**SUSTAINABLE WATER MANAGEMENT FOR IRRIGATION AND DOMESTIC USE**
**A PROJECT OF THE CNFA FARMER TO FARMER PROGRAM**
**AND**
**KITUI DEVELOPMENT CENTER, KITUI COUNTY, EASTERN PROVINCE, KENYA**

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## OVERVIEW

Lack of water availability compounded by inefficient water management practices limit the production of horticultural crops on small homesteads in the Kitui county of Kenya. Kitui possesses a semi-arid climate with a double rainy season. Between March and May there occur what are referred to as "long rains" and the rains referred to as "short rains" run through November and December. Rainfall ranges from 500 to 1050 mm per year with rain events being quite unpredictable. Annual evaporation rates, on the other hand, are relatively high, approximately 2000 mm per year.

Because of the scarcity of water and the unpredictable nature of rainfall events, growers of vegetable and horticultural crops in the area are always looking for ways to maximize water utilization and conservation.

The limitations to agricultural production presented by the semi-arid environment are especially evident in the activities and production of those growers who farm small areas of land. These small-holder farmers work to produce profitable crops on less than one acre. It is a difficult task, and ongoing development work continues in the areas of food security, natural resource management, and poverty alleviation.

## ACTIVITIES

Such small farm operations are scattered throughout Kitui county, and a survey of those growers in the immediate area of Kitui township was conducted during the first two weeks of March 2011.

Survey questions were designed to gain an understanding of on-farm field conditions, crop selection, soil type, current agricultural practices, and grower awareness of water usage and conservation.

The purpose of surveying the small plot farmers was to identify any constraints to efficient water management in the chain of water handling including collection, transport, and application to the field and to develop possible interventions to assist the farmers in the improvement of water utilization.

Small farmsteads around Kiui were visited and the growers interviewed. Survey questions were asked and a picture of the current practices, awareness, and attitudes emerged. Small-plot farmers in the area grow a variety of vegetables and horticultural crops. Vegetable crops grown by these farmers include tomatoes, peppers, kale, onions, and melons.

Meetings with small-holder farmers were conducted in Wikliliye and Katwala between March 12 and March 16. The purpose of the meetings was to establish a dialogue with local growers and to provide a forum for hearing their concerns and learning about their practices, operations and aspirations.

Efforts were made to discern their attitudes about and awareness of water management principles and to offer some fundamental training concerning the goals of irrigation and principles of plant water relations. In addition, question and answer sessions were conducted to gain additional feedback of growers' chief concerns.

Kitui government agricultural officers involved in providing local grower support in the areas of irrigation and horticulture provided important information concerning the area-wide status of water conservation efforts, historical data on water usage and demographics, and cultural practices.

The CEO of SASOL Foundation, the NGO responsible for construction of the Kitui sand dams, was also instrumental in providing an understanding of the challenges of conducting agriculture in a semi-arid environment.

Through the above mentioned on-farm visits, one-on-one interviews, surveys, and group meetings it was possible to arrive at some conclusions about small-plot agricultural water use and practices, as well as grower attitudes and aspirations concerning their livelihoods and the sustainability of small plot farming in this semi-arid region.

**FINDINGS**

Soil in the area was a reddish sandy clay loam with good infiltration and loose structure. Cultivated land area for the small farmsteads visited ranged from one to three acres, with 1/4 to 1/2 acre being irrigated and the remainder being rain-fed.

Growers that were interviewed had access to irrigation water from either a borehole well and kiosk system or from sand dams established in seasonal streams or from shallow wells dug on their property.

Kitui Development Center (KDC) has established a borehole well and a system of eight water kiosks that serve about about 2000 individuals in the Kitui township area. This same borehole also serves about 32 small plot horticultural growers.The establishment and management of the borehole water delivery system enables these growers to receive water piped directly to their homestead for both irrigation and domestic purposes.

Growers who lack access to an established borehole well water distribution system, must acquire water from either shallow hand-dug wells or at one of several sand dams built by SASOL throughout Kitui district.

KDC borehole water recipients pay cash for the water that they receive from either a kiosk or at their homestead. Simple bucket irrigation is the easiest and most common irrigation practice among these small-plot growers, whereby the farmer waters crops by hand from a jerrican, watering can, or bucket.

Users of hand dug wells and of sand dams retrieve water manually in buckets or jerricans. Those who utilize the sand dams scoop depressions in the sand and fill buckets or jerricans with the water that is stored by the sand dam. The water must then be manually transported back to their homestead by foot, by donkey, by motorcycle, or truck. Again, the common irrigation method for these small-plot growers is simple bucket irrigation

Through the meetings and conversations with small-plot farmers, they revealed their eagerness to convert their operations from the customary bucket irrigation methods to small scale, gravity-fed drip irrigation systems.

Bucket irrigation is slow and laborious. Growers walk through their field pouring some amount of water on each plant one at a time. The extent of the area of land they irrigate is limited by the amount of water they are able to collect or, in the case of growers with piped water, the length of hose they are able to practically use. If additional land is irrigated, the grower will fill a bucket with water from the hose and finish irrigating from the bucket.

Additionally, the time involved in walking the field and irrigating manually is a limiting factor and growers sometimes find it necessary to hire a helper to irrigate, increasing the costs of the operation.

Growers can only roughly estimate the quantity of water that is applied to each plant. In fact, the actual quantity of irrigation application is less important to them than being able to completely irrigate every part of the field with at least some water, given the quantity of water they have on hand and time constraints.

