in a privately initiated irrigation development by injecting more than ten percent of the total cost then you are in danger of killing it. This is not an accurate figure but it does give some order of magnitude of what can be done.

There are many examples of communal schemes in sub-Saharan Africa ranging from the very large (e.g. schemes in Nigeria, Kenya) to the more modest (e.g. Senegal, Zimbabwe, Tanzania). Most have run into serious problems, although there are some successes. They tend to be top-down in approach and the technologies used are not always conducive to simple water management practices and often add to the problems of sharing available water resources rather than helping to solve them.

For example, open channels are the most common system of supply and these are usually fitted with upstream control structures. This is one of the most complicated systems of water management available and so it is little wonder that farmers and scheme managers find it difficult to distribute water properly. There is no easy way of knowing if too little or too much water has been put into the canals without some sophisticated water indenting procedures and flow measuring devices. The hydraulic structures can favour those at the top end of the canals and there is usually a constant need to adjust the control gates. In contrast, pipe supply systems are much less common but are much simpler to operate and respond rapidly to changes in water demand. They can be less wasteful of water because it is easier to turn off a pipe supply when it is not needed. It is not possible to turn off a canal without draining it down.

When looking to the future it is vitally important to review past experience of similar developments to see what lessons can be learned about what and what not to do. Several comprehensive reviews of the Sahel region have been made in recent years (e.g. Moris 1984 and 1987, Brown and Nooter 1992). The two types of development are recognized in the reviews: those in which farmers have funded irrigation themselves using their own resources and those that have received external support from an agency, either in the form of direct aid or through a special loan arrangement. The former are usually based on the farmers’ perceptions of family needs and those of the local markets. Investment is likely to be made with great care to minimize the risk of failure. The latter have a much higher risk of failure for a range of reasons, and the fact that they are for smallholders (as opposed to large-scale irrigation) is no guarantee of success.

Review of the Sahel experience

Both Moris and Brown and Nooter’s studies concentrated on the Sahel region. The authors found that there were some strikingly successful privately
COMMUNAL IRRIGATION IN SENEGAL

Although communal schemes present a higher risk than individual schemes there are examples where they work well. In Senegal small village schemes of 20 ha or less have been constructed along the Senegal River. These usually comprise 40–80 plots of equal size supplied by an open channel system fed by 15 kW (20hp) engine pumps from the river.

It was important for farmers to find a way to stabilize rice production in areas where they no longer had easy access to the flood recession fields along the riverside. In most cases farmers all lived in the same village and worked together on the common objective of solving the rice problem with irrigation. The farmers, who invested labour in clearing bush and digging canals, constructed the schemes in part. They usually requested assistance from the local government irrigation agency and this usually resulted in the provision of a pump-set, pipes, site survey and equipment for construction using funds from aid donors. There was resistance to this farmer-initiated idea at first because of government plans for large-scale schemes in the area. A presidential decree recognized the benefits of technical assistance for irrigation and the importance of meeting farmer demands rather than imposing a solution. Over the past 15 years at least 700 schemes have been built.

Production has remained predominantly subsistence oriented even though attempts were made to extend irrigation to cash crops. Increasing farmer holdings did not encourage farmers to grow cash crops and they continued to grow rice in the rainy season and maize for cattle food in the dry season.

All infrastructure on the schemes is co-owned by farmers. Rotation of water supplies is a recognized way of sharing out the available supply. Repair and maintenance is handled in the same way as construction. The elements that make these schemes work well include:

- Construction through investment of labour by farmers, albeit using donor-funded equipment.
- Selection of sites not usually used for agriculture.
- Pursuit of an economic objective – in this case rehabilitating a farming system under duress.
- Full autonomy for each village scheme – hydraulically, operationally and managerially.

(Diemer and Huibers 1996)

Operated smallholder schemes in Mali, Mauritania, Niger and northern Nigeria as well as in Burkina Faso, Chad and Senegal. In some cases, these developments were entirely spontaneous, and in others, they were supported by NGOs or with minimal government assistance. Some farmers took advantage of earlier investment and used the infrastructure from earlier, failed large-scale projects. In some cases, expansion was facilitated by the use of new low-cost construction techniques that reduced the cost of installing tubewells and hence the costs of irrigation.

The reasons for success varied from country to country and depended on a range of technical and socio-economic circumstances. For example, in Niger private sector development had expanded well and responded to market forces. In Nigeria there was a similar story but it had been helped along by subsidised prices for equipment and farm inputs. Improved rural roads enabled farmers to market their surplus production and gain access to traders and decentralized food-processing plants. Mali demonstrated the extremes of success and failure. Where there is success in the private smallholder sector and failure in public sector large-scale irrigation. The Office du Niger, a parastatal corporation, concentrated to such an extent on ‘public services’ that it eventually had two staff members for every three farmers and for every 11 ha of irrigation. Only 20 percent of farmers’ fees went for actual inputs. Chad, although suffering from civil strife for more than a decade, has seen success built on simple low-cost techniques funded by non-governmental organizations.

Senegal exemplified the changing focus of irrigation. This shifted from large, publicly managed irrigation systems with the farmer as labourer, to unsuccessful attempts to make parastatal irrigation agencies more efficient, to government assisted smallholder irrigation, to experimenting with non-public sector irrigation. The early phases of this experience suffered from the inappropriate construction of irrigation perimeters and from selecting crops that were not economically viable. Project design, operations and reform attempts by both the Government and donors were carried out from the top-down, ensuring a low level of farmer enthusiasm. An attempt by the Government to stimulate smallholder irrigation failed when the plot size determined by the Government was too small to encourage farmer participation.

Successful projects in Burkina Faso have been the result of a relatively encouraging macro-economic framework. Farmers have often been able to use the irrigation infrastructure from “failed” projects and the migration of men looking for work made irrigation a profitable and necessary channel of agricultural development for women.
Cameroon has been an exception. Large-scale irrigation has been successful but mainly because of strong expatriate management using farmers as labourers rather than decision-maker. Farmers have accepted this situation because of the high financial returns and because of the lack of other opportunities.

From their comprehensive review, Brown and Nooter (1992) suggested several characteristics that are common to successful schemes:

- Technology is usually simple and low-cost (most frequently small pumps drawing water from shallow aquifers or rivers and streams).
- The institutional arrangements are private and individual.
- The supporting infrastructure permits access to inputs and to markets for the sale of surplus production.
- There is a high financial (cash) return to farmers at the times when they most need cash.
- Farmers are active and committed participants in project design and implementation.

The authors found the perception of ‘success’ was different for irrigation technicians, donors, governments and farmers. Their view was that success could only be assessed in terms of the farmers’ definition.

The most effective arrangements for schemes that were larger than individual ownership were found to be (in decreasing order of success): extended family groups; private voluntary groups; water users’ associations and then cooperatives. They concluded that project design should be based on the following concepts:

- Encourage smallholder, private and individual investment in irrigation and implement projects with many small components, where NGOs frequently are effective implementing intermediaries.
- Employ methods that ensure early and full farmer participation in project design and operations, devoting as much staffing and funding to studying the farmers’ economic and social situation.
- Identify and disseminate low-cost small pump technology and tubewell construction techniques and include provision of soil and water surveys beyond the purview of individual farmers but essential for sustainable irrigation.
- Ensure a macro-economic framework that will reward the farmers’ and merchants’ desires for low costs and high returns based on real costs. Both financial and economic rates of return must be satisfactory on a sustained basis and avoid unsustainable subsidies, since their removal could lead to a project’s collapse.
- Ensure the availability of foreign exchange needed to secure supplies of spare parts, inputs and adequate repair facilities and ensure that there is the essential infrastructure needed for access to imports and markets.
- Make provision for training in maintenance and irrigation techniques for farmers, preferably through private sector suppliers; and ensure that environmental considerations are provided for, such as the effect of irrigation on health, drainage and erosion control, which may not be evident to the farmer.

ROLE OF TRADITIONAL TECHNOLOGIES IN SUB-SAHARAN AFRICA

A wide range of established and well-documented traditional technologies is available for use by smallholders. These clearly play a significant role in the region and will continue to do so. There is still considerable room to adapt traditional technologies to different circumstances, which because of their low cost and simplicity can be used and maintained by smallholders with little or no external support. They are particularly suited to subsistence farming and equally have an important role to play in the transition to cash cropping. For this reason they have attracted much interest from aid donors and governments wishing to support subsistence farming. Many lessons learned about what needs to be done have been concerned more with the ways in which such technologies can be introduced into farming systems rather than the technologies per se. However, there are still concerns about the technology and the ability of people to design and construct good engineering works that will provide lasting service. There is also a danger that ‘low-cost’ solutions, which may be attractive to aid donors, may become a euphemism for poor engineering.
Modern technologies

The term ‘modern technology’ in relation to irrigation usually refers to on-farm irrigation systems such as sprinkler and trickle irrigation. It can also mean the introduction of piped distribution systems for surface irrigation as well as the use of treadle pumps (a recent innovation in Africa) or the use of petrol and diesel driven pumps in areas where such technology is not normally used. Some professionals and policy-makers perceive modern technologies as an intervention that can improve crop yields and quality and, at the same time, reduce water wastage (a better term to use than irrigation efficiency which can be misleading).

Most modern technology developments have been driven by the needs of the developed world to reduce labour inputs, keep energy costs as low as possible and reduce water wastage, while maintaining operational reliability. In the irrigation sector it is the large commercial agricultural enterprises that have driven such developments and the results have been impressive. Production costs have fallen and crop yields and quality have improved.

Can similar benefits be realized by smallholders in developing countries? Cornish (1998) summarizes the issues. He quotes Hillel (1989) who expressed concerns about the way in which manufacturers, and farmers as customers for their products, in the developed world are fascinated by sophisticated technology and eager to have more specialized and intricate hardware to use. He states that; “In the non-industrial countries, the important attributes are, low-cost, simplicity of design and operation, reliability, longevity, few manufactured parts that must be imported, easy maintenance and low energy requirements”. Hillel also suggests that generally the ‘labour economy is less important.’ Plusquellec et al. (1988) also argued that one of the driving forces for sprinkle and trickle irrigation development has been the interest and investment on the part of private sector manufacturers of irrigation equipment. For the majority of smallholders in developing countries growing staple crops with existing surface irrigation schemes and low labour costs, returns can seldom justify the capital expenditure associated with equipment.

Keller (1990) says that modern technology can result in less water wastage because water is conveyed in pipes and irrigators can control the amount of water applied and its timing more easily which can increase productivity per unit of water. He suggests that traditional methods have limited productivity and are dependent on farmers’ willingness to invest in land preparation and in coaxing water to spread evenly over the land. Buying modern irrigation equipment is trading money for labour and skill. Keller also stresses that the opportunity cost of money for smallholders is very high whilst that of labour and traditional skills is low. Farmers will make the investment in modern equipment only when the financial return is clear and relatively assured. For many poor farmers, the idea of a cash investment is inconceivable without credit and institutional support that ensures success. Very few farmers in Europe and the USA survive without subsidies and financial support from governments yet poor farmers in Africa are expected to stand on their own feet with little or no support.

Modern technologies are unlikely to be taken up by poor subsistence farmers because they are mostly concerned with food security and minimizing risk. These technologies are more likely to be adopted by farmers that have been able to diversify farming income beyond basic food crops and who are able to consider marketing produce outside the home. The issue here is how to help farmers move into the income-generating category through the development of a range of coping strategies.

How successful have these technologies been in the developing world as opposed to the more sophisticated social and economic environments of the developed world? Are the traditional technologies being ignored because it is psychologically easier to invest in sprinkler and trickle irrigation, which are perceived as ‘efficient and modern’, whereas surface irrigation is regarded as ‘old and inefficient’? Most important, are the new technologies, which are supposed to improve irrigation and reduce risk, only introducing new problems that might expose farmers to a higher level of risk than before?
Some useful sources of information include Cornish (1998) who provided a thorough review of modern technologies for smallholders in developing countries. He points out that many modern technologies are not suited to smallholder irrigation. Cornish lists available technologies and identifies features making them suitable for use by smallholders. Kay (1983) provides practical details of a wide range of sprinkle irrigation equipment and Keller and Bleisner (1990) describe both sprinkle and trickle irrigation systems in detail as well as providing design examples. Kay and Brabben (2000) have recently published a review of the potential for the use of treadle pumps in Africa. Bentum and Smout (1994) produced a report, which reviews the use of buried pipelines for surface irrigation and their potential to improve water management and reduce water wastage.

**Sprinkle irrigation**

Sprinkle irrigation is used on approximately five percent of irrigated land throughout the world, the majority of which is in developed countries. It is unlikely to replace the large areas under surface irrigation, (essentially the remaining 95 percent, except for a small amount of trickle). Sprinkle irrigation has a distinct advantage, because good water management practices are built into the technology. Sprinkle irrigation technology can provide the flexibility and simplicity required for successful operation, independent of the variable soil and topographic conditions. Pumps, pipes and on-farm equipment can all be carefully selected to produce uniform irrigation at a controlled water application rate and, provided simple operating procedures are followed, the irrigation management skills required of the operator are minimal. This puts the responsibility for successful irrigation in the hands of the designer rather than leaving it entirely to the farmer. Sprinkle can be much simpler to operate and requires fewer water management skills. However, it requires sophisticated design skills and on-farm support in terms of maintenance and the supply of spare parts.

Sprinkle is potentially less wasteful of water and uses less labour than surface irrigation. It can be adapted more easily to sandy soils subject to erosion on undulating ground, which may be costly to re-grade for surface methods. There are many types of sprinkle systems available to suit a wide variety of operating conditions. The most common for smallholders is a system using portable pipes (aluminium or plastic) supplying small rotary impact sprinklers. Because of the portability of sprinkle systems they are ideal for supplementary as well as total irrigation.

At the forefront of sprinkle developments is the centre pivot machine, which can irrigate up to 100 ha at a time. These machines are very adaptable. In the United Kingdom they have been used on small and irregular shaped fields crossing field boundaries to irrigate several fields growing different crops at the same time. One machine was used to irrigate several farms where the farmers decided to cooperate. Here the farmers’ role in irrigating large areas having multiple ownership and minimal inputs should not be underestimated. Libya is a well-known example of their use for irrigating large desert areas. As far as the farmers under the pivots were concerned it rained once a week as the pivot rotated. From a management point of view sprinkle irrigation provided a relatively simple system to operate and allowed farmers to do the farming. Although the skills needed to operate these machines and to maintain them must not be underestimated, they are no more than those required to keep motorcars running. In most developing countries technicians do this very successfully in the private sectors. This is not so much to advocate the widespread use of centre pivot machines for smallholders but to point out that technology can be very adaptable and can be used in innovative ways when the conditions are right.

Table 2 provides a summary of the different sprinkle systems available.

**Sprinkle for smallholders?**

Sprinkle irrigation was mainly developed for larger farms. The system is not very flexible and adaptable to the multitude of small plots usually found on small farms. In some cases there are ways around the problem, such as using the same equipment in imaginative ways as can be seen in the following section, which is based on experience gained in Zimbabwe. New ideas are being developed for equipment specifically suited for use by the small farmer both in terms of technology and cost.

Cornish (1998) lists several countries where sprinkle irrigation has been used to support smallholder development in countries outside of sub-Saharan Africa such as Jordan, Israel, Cyprus and others. The problem is that most reports do not usually answer such important questions as who pays for the equipment, who owns and runs the
schemes and just how successful they have been in meeting users aspirations?

Zimbabwe experience

Zimbabwe is special when it comes to irrigation equipment because it has a history of large commercial farming (200 ha and more) on which a sprinkle and trickle irrigation manufacturing, distributing and support network has grown. Zimbabwe also has a large smallholder farming community and attempts have been made to adapt these same systems to their needs. Satisfying one large farm having a single crop is rather different from satisfying 200 farmers on the same land area growing many different crops at different times. The technical problems of adaptation can be considerable. Diemer (2000) looked at a sprinkle scheme where the layout normally used for large commercial farms was transferred without change to the smallholder situation. It created endless management problems that were eventually solved by re-arranging the same equipment in a different layout. By using flexible hoses to supply water to sprinklers rather than the rigid aluminium pipe layout, this system was found to be much more adaptable to the needs of smallholders.

The government irrigation design and construction service, Agritex, has been at the forefront of developing new schemes for smallholders. A recent, comprehensive study (FAO 2000) of ten smallholder schemes (six sprinkler and four surface) has highlighted some of the successes and failures. The schemes are all typical smallholder developments that were initiated and financed by a government agency to stimulate development. All have several farmers sharing the same water source and distribution system. All have been handed over to the farmers for them to operate and maintain. Two examples, a success and a failure, are highlighted in the box Chitora, Zimbabwe – a success; Ngezi Mamina, Zimbabwe – a failure.

Except in one or two cases where there was reference to poor design of layouts and equipment, the technology used was not a major determinant in the success or failure of the schemes, although it may have played a role. Sprinklers can simplify irrigation management and although it was not discussed, the long history of sprinkle irrigation in the country is likely to have created confidence among farmers that the technology would work well and if not then it would not be difficult to get it fixed.

What is clear from the study are the complex social, economic, technical and institutional issues surrounding smallholder irrigation schemes making each one unique and demonstrating the importance of getting the mixture right. It also emphasizes the point made by others that small-scale does not mean simple.

The FAO study has some general conclusions:

- It is essential for farmers to truly participate throughout the project planning, implementation and evaluation phases and be treated as “owners” and not just beneficiaries of projects.
- Consultants engaged to implement such schemes should have experience in participatory rural appraisal and smallholder irrigation development.
- Only projects that are technically sound should be handed over to farmers.

---

Table 2. Summary of sprinkle irrigation systems

<table>
<thead>
<tr>
<th>System</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional systems</td>
<td>Portable Hand-move</td>
</tr>
<tr>
<td></td>
<td>Roll move</td>
</tr>
<tr>
<td></td>
<td>Tow line</td>
</tr>
<tr>
<td>Semi permanent</td>
<td>Sprinkler hop</td>
</tr>
<tr>
<td></td>
<td>Pipe grid</td>
</tr>
<tr>
<td></td>
<td>Hose pull</td>
</tr>
<tr>
<td>Mobile gun systems</td>
<td>Hose pull</td>
</tr>
<tr>
<td></td>
<td>Hose drag</td>
</tr>
<tr>
<td>Mobile lateral systems</td>
<td>Centre pivot</td>
</tr>
<tr>
<td></td>
<td>Linear move</td>
</tr>
<tr>
<td>Spray lines</td>
<td>Stationary Oscillating Rotating</td>
</tr>
</tbody>
</table>
It is important to help farmers with inputs for the first season so that they can build a cash base to ease cash flow.

Farmer managed irrigation schemes can reduce the financial burden on the government in terms of operation and maintenance.

Government needs to produce a clear and systematic strategy for handing over government managed schemes to farmers.

The issue of inheritance as it affects land tenure should be decided in the planning and management of smallholder irrigation schemes.

One interesting fact, which is not raised by other investigators, is the age profile of the farmers on the Chitora irrigation scheme. It is well recognized throughout the world that younger people tend to be more receptive to new ideas, particularly to new technology, and may also be in a position to take greater risks than their elders who have more family responsibilities. Targeting young farmers may be one strategy that is worthy of further attention.

**South Africa experience**

An interesting development has been underway since 1981 using large mobile irrigation machines as part of the Taung project in South Africa. Centre pivots and linear move machines were installed with the aim of providing income and livelihoods for smallholders on farms varying in size up to 10 ha.
Irrigations to individual plants. This technology can and emitters that can deliver small frequent Trickle or drip irrigation comprises a system of pipes. This is the way in which it can be adapted to small and varied plots of land. This technology can provide farmers with a method of precise control over the timing and amount of irrigation and so they can easily meet the crop water demand without wasting water. Wastage can only occur if the system is left running for too long or there are leaks in the pipes.

Trickle irrigation is not yet widely used on a world scale, and covers less than 0.1 percent of irrigated land. Even in Israel, where much of the early research and development was done and water is very scarce, trickle has not flourished as much as might be thought. Sprinkle irrigation still provides more than 70 percent of Israel’s irrigation because this is still considered to be a most efficient method of irrigation and one that is financially viable.

Claims made about crop yields and water saving need to be judged with care. Sales people often imply there is something magic about trickle irrigation when they refer to substantial increases in yield and savings in water use. There is no magic. Crops respond primarily to water and not so much to the method of application. They need the same amount of water to grow properly whether this is applied with trickle irrigation or with surface flooding methods. If the right amount of water is applied to the crop at the right time it will flourish. Similarly, water savings can only be made by reducing wastage and not by reducing the amount of water the crop needs. Ironically many farmers end up applying more water when using trickle irrigation because the system allows them to apply water more easily than with other methods.

A major technical problem with trickle irrigation is emitter and lateral blockage from sand and silt, chemical precipitation from groundwater and algae from surface water. Each of the problems takes the use of trickle into a level of technology and support that can be difficult to sustain in a developing country. On a small scale the farmer can simply go around and clean the system regularly, which can overcome these problems but on a larger scale this would not be practicable.

However, there are conditions that make this method of irrigation a very attractive option. It is ideally suited to areas where water is scarce or expensive, where water may be saline, where labour costs are high and where soils are poor. An important advantage is the ease with which nutrients can be applied with the irrigation water. This is much more difficult to do with other irrigation methods.

A distinct advantage of trickle for smallholders is the way in which it can be adapted to small and varied plots of land. This is how trickle is being used

**Experience from outside the region**

Mexico has a history of irrigated agriculture having over 6 million ha under irrigation (Manuel and Maldonado 1999). Sprinkle irrigation has long been used to support smallholder irrigation development on a large scale and in particular by FIRCO (Trust Fund for Shared Risk) which is part of the Secretariat of Agriculture, Livestock, and Rural Development of the Government of Mexico.

A recent development was undertaken in a hilly region of the country. During the three years of this programme it was reported that 1 000 sprinkler irrigation modules (each of 0.1 ha) were installed in 60 communities belonging to 35 different municipalities. The reason given for using sprinklers and trickle was water scarcity and the problems related to using more traditional methods of irrigation. The cost of materials was US$500/ha. Installation costs were borne by the farmers who contributed their labour and government engineers provided technical assistance. The main crops grown included corn and beans mainly for self-consumption as both staple crops are expensive for isolated communities who are distant from markets. Farmers were reported to be seeking to change their cropping pattern to satisfy both their home needs and to grow vegetables for the city markets.

Although there were no indications of the extent of farmer funding and involvement in the scheme, Mexico has a well-developed irrigation sector and it is likely that this scheme will build on this tradition. Whether it is ultimately successful remains to be seen.

cropping wheat, barley, corn, peanuts and cotton (Valmont personal communication). The project, which was originally installed to settle farmers in the former ‘homelands’, so far has 73 pivots installed each irrigating 40 ha. The operation and maintenance services are all contracted out to an independent contractor whose role is to keep the irrigation system running. Government supports the farmers through a full range of extension services. The installation costs were estimated to be around US$1 000/ha. Unfortunately there is very little information available about how successful and sustainable this kind of development can be. There are worrying signs that the approach may be too ‘top-down’.

**Trickle irrigation**

Trickle or drip irrigation comprises a system of pipes and emitters that can deliver small frequent irrigations to individual plants. This technology can
Modern technologies

**Farmers solve their own problems in Ghana**

A small-scale irrigation project was established on the outskirts of Khumasi for a group of women growing vegetables for the local markets. The scheme uses open irrigation channels supplying many plots, less than 0.1 ha each owned by a different person. The scheme was designed and built to supply water on a rotational basis and each woman was given an allotted time when she would receive water. The women objected to the scheme and said that the rotation was unworkable because they had lots of other household and family duties that took priority over irrigation. They solved the problem themselves by building small storage tanks on their farms. This allowed them to receive water when it was available and to irrigate their crops when it was convenient to them.

in India where farmers have gone from surface irrigation to trickle and have bypassed sprinkle because it is considered an inflexible system for use on small plots. Local manufacture of trickle parts has encouraged Indian farmers to take up the method where they are assured of spare parts.

A further advantage of trickle is the ease with which it can be operated. It is a pipe system and so can be switched on and off easily. The potential for making timely and adequate irrigations as well as for reducing water wastage is good. The challenge is to realize that potential.

**Trickle for smallholders?**

A critical issue for smallholders is the cost of trickle irrigation. It does tend to require a larger capital outlay than most other methods of irrigation. The cost may well be justified by improved crop production and hence financial returns for farmers. The high initial cost is a result of the set nature of the system, its reliance on precision-engineered components and need for water filtration, all of which can be expensive.

The cost of a trickle system is determined by crop type, row spacing and the total field area irrigated. System costs can range from US$1 000–3 000 per ha (Cornish 1998). In addition the systems require skilled management for effective operation and maintenance – filters require regular cleaning, systems may require periodic flushing to prevent build-up of slime. Equipment must be regularly inspected to identify and replace damaged components. The combination of high cost and demanding technical management means that conventional trickle technologies are normally considered to be inappropriate for resource poor, smallholder farmers.

**Trickle experience from outside the region**

Little has been reported on the use of trickle irrigation in sub-Saharan Africa. There is, however, a growing experience of its use in other developing countries. In India, trickle irrigation has been introduced for high value crops (vegetables, flowers, spices) in some of the more arid parts of the country where water is scarce. In 1993 it was reported (Singh et al) that over 50 000 ha were being irrigated by trickle irrigation, this has now risen to over 225 000 ha. This substantial increase in the use of trickle methods is not so much a result of market demand but the low-cost of the systems, which are heavily subsidized by the Indian Government. Over the past ten years more than 100 companies have been set up to produce trickle equipment. Claims of water savings as high as 30–60 percent and yield increases of 20–40 percent have been made. Success was, however, masked by heavy subsidies. Even with subsidies the systems were too expensive for most small farmers. Trickle systems were also thought to be too complicated to operate and maintain and not easily divisible to fit small plots (Polak and Sivanappan 1998).

**Improving traditional methods**

Most smallholders in sub-Saharan Africa use surface irrigation methods and distribute water using open channels. When several smallholders use the same water source and distribution system there are greater risks of failure. The result all too often is poor water distribution and unreliable and inadequate water supplies to the field.

Most smallholder irrigation schemes use open channels to supply water because they are considered cheap and simple to use. In reality, from a management point of view, this type of irrigation is the most complex and inflexible of supply systems. Open channels can only be used for fixed schedules, flows are often unreliable and inadequate and distribution between the various canals is often difficult to manage. Even the choice of gates (weirs and sluices) for discharge and water level control can exacerbate the problems leading to the classic “top-end versus tail-end” problems of water distribution along canals.
Canal management can be simplified through use of relatively simple technologies, such as fixed regulators (e.g. solid weirs), or by building small storage reservoirs along the canals or replacing canals with pipes.

**Storage reservoirs**

Constructing small storage reservoirs along a canal system or on farms means farmers can take water as and when they need it and suppliers can supply as and when it is convenient to them. The reservoirs work in very much the same way as domestic water storage. The simplest example of this is water storage in dams, where water is held back in times of flood for use in the drier seasons. Storing water underground is much the same idea. The ground conveniently holds the water so that it is available for pumping when the farmer chooses to irrigate.

Storage in the supply system itself has been widely exploited in the Sudan and in schemes in northern Nigeria. This is usually storage over a short period of 24 hours. Although it adds to the cost of a scheme the benefits in terms of reduced water wastage can be significant.

**Buried pipelines**

Burying pipelines to replace canals offers an opportunity to simplify water management and reduce wastage (Bentum and Smout 1994). They use examples in Bangladesh for much of their conclusions on the benefits of pipe systems. Similar benefits were reported in India (Campbell 1984) and in Sri Lanka (Merriam 1987). Merriam has always argued that buried pipe distribution systems for surface irrigation represent an intermediate solution between lower-cost earthen channels and the more expensive sprinkle and trickle systems.

Benefits include:
- Systems become demand rather than supply oriented when pipes are used. Pipe systems respond rapidly to changes in water demand.
- There is reduced wastage, greater flexibility and reliability of supply.
- Short water transit times enable water to be moved around a command area more rapidly than with channels.
- Less land is taken up with the irrigation system.

Pipe systems are generally thought to be expensive. This term is relative in terms of the savings made in land and water. The simplification of management practices means that the additional cost may well be justified. However, there is little evidence of these systems being used in sub-Saharan Africa.

**A role for modern technologies in sub-Saharan Africa?**

Modern technologies undoubtedly have the potential to raise the productivity of water and labour. Technically, they are best suited to conditions where water is scarce and the opportunity costs of labour are high. Modern technologies have yet to be seriously tested and evaluated in the region. There is also concern that their introduction into developing countries is driven more by commercial interests rather than need. This can lead to inappropriate use.

Experiences in Zimbabwe are of particular interest. Success in this country is clearly linked to the long history of sprinkle irrigation and support throughout the country by the private sector. The success of the small Chitora scheme, Zimbabwe, may be due in part to young people who are willing to accept new methods of working. This may be an important point to be borne in mind by developers when persuading farmers to change or take up modern systems.

What is clear is that modern systems are only accessible to farmers who can afford to buy them and who are growing cash crops such as vegetables, fruits and flowers providing sufficient returns to pay for the investment. Farmers will make the investment in modern equipment only when the financial return is clear and relatively assured. Modern systems have little to offer poor subsistence farmers and so are unlikely to be taken up by them.
A new philosophy

If the investment costs and the inherent risks of conventional trickle and sprinkle irrigation are too high for most smallholders, are there any low-cost alternatives? Most of the innovations in this direction have been in trickle and to some extent sprinkle irrigation. India, Nepal and China stand out as countries that have sought to promote the use of low-cost systems by smallholders. These countries have established national manufacturing capacity and placed emphasis on ‘simple’ systems that do not rely on automatic control or other labour-saving devices.

Low-cost systems attempt to retain the benefits of conventional systems whilst removing the factors preventing their uptake by poor smallholders: purchase cost, the requirement of a pressurized supply, the associated pumping costs and complexity of operation and maintenance.

Low-cost systems are not widely reported in the literature, although this could be a consequence of the nature of the organizations and agencies involved in their development and promotion, which are mainly development NGOs, rather than a reflection of their potential value for smallholders. Some equipment has been developed and tested by NGOs and church affiliated groups but such centres are often not well resourced to engage in wide-scale production and marketing of their products.

Irrigation kits

Several low-cost trickle technologies and some sprinkle systems have been developed, which are now in use in several countries. In most cases these are aimed at improving distribution and application of water. Attempts have been made to make them as simple as possible so that they can be manufactured at lower cost and operated and maintained easily. Systems are usually sold in kit form for relatively small areas of land (e.g. 25 m²). This too helps to keep the cost down and the idea is that farmers can add to the kits as they receive cash from the increased profits on their crops. This incremental development is not easily accomplished with normal commercial systems, particularly when pumps are needed to pressurize the systems. Low-cost can mean low initial capital outlay rather than low-cost per hectare. Some recent innovations are given in the following sections.

Bucket kits (developed by Chapin)

These are manufactured by Chapin Watermatics, USA. Each kit supplies water to two 15 m laterals laid on a 1 m raised bed, cropping just 15 m².

Chapin estimates that his company has donated 15 000 – 20 000 bucket kits to different programmes in Africa. These kits are given to the projects and sold to the users for US$7. When the cost is worked out for a hectare it comes to US$4 660/ha, which is not so low. However, it is the low incremental cost that enables farmers to begin using this system. Even US$7 per kit is a subsidized price and it is argued that this is not sustainable development. Equipment is imported and distributed at this price by mission stations and aid programmes. USAID has already funded the distribution of Chapin’s kits and KARI (Kenya Agricultural Research Authority) is evaluating the equipment. Chapin has also promoted larger one-quarter acre (0.1 ha) kits which International Development Enterprises replicates with its low-cost, locally manufactured kits.

Wagon wheels

The ‘wagon wheel’ systems are found in Western Cape, South Africa. They comprise a central water tank with laterals radiating as spokes to a length of about 5 m. Each wheel irrigates a circle of about 8 m².

Irrigation kits (developed by IDE)

International Development Enterprises (IDE) is an international NGO that first started to develop low-cost irrigation kits in India and Nepal in 1995. Field tests are now being conducted in Sri Lanka, Bangladesh, and Viet Nam.

Various kits have been produced to meet different circumstances:
• **Bucket kits.** These are for home gardens and were based on the Chapin Bucket System and cost approximately US$5. Each comprises a 20 litre household bucket installed on a pole at shoulder height. The bucket is fitted with a 10 m lateral line and is filled two to four times a day. The single lateral line has 26 micro-tubes attached and each waters four vegetable plants, irrigating 50 m², enough to provide vegetables for a family.

• **Drum kits** use a 200-litre drum made of steel or plastic and costs around US$25 and irrigates a 125 m² plot. Water is supplied through a simple filter and supplies five 10 m-laterals each fitted with 26 micro-tubes.

• **Micro sprinkler kits** are suitable for farmers with access to a pressurized water supply. Each comprises 15 micro sprinklers with laterals and can irrigate up to 250 m² at a cost of US$25. It is well suited to a small garden growing a range of vegetables.

• **Overhead sprinkler kits** comprise two sprinklers on tripods with pipes and rely on the availability of a pressurized water supply, e.g. a domestic 0.4 kW (0.5 hp) pump. The cost is US$30, with the pump it is estimated to cost US$120. It is well suited to field crops such as wheat, green gram and soybeans.

The kits were all designed to be incremental, allowing farmers to start with a small kit and then expand by investing profits derived from the crop sales. The divisibility of the systems as a means of reducing the initial and subsequent capital investment is a vital part of making such systems available to poor farmers who cannot afford significant capital expenditure. Laterals are designed to be moved, which can significantly reduce the amount of equipment needed.

In Nepal, a typical trickle user has invested about US$26 for the trickle system, US$15 for other inputs, uses family labour (idle in the off-season), and increases his/her income from cash cropping from around $10 to around $100 (per capita GNP in Nepal is around $200).

IDE fully recognize that coming up with an appropriate technology is a small part of the solution. Focus is on reducing costs by using locally available materials, involving local manufacturers and dealers and placing emphasis on sustained marketing and demonstration so that the manufacture and supply of the equipment is commercially attractive.

IDE has developed a highly effective strategy for mass marketing of low-cost income-generating technologies in developing countries.

The basis of this is that:

• technology must be affordable to the farmer and must have a very high return on investment over the short term;
• manufacturing should be done locally by private, non-profit entities;
• a dealership network should be developed with the manufacturers that can deliver goods to remote areas of the country for a reasonable profit;
• local expertise in installation and repair needs to be developed through training;
• a massive public information campaign needs to be conducted to stimulate demand for the product up to a sustainable level.

By following this strategy, a sustainable delivery infrastructure can be put in place. Demand for the technologies has a chance of increasing together with income that can support this infrastructure.

Using this strategy IDE has already had a great deal of success with the marketing of treadle pumps in Africa. The intention now seems to be to promote the same model for low-cost irrigation systems.

**Family kits (developed by Netafim)**

Netafim, an Israeli trickle irrigation manufacturer, has developed what it calls the Family Drip System that can be adapted to variable plot sizes. This was developed in China and comprises their standard emitters, pipes and filter equipment. The kit works at low head and is pressurized from a tank rather than by pumping. It has the appearance of a large-scale system that has been scaled down for use by smallholders rather than a system that has been designed specially for this market.

The costs of the system range from US$150–240 for 1 000 m² (US$1 500–2 400 per ha). Having introduced these systems in China, Netafim plans to replicate this experience in 50 other countries. There is as yet little evidence of how successful these systems are for smallholders.
West Africa experience

An FAO/Japanese funded programme is investigating the potential for smallholder irrigation using a combination of surface irrigation methods and water distribution using pipes (FAO 2000). A wide range of ideas is under evaluation at a training school in Ouagadougou, Burkina Faso, which includes the use of low head tanks, simple drippers for applying water and the use of hose pipes. The intention is to find suitable systems that help to reduce water wastage in water short areas, and which at the same time are low in cost and simple to use. Local materials such as PVC piping is being used with simple connections so that components can be resourced locally rather than relying on imported materials. The tests are still at an early stage and it will be some time before they are tested and evaluated in the field.

Many other examples of various technologies being adapted for use by smallholders are listed in the report of a workshop organized in Ouagadougou by IPTRID and FAO in 1998.

Some early experiences

Technical studies were reported by Miller and Tillson (1989) in Sri Lanka and Batchelor et al. (1993) in Zimbabwe on the use of low-cost trickle systems for smallholders. In both cases the systems evaluated relied on imported, high-cost, commercial trickle tapes although both systems were low head and had very simple filtration. Batchelor et al conclude that even with these simplifications the equipment was too expensive and difficult to obtain. Neither study led on to programmes of wide-scale promotion or adoption.

Some common characteristics of low-cost systems

Low-cost systems have several characteristics in common:

- These systems are designed specifically for small plots, which can be added to as and when the farmer chooses. Low-cost systems are aimed specifically at smallholders. They are usually in kit form for small plots from just 15 m² up to 1 000 to 2 000 m².
- They use low pressure (or head). Lowering pressure reduces the energy needed to lift the water and lessens the burden on farmers, particularly if the water is lifted by hand. Whereas commercial systems operate around 10 m head, low-cost systems usually work around 2–4 m head. A raised bucket, oil drum or other storage tank may provide enough pressure and could be filled manually. Low operating heads means that any head loss along the lateral is a larger percentage of the total operating pressure and has a direct effect on emitter flow rates. This can be overcome to some extent by keeping laterals short.
- Some irrigation precision is lost. Operating at low pressure can mean a loss of irrigation precision. This can also happen using low-cost emitters. Many manufacturers have chosen to use simple emitters, such as orifices or holes punched into the lateral. It is not always possible to form the holes accurately. The result can be large variations in discharge along a lateral as a result of different sized holes. Changes in pressure along a lateral exacerbate this problem. Some manufacturers supply their normal emitters (e.g. Chapin’s bucket kit) that tend to be more costly. This can increase the cost of the system because the emitters are built into the pipe wall and any manual cleaning of clogged emitters is not possible.
- Precise irrigation may not be as important to smallholders as it is to farmers in the developed world. This depends on how much precision is lost and it may well be that low-cost systems, although not perfect, are far better at applying water than the other methods used by farmers. The farmer’s ability to manage the irrigation application properly is more important than worrying about some of the system’s technical shortcomings.
- They use simple filtration. Clogging of the very small flow paths in the individual emitters is the single greatest problem of any trickle system. To minimize this risk, conventional trickle systems rely on a primary fine wire-mesh filter and in some cases (depending on water source) additional filtration through a sand medium is necessary. The filters are a high-cost item. They require careful routine maintenance and impose a head loss, and therefore need additional energy input.
- Low-cost systems use simple cloth or wire-mesh filters to prevent large particles entering laterals. In addition the systems using simple holes in the lateral rely on the farmer using a pin or fine wire to clear any emitter that becomes blocked. This is practicable on a farm of 0.1 ha, which may
have 2,500 emitters to maintain, but would be unrealistic on larger systems. Cleaning by hand is not possible on most commercial trickle tape because of the way it is manufactured.

- Movable laterals are often used. Some technologies reduce the cost of equipment through use of a single lateral to irrigate ten row crops, the lateral being moved by hand between each row. IDE uses this idea to reduce costs although early Israeli use of trickle systems used the same approach.

**Treadle pumps**

Over the past decade, a small, but significant revolution has been taking place in smallholder irrigation in the developing world with the introduction of the treadle pump. This simple, human-powered device can be manufactured and maintained at low-cost in rural workshops in developing countries. Acceptance of these pumps in Bangladesh, where it was first developed in the early eighties, has been described as extraordinary. Over 1.3 million pumps are now in daily use in that country. Farmers have spent US$40 million on treadle pumps at approximately US$35 each (IWMI 2000). Their use in Africa is growing and a recent appraisal of their potential has just been published (Kay and Brabben 2000). Some 10,000 pumps are reported to have been sold across West, East and southern Africa since 1997 at a cost of US$50–120. Most are used for vegetable production and enable smallholders to enter the market economy.

The experience of introducing treadle pumps into Africa serves as a useful model for the introduction of other irrigation technologies.

Treadle pumps work on the principle of suction lift using a cylinder and piston to draw water from a resource below ground level, e.g. a river or shallow groundwater. It was originally developed for the hand pumping of domestic water and has been skilfully adapted for use in irrigation, where a much greater volume of water is needed, by changing the driving power from arms and hands to feet and legs. These are more powerful muscles and are capable of lifting much more water. Two pistons are used, each connected to a treadle on which the operator stands and presses them up and down in a rhythmic motion.

The pumps were initially imported. Now most treadle pumps are manufactured locally although they do need special tooling to produce good quality pumps. The emphasis is on selling pumps to farmers on a commercial basis rather than supplying them as gifts. For this reason the supply chain is a vital aspect of the pump’s success. These have been set up in Kenya, Zambia and in countries in West Africa. The supply chain must also function as a conduit for spare parts, maintenance services and feedback to manufacturers. The poor uptake of pumps in Zimbabwe is undoubtedly linked to the lack of an effective supply chain. Although treadle pumps are well known in the country, no agency has taken on the responsibility of wide-scale marketing, and production is not continuous.

The economic benefits of introducing treadle pumps have been significant. In Zambia incomes have risen more than six fold from US$125, achieved with bucket irrigation on 0.25 ha of land, to US$850–1,700 using treadle pumps. This was attributed not only to increased crop yields but also to being able to increase the area of land irrigated. Cropping intensity rose in some cases up to 300 percent (three crops a year) with noticeable increases in the variety of crops grown. Because of the increase in water availability, farmers were more willing to take risks with new crops. Similar benefits have been reported in other countries where treadle pumps have been introduced.

Problems have also been created through the increase in crop production. Higher yields can bring about the problem of a market glut when supply exceeds demand. This is a particular problem with common household crops and it is exacerbated by the tendency of farmers to grow the same crops at the same time of year. Exploiting more distant markets increases transport costs and highlights the problem of poorly developed feeder roads in remote rural areas.

Attempts to use treadle pumps in Africa in the early 1990s were less successful than in Bangladesh, because conditions in Africa are very different. The groundwater is much deeper and the irrigated land much more hilly. Water must be pushed further from its source to the point of use. The development of pressure pumps has helped to overcome this constraint in many countries thus resulting in significant sales of pumps over the past few years.

**Combining treadles with low-cost delivery systems**

Attempts are underway to combine the use of treadle pumps with low-cost water distribution systems such
Smallholder irrigation technology: prospects for sub-Saharan Africa

as trickle kits and hosepipes in Zimbabwe, Kenya and in countries in West Africa where treadle pumps are used. The argument is that once water has been lifted by treadling there is every incentive to use it as effectively as possible. Water is usually pumped into tanks for distribution, although there is no reason why it cannot be pumped directly into the distribution system. The output from a treadle pump tends to be intermittent yet this should not pose too much of a disadvantage. However, it is still early to say if such combinations will be useful.

PREREQUISITES FOR UPTAKE

Enterprise Works, an NGO working in Niger, looked into the prerequisites for uptake of treadle pumps. Many of their findings would apply equally to other low-cost technologies. In order for a technology to be commercialized and adopted it should be produced as close to the end user as possible. It must be affordable for the buyer and profitable to the producer. The technology must also function reliably and the purchaser must be satisfied. It only takes a few dissatisfied customers to ruin the market for a new product. No technology can be considered appropriate for all conditions. This is where the identification of appropriate sites becomes important. Appropriate site criteria include:

- a market for vegetable products, usually of higher value;
- a reliable and adequate water source;
- a concentration of market gardeners amenable to innovation;
- adequate land available for garden expansion.

The setting up of supply chains and ensuring that there is sufficient manufacturing capacity of a high enough quality to meet the demand is also essential. As demand is something that usually needs to be stimulated when new technologies are introduced, there is the opportunity to balance marketing activities with the development of the supply chains. In this way it may be possible to balance the level of expectation created among farmers with the means of satisfying it.

To be profitable a technology must have a low overall cost that does not expose the owner to debt. It must then make money. Fear of failure has often driven people towards high tech solutions to avoid the problems of breakdown. All machinery fails eventually and in developing countries, failure tends to occur sooner because maintenance is poor and conditions more hostile. The result is machinery graveyards that can be seen surrounding many towns and villages. For this reason the need for strong supply chains to support the supply of spare parts and maintenance must not be underestimated.

A ROLE FOR LOW-COST TECHNOLOGIES IN SUB-SAHARAN AFRICA?

Comments about the role of low-cost irrigation systems in sub-Saharan Africa are similar to those made for modern technologies. Low-cost systems have the potential to raise productivity and enhance rural livelihoods. Even though costs for these technologies may be relatively low they are still only accessible to farmers who can afford to buy them. Usually they are growing cash crops such as vegetables, fruit and flowers that provide sufficient returns to pay for the investment. They have little to offer poor farmers and so are unlikely to be taken up by them without appropriate financial and technical support.

Low-cost systems have yet to be tested and evaluated properly in the region. There are also concerns about commercial interests encouraging farmers to use modern technologies when other less expensive options may be appropriate.

One exception to this is treadle pumps, which have been undergoing various evaluations in the laboratory and in the field over the past five years. So far the results in terms of uptake and benefits have been encouraging. Their adoption by smallholders and the way in which support services have been developed is undoubtedly a model that the developers of other technologies might emulate.
Matching technologies to agricultural regions

The most appropriate technologies to use will vary from place to place depending on a wide range of circumstances. A broad classification may be made based on climate, Figure 2, and the traditional agricultural background of local people. Table 3 links technology options to agricultural regions and Table 4 links them to countries.

Irrigation has been associated with the flood plains of large perennial rivers. Major examples include the Niger River in Niger, Mali and northern Nigeria, the Senegal River in Mauritania and Senegal and the Juba and Shebelli Rivers in Somalia. Outside the region the Nile in Sudan and Egypt is famously associated with irrigation. These areas have always been prime sites for large-scale irrigation schemes and have long traditions of smallholder irrigation. For instance, in Niger, during the wet season, floating rice is planted in the river bed at the beginning of the rains and is flooded as the river rises. Later, from November to April, small vegetable gardens are cultivated on the river banks and alluvial terraces that are not flooded during peak flow in January-February. When the floods recede crops such as sweet potatoes, maize and onions are planted and irrigated from shallow groundwater. Small pumps are gaining increasing acceptance in many countries wherever spare parts and fuel are readily available.

Desert and semi-desert

This zone is characterized by very low, erratic rainfall (less than 500 mm per annum), which renders purely rainfed agriculture impossible. The major agricultural activity is nomadic stock raising with camels, goats, sheep and cattle being the principal stock. In this zone the most important form of smallholder irrigation development is likely to be water harvesting. Spate irrigation could also be practised in occasional watercourses as well as shallow groundwater development.

In some places such practices are traditional. For example, in the Lower Omo Valley in Ethiopia, (rainfall 300 mm/year), fodder and food crop production depends almost entirely on seasonal floodwater from the River Omo and recession farming in the old river channels. Successful systems of run-off farming have also evolved in the adjacent Woito Valley.

The techniques of runoff agriculture are still at an experimental stage in Africa (see Tanzania box). The success of smallholder schemes in these regions is to a large extent dependent on the acceptability of settlement to the nomadic tribes who generally populate this area. Without their cooperation any irrigation development is likely to be unsuccessful.

Water harvesting is the only alternative to making a living through semi-nomadic stock raising or famine relief. Where these semi-nomadic people have become destitute, as is happening in vast areas of Ethiopia and Somalia, they may be prepared to settle on permanent smallholder irrigation schemes. The future prospects for this zone are not promising because of the increasingly tight definitions of boundaries and territories and continuing encroachment of agriculture into traditional pastures.

An example of the establishment of water harvesting by semi-nomadic tribes was in Turkana in northern Kenya in the early 1980s. There were reports of local resistance in the form of apathetic attitudes and inherent scepticism towards the idea that crops could be produced on what was traditionally regarded as grazing land. Once there was demonstrable success in increasing fodder production the level of participation grew rapidly and a large number of fields were under regular cultivation producing grain, fodder and wood.

Dry savannah agriculture

This zone extends over large areas of Africa. It differs from the desert and semi-desert zone in having a higher annual rainfall of 500–600 mm (occasionally up to 1 000 mm) which falls in a single three to six month long rainy season. The main form of agriculture is sedentary stock raising in some areas and arable farming in others. The types of irrigation likely to succeed in these areas are water harvesting and irrigation of river flood plains and other extensive plains, either in the wet season with bunds to control occasional floodwaters or with exploitation of shallow groundwater throughout the year.
Matching technologies to agricultural regions

Figure 2. Agricultural regions of Africa in relation to smallholder irrigation

Table 3. Relative importance of small-scale irrigation in agricultural regions

<table>
<thead>
<tr>
<th>Region</th>
<th>River flood plains</th>
<th>Swamp irrigation</th>
<th>Hill irrigation</th>
<th>Rainwater harvesting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wet season</td>
<td>Dry season</td>
<td>Groundwater</td>
<td>Swamp irrigation</td>
</tr>
<tr>
<td>Desert and semi-desert</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Dry savannah agriculture</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Humid savannah agriculture</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Humid tropical forest agriculture</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Pastoral stock raising</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Semi-nomadic stock raising</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>High tropical and sub-tropical Plateau agriculture</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: 1 very important, 2 fairly important, 3 less important

Source Kay et al. 1985
An example of successful runoff agriculture comes from Burkina Faso where an NGO initiated a combined agro-forestry and water-harvesting project. In 1979 a small experimental area of micro catchments for fuelwood trees was established with farmer participation. The farmers involved subsequently adopted these runoff-farming techniques and used them to improve their traditional erosion control methods, thus increasing their normal agricultural production. Fields long abandoned are being reclaimed and farmers are increasing infiltration through the construction of simple contour bunds.

Humid Savannah Agriculture

In this zone the annual rainfall is normally, 1 000–2 000 mm, falling either in two rainy seasons close to the equator, or as one long rainy season further north or south. This is sufficient to grow two rainfed crops in countries close to the equator (e.g. Rwanda, Burundi, Central African Republic) and one rainfed crop in a more northerly or southerly area. The role of irrigation in this zone is therefore to (a) improve the yields of existing crops, such as maize, groundnuts and cotton, (b) to reduce risks by extending the length of the growing season or allowing a second (or third) crop to be produced in the dry season, and (c) to allow new areas of land to be developed for crop production through drainage of swampy areas for dry season cropping or water control for wet season rice growing.

In general, in countries with adequate agricultural land reserves, the main emphasis should be on the development of improved agronomic techniques in rainfed agriculture. However, where the available agricultural land is scarce and the population is high there will be an inevitable acceleration in the development of irrigation. Rwanda is a prime example of this with an average population density over 200 persons/km².

The physical types of irrigation will largely depend on the topography of the areas but most irrigation will be on river flood plains or extensive plains. Emphasis will be on supplementary irrigation in the dry season, followed by control of water in the wet season for rice cultures. Irrigation of small areas from channels and non-seasonal irrigation in flood plains and extensive plains will be important in localized areas.

Humid Tropical Forest Agriculture

This zone is the wettest region with annual rainfall in excess of 1 500 mm, usually falling in two main wet seasons. This zone therefore differs from others in that it is wet throughout most of the year and has no major constraints to rainfed agriculture, except during the short intervening dry season. The major irrigation issues will be concerned with water control and drainage rather than with irrigation per se, although supplementary irrigation can be practised particularly for crops, such as vegetables grown in the short dry season as in parts of Nigeria. The most important will be small areas commanded from weirs and channels, such as the inland valley swamps of Sierra Leone, Liberia and Guinea. In the wet season, deep-water rice may be grown in the same small swamps. In Togo and Benin the main form of irrigation will involve small to medium-sized earth dams commanding the downstream areas by channels and with various lifting techniques, for irrigating upstream of the dams. In coastal regions there are large areas of rice grown in the mangrove swamps and in river estuaries during the wet season. Sierra Leone has 20 000 ha of mangrove swamps cropped with a potential for 74 000 ha.

High Tropical and Subtropical Plateau Agriculture

The high tropical and subtropical plateaus, which are greater than about 1 500 m above sea level are characterized by low temperatures, particularly in the cool seasons away from the equator, which can restrict the choice of crops. Rainfall varies from 500 mm/year upwards.

The most suitable form of irrigation will vary depending on topography and rainfall but will generally involve small areas commanded by channels. In the high veld of Zimbabwe many small farm dams have been constructed in small catchments that are used for smallholder irrigation and stock watering. The techniques employed in Zimbabwe tend to use modern technology with sprinkler irrigation being very important. In the Rumphi district of Malawi small channels lead away from streams to suitable areas for irrigation, which may be several kilometres away. In many of the areas (e.g. South Tanzania, Zambia, Malawi), supplementary irrigation of cash crops such as tea and coffee during the extended dry season is practised commercially and opportunities exist to extend this to smallholder schemes.
How fast can smallholder irrigation develop?

It is important that agencies wishing to support irrigation development have some idea of how fast future irrigation development can take place so that the agencies can plan for the labour and technical resources they will need to provide. Given the current socio-economic constraints on smallholders the question is a difficult one to answer. Removing constraints can encourage farmers to move into irrigation and speed up the process but this is not easy and so major changes are unlikely in the foreseeable future.

One option is to look at what has happened in the past decade as an indicator of what might happen in the future.

**REVIEW OF EXPERIENCE FROM SUB-SAHARAN AFRICA**

A recent review of IFAD’s smallholder projects (Internal review 2000) is of particular interest not only because of its wide geographical spread but because it highlights the challenges that face any international agency wishing to support smallholder irrigation in what is essentially the private sector. As the majority of such investments tend to go to the larger schemes involving communities, rather than to support individuals, they have inherently higher risks built into them. Past experience has shown that individual farmers developing irrigation on their own or with family have a much lower risk of failure than those who work in groups or communities requiring collective responsibility and a sharing of the assets.

In 1986 IFAD launched its special programme for countries affected by drought and desertification in sub-Saharan African in response to the devastating droughts of the 1980s with a sub-programme, Small-scale Irrigation and Water Control. The principal objectives were to increase smallholder productive capacity, improve household food security and build the capacity of farmers to take over scheme operation and maintenance responsibilities by involving local communities. This was to be achieved through the development of a wide spectrum of simple low-cost technologies. The adoption of a participatory demand-driven approach was considered essential for ensuring sustainability.

Under this approach, it was assumed that beneficiaries would be key partners involved in the selection of activities, their design and subsequent implementation.

In all, more than 80 000 were to benefit, including an appreciable number of women heads of households, and an area of 20 000 ha would be irrigated. The schemes included:

- **Individually owned systems (7 percent of schemes).** Small mobile pump schemes or various lift systems using seasonal river flow, stored water in ponds, or shallow aquifers.
- **Community-based schemes with partial control of water (21 percent).** Water harvesting, inland bottom valley schemes, and flood recession and control in West Africa.
- **Communal gravity or pumping schemes (46 percent).** Pumping systems operated by the villagers, mostly developed in West Africa; gravity smallholder irrigation schemes based on the diversion of water stored in small dams (Ghana); and collective tube-wells with submersible pumping systems using deep groundwater (Senegal, Niger).

A review of the projects has produced some valuable insights into the challenges that this kind of intervention faces. Many of the projects were still being implemented and so a full assessment of their impact was premature. It was possible to see the progress made and identify the constraints that had hampered their implementation. Some of the key findings of the review included:

**Impact on smallholder living conditions**

In most cases the projects had a favourable impact in that they generally expanded the irrigated area, increased water availability and improved its use.

In regions where water supplies are dependable they enabled producers to use water for supplementary irrigation in the rainy season, to mitigate the effects of erratic rainfall on their traditional crops and, in the dry season, to produce high-value cash crops, (Ghana, Ethiopia, Sudan and Niger). In Niger about 400 smallholders, who
had difficulty in making the initial investment from their own resources, benefited significantly. Smallholders were able to buy small mobile pumps and in this way avoid being dependent on private wealthy pump owners, to whom they formerly had to pay one third of their harvests in exchange for rental of similar equipment. In Senegal, farmers were able to increase their irrigated plots and the quality of construction was improved making maintenance easier. In Ghana, farmers benefited from irrigation during the dry season and saw this as the single most important factor in the achievement of household food security.

Impact on women’s access to natural resources

Almost all projects had as a goal the introduction of increased equity and security in access to developed land, especially by women. In Tanzania and Ghana, about a third of the irrigated plots were allocated to women. In addition, women reportedly contributed much of their labour towards scheme construction in order to assures themselves of a plot or extra income. However, it was mainly men who decided on land tenure issues rather than women (The Gambia, Mali, Senegal and Ghana). This still continues to be the case and the projects have not changed this.

Farmers’ participation

Conventional wisdom calls for farmers to become the principal partners and decision-makers in a project because this is perceived as the best way of ensuring ownership and development success. For this reason participatory approaches were a central plank of the planning phase. In practice, however, the projects were implemented under a project-led rather than a demand-driven approach. Participation was sacrificed in favour of speeding construction activities in order to develop as many schemes as possible. Even in cases where participatory processes were used, schemes were usually designed in response to requests received by Project Managers. These were often based on the perception of landowners and village chiefs had of priorities, rather than those of the direct beneficiaries.

Generally, people implementing the projects did not have enough experience of participative techniques or were not convinced of their importance and paid only lip service to the process. Farmers were not always willing to contribute their labour for free, preferring instead to work on their farms or for off-farm income-generating activities. This was contrary to the early expectations that people would be willing to invest their labour and this would engender a feeling of ownership. In many cases labour had to be paid for, which made translating theory into practice difficult. Time was also a major constraint. The demands of farmer participation, which require time to evolve, did not fit with the short time constraints that agencies normally place on project investment and construction possesses. The result was that the pace of development was much slower than originally anticipated.

Many projects failed to get farmers to participate. They were not convinced of the need to take full responsibility for bringing land into production, which in most cases they did not own. They would not take on the responsibility for operation and maintenance, which was viewed by farmers as a government provided source of employment and income rather than a self-help activity. Increasingly farmers are becoming aware that substantial support and subsidies can no longer be expected from the government and that they must begin to rely on their own efforts.

Suitable technologies

When dealing with communities living in harsh environments, existing production systems give farmers some basic security from starvation, even if they have low yields. Any external intervention should be developed around existing systems rather than bringing in new technologies. Expectations of cropping intensity, yield and reduced water wastage

---

THE CHALLENGES OF PARTICIPATION

An engineer-agronomist told the anthropologist that he worked in close collaboration with the farmers every time he went out in the field. By this he actually meant that he was accompanied by the manager of the perimeter and the head of the county government.

In another instance, at an introductory meeting of experts, who were going to work together on an irrigation project, the anthropologist was introduced for the first time to the irrigation engineer who said, as they shook hands, ‘What are you doing here, we don’t need you. We know everything we need to know about the farmers’.

From Brown and Nooter (1992)
need to be realistic. The outcome is determined more by the capacity of small-scale farmers to adopt new technologies where services are erratic and market prices are high, rather than on what is potentially possible.

Although irrigation is meant to reduce risk, new technology introduces other risks that might expose farmers to a higher level of risk than before. Project reviews have shown that this extra risk falls exclusively on the farmers without being shared by the government. This has resulted in conflicts between farmers and credit institutions, and in farmers abandoning projects.

The most successful technologies proved to be those initiated to improve existing farming systems and which continue to be under the full control of the communities or individuals, such as flood recession improvement, individual low-lift pumping systems, and abstraction and diversion of water from rivers. The risks increased considerably when larger-scale pumping from tubewells for whole communities was introduced.

The idea of using ‘low-cost technology’ is attractive to donors and farmers alike although it can and does create problems. There is usually an assumption that once a scheme has been planned, the design and construction is a straightforward process and the outcome is a well-engineered system of supply that farmers can use with confidence. This is not always the case and the phrase ‘low-cost technology’ is in danger of becoming a euphemism for poor engineering design and construction. Canal embankments are often not compacted properly and so they do not last very long. Concrete is not prepared properly and compacted during placement with the result that it crumbles during use and so structures do not give adequate service. If the technology does not work properly, the seeds of failure are already sown.

The principal reason for much of the poor engineering was a serious shortage of suitably trained irrigation engineers and technicians who could undertake design work and supervise construction properly so as to produce sound engineering works.

Prospects for development

Many countries south of the Sahara are becoming increasingly dynamic in response to more liberal marketing and pricing policies and greater competition between private sector interests. There are concerns that while the state may withdraw from a number of functions that may be better handled by the private sector, assistance for smallholder irrigation schemes targeting the poorest of the rural population can be expected to remain an important area for public sector investment and support. Without targeted assistance, at least during a transition period, the rural poor will become increasingly vulnerable to the new emphasis on an ‘open economy’ environment, and hopelessly marginalized.

Simple and appropriate water control technologies are becoming better known, and some decline in unit costs of development can be expected as smallholder irrigation systems gain greater credibility and farmers’ awareness of their role and responsibilities in relation to water management increases. The institutional capacity of governments, NGOs and the private sector to work together is also improving. These factors would support continued investments in smallholder irrigation, especially since without investment in water infrastructure the prospects for increasing food production and improving food security are remote in many countries. Table 5 summarizes the technical and institutional issues and gives an indication of costs.

Summary of IFAD review

The following summarizes some of the key lessons learned from the IFAD review:

- The identification of local community representatives or farmers’ organizations capable of acting as responsible partners is a prerequisite for any smallholder irrigation development. Beneficiary involvement should be a partnership process where each partner has the right to agree or not and therefore has the capacity to influence the decision and to share in the responsibility. In addition, attention should be given to matching the scale and scope of a project with the implementation capacity of local institutions and the farmers’ capacity to participate.
- A detailed plan and procedures should be established so that implementers are well prepared for the tasks expected of them. This would not be a simple detailed list of physical activities, but rather a plan of who should do what, when and how.
- A distinction should be made between projects aiming to improve existing practices under the responsibility of traditional communities/villages from those introducing new ideas and technologies.
How fast can smallholder irrigation develop?

- More attention should be paid to the criteria for site selection, targeting and implementing procedures. Several rounds of project design and consultation are needed if the trust and assistance from groups of farmers is to be forthcoming. Time is needed to apply a participatory approach and to create necessary capacities at the local level.
- The free labour that beneficiaries are expected to contribute should be no more than the equivalent of 15 percent of the total costs. It is essential that this contribution is recognized as being at the expense of other demands on their time.
- Appropriate methods of construction appear to be those that optimize the use of small local contractors and the labour of the beneficiaries, combined with independent professional checks on the design and construction standards to ensure these conform to specifications.
- It is essential to prepare an agreement between the sponsoring agency and the beneficiaries specifying their respective roles, contributions and obligations during construction and later for operation and maintenance. Cost recovery and financing mechanisms and procedures are still a major problem in many countries and still need to be worked out. Agreement must be reached on appropriate mechanisms based on the technologies used, the cropping system and the organizational features of farmers.
- Forming Water Users’ Associations (WUAs) and transferring project assets to them proved to be a long and difficult process incompatible with the short period of project implementation. This has administrative, financial and legal implications. Therefore, adequate support is needed for the creation of WUAs and for training members and office holders sufficiently early in the course of a project to ensure they are properly prepared to assume operation and maintenance responsibilities.
- It should be taken into account that effective beneficiary involvement and development of a sense of ownership is not always achievable for every type of scheme.
- Other support services (agricultural extension, input supplies, market access, rural finance, land allocation, etc.) must also be in place. A realistic assessment of the institutional viability of

Table 5. Summary of IFAD funded smallholder developments

<table>
<thead>
<tr>
<th>Type and nature of systems</th>
<th>Traditional Community based schemes</th>
<th>Individuals and private schemes</th>
<th>Inter-village and communities schemes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water harvesting. Inland valley</td>
<td>Small mobile petrol pumps.</td>
<td>Village irrigated. Diversion from</td>
</tr>
<tr>
<td></td>
<td>bottom. Flood recession</td>
<td>Various lift systems (treadle</td>
<td>rivers and small dams. Deep</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pumps, wind pumps, etc. Small</td>
<td>tubewells</td>
</tr>
<tr>
<td></td>
<td></td>
<td>collective pumps</td>
<td></td>
</tr>
<tr>
<td>Water users association</td>
<td>Not necessary/community matters</td>
<td>Not necessary, individuals or</td>
<td>Necessary</td>
</tr>
<tr>
<td>Water management</td>
<td>Necessary because of impact on</td>
<td>small groups responsibility</td>
<td></td>
</tr>
<tr>
<td></td>
<td>other communities</td>
<td>External monitoring necessary</td>
<td>Necessary for sustainability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>to avoid depletion of aquifers</td>
<td></td>
</tr>
<tr>
<td>Risks</td>
<td>Limited risk</td>
<td>Medium risk. No sharing of risk</td>
<td>High risk. Sharing mechanism needed</td>
</tr>
<tr>
<td>Average cost (US$/ha)</td>
<td>600 to 1 000</td>
<td>1 500 to 3 000</td>
<td>3 000 to 8 000</td>
</tr>
</tbody>
</table>

Figure 4. Rates of irrigation development in selected countries

- Ethiopia
- Mali
- Zimbabwe
- Zambia
- S. Leone
- Burkina Faso
securing these services during implementation is essential.

**EXISTING SITUATION**

No recent and accurate information is available on the full extent of smallholder irrigation in sub-Saharan Africa. In this section an attempt is made, based on available data, to look at what has already been achieved and at future possibilities on a country-by-country basis. The speed of past development may hold clues as to how fast we can realistically expect developments to be made in the future.

The extent of irrigation development and how it has changed over the period 1960 to 1997 is summarized by Gleick (2000) on a country-by-country basis using FAO data sources. What is not readily available, however, is the current extent of smallholder irrigation relative to larger-scale developments. For this it is necessary to go back to 1986 when FAO estimated the split between the two. For this reason the FAO 1986 data are used to show the extent of smallholder irrigation in relation to the total developed in 1986. A comparison is made of the estimated potential for irrigation based on available land and water resources (Table 6). In addition to this, data from 1985 to 1997 (a 12 year period) quoted by Gleick have been used to calculate the average rate of irrigation development (smallholder plus large scale) in each country (see last column in Table 3). As this information provides an important insight into the capacity of each country to expand irrigation development in the future, the countries have all been ranked according to this rate of development.

The FAO consultation in 1986 concluded that in 32 of the 40 countries in sub-Saharan Africa, the first priority was for rainfed agricultural development. In eight countries Botswana, Burkina Faso, Kenya, Niger, Mali, Mauritania, Senegal and Somalia, irrigation is an essential part of any food security strategy because of the population pressures and the lack of rainfed capacity.

FAO data also show that sub-Saharan Africa includes 11 of the 16 nations of the world having less than 1 000 m³/head/year of water, a situation described as ‘absolute water scarcity’ where food shortages are a constant threat and water shortage can only increase (FAO 1995).

What is clear from the data is that the potential for further irrigation development in terms of land area and, to a lesser extent, water availability is very significant even allowing for the development that has taken place over the past 14 years (since 1986). Although there may be some differences over the definition of smallholder irrigation, the table clearly shows some 66 percent of irrigation development is in this sector. Since the emphasis in the intervening 14 years has also been on smallholder irrigation the true percentage may be even higher.

The average rates of development of irrigation over the past 12 years (1985-97) provide an interesting insight into what has been achieved in each country and what might be achieved in the future. Of the eight countries identified by FAO as being dependent on irrigation, the rate of development in Botswana, Mauritania and Senegal has been zero, whereas Burkina Faso, Kenya, Niger, Mali and Somalia are in the top 14 best performing countries.

Unfortunately, even in the countries most active in irrigation the rates of development are still very modest and over 50 percent have a rate less than 500 ha/year. In fact 13 countries show no growth at all. It may well be that irrigation is not as important in those countries. There are some on the list however that would clearly benefit from some resurgence of interest in irrigation. The total estimated rate for the whole region is 43 600 ha/year – an average of 1 150 ha/year for each country.

Some countries appear to have encouraging rates of development (e.g. Tanzania, Nigeria, Niger, Zimbabwe and South Africa – the latter two are special as they have substantial private irrigation sectors). The question is, can this rate be sustained or increased in the future? Many development processes follow a classic ‘S’ curve and irrigation is no exception. The curve usually has three distinct phases:

- A preliminary lag phase at the start of a new initiative when the ideas and technologies are relatively unknown and untired.
- An intermediate, rapid growth phase which takes place when the area under irrigation is being expanded very fast with active farmer participation using by now well tried and tested techniques.
- A tailing off into a flatter section when the available land or water is nearly used up and any further developments are on marginal areas with less potential benefit to the farmer.

Data from five countries over the period 1960 to 1997 demonstrate this, see Figure 4. Two countries are in the lower development rate group and three
How fast can smallholder irrigation develop?

In each case it is apparent that development has passed through the rapid growth phase and is in the tailing off phase. These data are typical of all the countries listed in Table 6, which all exhibit a similar trend.

The realities of these development curves add to the view that it is factors other than natural resources that constrain development. These include marketing, infrastructure, availability of fuel and spare parts, social background, labour availability, pricing policy, population density and land availability as well as the knowledge and expertise in irrigation technology.

### FUTURE POTENTIAL

If the above data foretell the future then rates of development are likely to be slower than over the past 12 years unless the key constraints are identified in each country and steps taken to remove them.

---

### Table 6. Irrigated areas in sub-Saharan Africa in 1982

<table>
<thead>
<tr>
<th>Country</th>
<th>Potential (000ha)</th>
<th>Large-scale (000ha)</th>
<th>Smallholder (000ha)</th>
<th>Total (000ha)</th>
<th>% developed</th>
<th>Rate of development (ha/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>6 700</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>&lt; 1</td>
<td>0</td>
</tr>
<tr>
<td>Botswana</td>
<td>100</td>
<td>0</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Burundi</td>
<td>52</td>
<td>2</td>
<td>50</td>
<td>52</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Cameroon</td>
<td>240</td>
<td>11</td>
<td>9</td>
<td>20</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Congo</td>
<td>340</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Guinea Bissau</td>
<td>70</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>0</td>
</tr>
<tr>
<td>Lesotho</td>
<td>8</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Liberia</td>
<td>na</td>
<td>3</td>
<td>16</td>
<td>19</td>
<td>na</td>
<td>0</td>
</tr>
<tr>
<td>Mauritania</td>
<td>39</td>
<td>3</td>
<td>20</td>
<td>23</td>
<td>59</td>
<td>0</td>
</tr>
<tr>
<td>Rwanda</td>
<td>44</td>
<td>0</td>
<td>15</td>
<td>15</td>
<td>34</td>
<td>0</td>
</tr>
<tr>
<td>Senegal</td>
<td>180</td>
<td>30</td>
<td>70</td>
<td>100</td>
<td>56</td>
<td>0</td>
</tr>
<tr>
<td>Togo</td>
<td>86</td>
<td>3</td>
<td>10</td>
<td>13</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Uganda</td>
<td>410</td>
<td>9</td>
<td>3</td>
<td>12</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Gambia</td>
<td>72</td>
<td>6</td>
<td>20</td>
<td>26</td>
<td>36</td>
<td>83</td>
</tr>
<tr>
<td>Mauritius</td>
<td>na</td>
<td>9</td>
<td>5</td>
<td>14</td>
<td>na</td>
<td>83</td>
</tr>
<tr>
<td>Sierra Leone</td>
<td>100</td>
<td>5</td>
<td>50</td>
<td>55</td>
<td>55</td>
<td>83</td>
</tr>
<tr>
<td>Congo Democratic Republic</td>
<td>4 000</td>
<td>4</td>
<td>20</td>
<td>24</td>
<td>1</td>
<td>167</td>
</tr>
<tr>
<td>Gabon</td>
<td>440</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>&lt; 1</td>
<td>250</td>
</tr>
<tr>
<td>Namibia</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>4</td>
<td>na</td>
<td>250</td>
</tr>
<tr>
<td>Ghana</td>
<td>120</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>8</td>
<td>333</td>
</tr>
<tr>
<td>Guinea</td>
<td>150</td>
<td>15</td>
<td>30</td>
<td>45</td>
<td>30</td>
<td>417</td>
</tr>
<tr>
<td>Swaziland</td>
<td>7</td>
<td>55</td>
<td>5</td>
<td>60</td>
<td>&gt;100</td>
<td>583</td>
</tr>
<tr>
<td>Chad</td>
<td>1 200</td>
<td>10</td>
<td>40</td>
<td>50</td>
<td>4</td>
<td>833</td>
</tr>
<tr>
<td>Malawi</td>
<td>290</td>
<td>16</td>
<td>4</td>
<td>20</td>
<td>7</td>
<td>833</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>350</td>
<td>9</td>
<td>20</td>
<td>29</td>
<td>8</td>
<td>1 083</td>
</tr>
<tr>
<td>Benin</td>
<td>86</td>
<td>7</td>
<td>15</td>
<td>22</td>
<td>26</td>
<td>1 167</td>
</tr>
<tr>
<td>Mozambique</td>
<td>2 400</td>
<td>66</td>
<td>4</td>
<td>70</td>
<td>3</td>
<td>1 167</td>
</tr>
<tr>
<td>Zambia</td>
<td>3 500</td>
<td>10</td>
<td>6</td>
<td>16</td>
<td>&lt;1</td>
<td>1 500</td>
</tr>
<tr>
<td>Cote d’Ivoire</td>
<td>130</td>
<td>42</td>
<td>10</td>
<td>52</td>
<td>40</td>
<td>1 583</td>
</tr>
<tr>
<td>Kenya</td>
<td>350</td>
<td>21</td>
<td>28</td>
<td>49</td>
<td>14</td>
<td>2 083</td>
</tr>
<tr>
<td>Mali</td>
<td>340</td>
<td>100</td>
<td>60</td>
<td>160</td>
<td>47</td>
<td>2 167</td>
</tr>
<tr>
<td>Somalia</td>
<td>87</td>
<td>40</td>
<td>40</td>
<td>80</td>
<td>92</td>
<td>1 667</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>670</td>
<td>82</td>
<td>5</td>
<td>87</td>
<td>13</td>
<td>2 333</td>
</tr>
<tr>
<td>Tanzania</td>
<td>2 300</td>
<td>25</td>
<td>115</td>
<td>140</td>
<td>6</td>
<td>2 333</td>
</tr>
<tr>
<td>Nigeria</td>
<td>2 000</td>
<td>50</td>
<td>800</td>
<td>850</td>
<td>43</td>
<td>2 750</td>
</tr>
<tr>
<td>Niger</td>
<td>100</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>30</td>
<td>3 000</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>280</td>
<td>127</td>
<td>3</td>
<td>130</td>
<td>46</td>
<td>5 000</td>
</tr>
<tr>
<td>South Africa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central African Republic</td>
<td>1 900</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>&lt;1</td>
<td>na</td>
</tr>
<tr>
<td>Equatorial Guinea</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Total</td>
<td>29 141</td>
<td>778</td>
<td>1 531</td>
<td>2 313</td>
<td>16.6</td>
<td>43 583</td>
</tr>
</tbody>
</table>

Source: FAO 1986 and Gleick 2000

1Countries are ranked in terms of their rate of irrigation development over the past 12 years

are in the higher group. In each case it is apparent that development has passed through the rapid growth phase and is in the tailing off phase. These data are typical of all the countries listed in Table 6, which all exhibit a similar trend.
If the current rate is sustained then an extra one million ha of irrigation could be brought into production in the next 25 years – only a 50 percent increase on what has already been achieved. To sustain this rate, let alone increase it, would require not only massive investment but also a considerable leadtime of several years to build the infrastructure and the absorptive capacity to support it. In view of this, perhaps a more realistic estimate might be half this – say 0.5 million ha.

Many leading experts recommend that development should be a slow, incremental process requiring low investment sustained over a long period. Some argue that low world grain prices are the main cause of irrigation stagnation, put simply, irrigation does not pay well at the moment. Increases in grain prices would stimulate the markets and encourage farmers to produce more. The message is clear; it is not the availability of physical resources that is likely to constrain the development of irrigation in Africa but economic, social and institutional constraints that could hamper progress. Unless radical steps are taken to ease these constraints the result will be only a modest reduction of Africa’s food problems over the next 25 years.

<table>
<thead>
<tr>
<th>Rates of development</th>
</tr>
</thead>
</table>
| In general, areas with small reserves of land and high populations are likely to show the fastest change as farmers will be under pressure to intensify their agricultural production in the face of falling land availability. In Burundi the first record of the use of valley swampland appeared in 1936. By 1959 this had risen to 200 ha under dry season cultivation and by 1975 had increased to 4,000 ha. By 1979 a survey recorded 5,700 ha of swamp irrigation, an increase of nearly 43 percent in four years (Gerard 1982 in Hekstra 1983).

A similar growth curve was observed in Nigeria with an increase in traditional fadama irrigation from 120,000 ha in 1958 to 800,000 ha in 1978. This has gone on with little or no support from the Government. This growth in smallholder irrigation contrasts strongly with the actual development of formal large-scale irrigation in Nigeria. The lag phase has lasted more than 30 years. This is contrary to the predictions of both the Federal Department of Agriculture and the World Bank, that predicted areas of 320,000 ha and 125,000 ha respectively would be under irrigation by 1982. By contrast the actual total area under formal irrigation in 1982 was only 30,000 ha. The declared total irrigation in Nigeria in 1995 was 2.3 million ha and the majority of this is likely to be in the smallholder sector.

Carter et al. (1983)
The right direction: prospects for sub-Saharan Africa

For smallholder irrigation development to succeed in sub-Saharan Africa experience shows that several broad issues must be addressed.

- Technology plays a central role in irrigation development. It can reduce the drudgery of lifting and distributing water and in the process make more effective use of limited water resources. Selecting the most appropriate technology is an essential pre-requisite for success.
- Smallholder irrigation should be a slow incremental process of improvement with low investment over a sustained period (perhaps greater than five years).
- Assistance given to farmers should be of a self-sustaining nature, which does not require continuous support from an external agency over an extended period.
- Any system set up to respond to farmer demand is more likely to succeed than one which is imposed, however well meaning this might be.
- National and local NGOs are more likely to reflect local needs for irrigation than government and so there is a need to link more strongly the activities of NGOs with the development programmes of government and aid donors for the benefit of all.
- In the current climate of public sector retrenchment it will be important to ensure private sector involvement in the manufacture, promotion, supply and support of irrigation technologies.
- Access to credit, particularly informal systems, will continue to be important to ensure that irrigation equipment and inputs are sufficiently affordable and accessible to farmers.

Of particular importance is the need to strengthen and sustain the education and training of professionals, technicians and ultimately farming communities. Only by developing the skills and broadening the experience of the farmers and the institutions created to support them, can the benefits offered by technological innovation be taken advantage of.

DEVELOPING HUMAN RESOURCES

Training in irrigated agriculture is a wide and complex issue. It is raised here in the context of irrigation technology, i.e. as it concerns the planning, design, construction and maintenance of irrigation schemes. FAO (1985) identified the problems of human resources development in irrigation and the dearth of experienced people across the irrigation sector that can put plans into action. Moris (1984) also refers to the lack of suitable training at the smallholder level, particularly in water control and management and emphasizes the need for training both farmers and government personnel. A review of IFAD’s experience over the past 20 years or so highlights a serious shortage of suitably trained irrigation engineers and technicians. It cites this lack of people who could undertake design work, supervise the construction properly and to produce sound engineering works, as the principal reason for much of the poor engineering on schemes. It would appear that the situation has not generally improved over the past 15 years.

It is difficult to attract people into irrigation for a variety of reasons and it can take many years for individuals to build up sufficient experience for this work. There are not enough people having the technical skills and experience to design and build schemes properly and who have sufficient experience in participatory methods. There are also too many examples of inappropriate training of technicians. Many are still learning about sophisticated technologies practised in the United States because this is what their teachers learned. Too many instructors are more concerned about showing what they know rather than getting good ideas across. Too much training is done in the classroom and not enough in the field. Too many technicians lack the skills to work closely with farmers and assume that communication is about telling farmers what to do rather than listening.

For smallholder irrigation to develop it will be essential for each country to undertake a study of labour requirements to assess the supply and demand for trained people. Demand is based on the expected
growth rates in irrigation and the supply of trained people, at all levels, is based on the output from both the institutional and in-service training arrangements. Curriculum support is needed to establish appropriate institutional and in-service training programmes that properly equip people for the jobs they must do. With wider acceptance and application of appropriate irrigation technologies smallholders in sub-Saharan Africa may then be in a position to increase crop production and in this way improve their rural livelihoods.

### A Lack of Skills

This is not an overstatement of affairs. An engineer-agronomist told the anthropologist that he worked in close collaboration with the farmers every time he went out in the field. By this he meant that he was accompanied by the manager of the perimeter and the head of the county government. In another instance, at the introductory meeting of experts who were going to work together on an irrigation project, the anthropologist was introduced for the first time to the irrigation engineer who said, as they shook hands, ‘What are you doing here, we don’t need you. We know everything we need to know about the farmers’.

Anthropologists or sociologists hired for project teams are often either geographic specialists who know the area but not irrigation and are unaware of the precise information technicians need to make decisions, or they know irrigation but not the geographical area and so they do not understand the local farmers’ interests and social, economic and agronomic constraints. Both options give disappointing results. Technicians and geographically specialized sociologists need to work more closely together so that the sociologists understand clearly the kinds of information that will be useful to the technicians.

From Brown and Nooter (1992)
References


The International Programme for Technology and Research in Irrigation and Drainage (IPTRID) aims to enhance the standard of irrigation and drainage research and development in and by developing countries, giving due regard to the needs of the environment. Its main objectives are to improve technology and management in order to increase the production of food and agricultural commodities, enhance food security and assist in eliminating poverty. The programme focuses attention on four priority themes:

- Synthesizing knowledge
- Building national capacity
- Formulating research and development strategies and programmes
- Networking

IPTRID's sponsors are FAO, UNDP, World Bank, the International Commission on Irrigation and Drainage (ICID), the International Water Management Institute (IWMI), international and national research institutes, multi- and bilateral donors, and development foundations.

For further information about the IPTRID Programme please contact the IPTRID Secretariat at the following address:

Programme Manager – IPTRID
Room B-712
Land and Water Development Division
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla
00100 Rome
Italy

Tel.: (+39 06) 570 54033 Fax: (+39 06) 570 56275
E-mail: iptrid@fao.org
Web: www.iptrid.org

One of IPTRID's priority activities is synthesizing knowledge on topics that are research- and technology-orientated and relevant to sustainable irrigation and drainage development. The outputs are published by IPTRID in its series of Knowledge Synthesis Reports. These reports contain the latest research and development information on selected topics and include analyses and recommendations. The target readership includes planners, researchers and irrigation and drainage professionals. Specialists, in collaboration with IPTRID partner institutions, prepare the reports.

Smallholder irrigation technology: Prospects for sub-Saharan Africa is the third in the Knowledge Synthesis Report series. Previous publications in this series are Treadle pumps for irrigation in Africa (October 2000) and Review of research and development needs in irrigation and drainage (February 2001). Topics to be included in the future include:

- Water conservation technologies in the Mediterranean basin
- Biodrainage

Publication details will be announced in IPTRID's biannual Network Magazine GRID. Requests for GRID magazine and for copies of other IPTRID publications should be sent to the IPTRID Programme Manager at the above address.