In response to the difficulties presented by the scarcity of water resources, the associated costs and labor involved in purchasing and retrieving water, and the limits on production and water conservation presented by bucket irrigation, some growers have undertaken small-scale, low-pressure, drip irrigation techniques.

Low pressure drip systems (also called low-head drip) is a technology that is appropriate for rural areas lacking the infrastructure for pressurized systems. Low head drip systems are gravity-fed and, in the Kitui area, are most common on larger scale farms and in greenhouse operations where the land holder has adequate finances to purchase such a system and can reliably generate enough revenue to recover the costs of purchasing and maintaining the irrigation systems.

A typical low-head drip system consists of a bucket or barrel that is situated on a platform that sits one to three meters above the ground. A main outlet tube or pipe that is attached to a tap at the bottom of the barrel allows water to flow out of the barrel when the tap is opened.

The water passes through some kind of simple filter like a screen, or cloth, or an in-line filter, and into a manifold tube or pipe that lies on the ground, at the head of, and perpendicular to the cultivated rows.

Drip lines with emitters evenly spaced along it's length run down the center of each row of plants and are connected to the manifold tubing at the head end of each row. At the tail end of each row, the drip tubing is sealed.

When there is water in the barrel, and the tap is opened, water flows through the filter, and into the manifold. From the manifold the water flows into each drip line and down the rows. As low pressure builds in the drip lines, water drips from each emitter, at a constant and known rate, onto the ground at the base of each plant.

This method of irrigation has several advantages over simple bucket irrigation. Growers using bucket irrigation will typically irrigate only once a day. Two small applications of carefully measured water is much better than one application of poorly measured water.

Applying a large (and unknown) quantity of water through bucket irrigation can waste water in, at least, two ways.

First, over-application of water pushes the sub-surface wetted front of soil water below the level of the plant root system, making it unavailable for uptake by the plant. Soil water that is below the level

of plant uptake is wasted water that cannot be retrieved or reused. Growers using drip irrigation are able to make two small applications of water rather than one large application. In this way, they avoid applying excess water that is forced below the root zone.
Secondly, applying a larger quantity of water to the base of the plant through bucket irrigation creates a larger surface area of wetted soil. Exposure of this larger surface area to the air and the heat of the day causes greater loss of water to evaporation. In the case of drip irrigation, smaller, more frequent applications of water greatly reduce the wetted surface area and therefore evaporative losses are reduced.

In addition to the conservation of water afforded by drip irrigation, this technology also maintains a more constant overall soil moisture level since water is applied more than once during the day, and the uniformity of application over the area of the field is improved. These two factors combined tend to increase plant growth uniformity and therefore increase yields.

Drip irrigation, therefore, is advantageous over bucket irrigation. It helps the grower to reduce water losses due to over-irrigation and excessive evaporative losses, and it increases yields because it increases uniformity of water application over the entire field.

The increases in output (yields) under drip irrigation are coupled with savings in inputs (water, labor and time). In the case of piped water users, the savings is realized in cash terms as well as in terms of labor. In the case of shallow well or sand dam water users, the savings is in terms of labor and eliminating the need to hire a worker to apply water by bucket.

Due to the increases in production and the savings in water and labor, revenues from a small-holder vegetable operation using drip irrigation can be double the revenues from a comparable small-plot farm using bucket irrigation.

Interviews with small-holder growers revealed that they are aware of the advantages of drip irrigation since they have seen for themselves successful drip utilization on larger properties and in greenhouses in the immediate area.

The small farmers, when interviewed, indicated that the limiting factor in converting from bucket irrigation to low-pressure drip systems is the initial cost associated with the purchase and set-up of the drip systems.

They understand the basic principles of drip system components, installation, maintenance, and operation. They simply do not have the capital to make the purchase, nor are they able to generate sufficient capital from the low yielding small plots they farm.

**RECOMMENDATIONS**

Small-plot growers in the Kitui area were found to be hard-working, driven, and motivated to produce the very best they can with the resources they have. There are likely many who would do well with drip irrigation given the opportunity. With the scarcity of water in the Kitui area and the need for improved food security and increased personal income, drip irrigation may well provide part of the solution.

Several growers showed an interest in learning more about drip irrigation operation and maintenance and in general irrigation and plant water relation principles. In small-holder meetings in Wikliliye and Katwala, growers raised questions about the best times to irrigate and how to determine how much water to apply.

The cost of irrigation systems was always a concern and there were discussions concerning various drip acquisition alternatives. Upon further investigation and through interviews with local agricultural officers, some options for sources of such drip systems emerged. In discussions with growers and advisers, it was proposed that any small plot irrigation system employed on small plot farms must meet certain criteria.

First, the system must be affordable to the small-holder farmers. This may mean that the price of a particular drip system or "kit" used for converting to drip irrigation must be within the grower's ability to pay or to save for. It may also mean that the price is such that a small loan to the grower could cover the cost. It may mean that the manufacturer, the government , or a local NGO subsidize the purchase or that it has a program that helps small-plot farmers pay for a new system over time. Whatever the case, this is the number one consideration for the growers, as revealed in interviews and meetings conducted with them.

Second, the size of the system must me adequate to provide for the cultivation of enough land area that the grower has a realistic opportunity to generate sufficient revenue to pay for the drip system plus any upkeep and maintenance that may be required. It is obvious that a grower needs to be able to realize a profit. A system that is too small, while acting as an introduction to drip technology, will not be sufficient to generate enough revenue to make a difference in the lives of the growers and their families.

Thirdly, the system must be flexible enough to accommodate a variety of farm layouts and arrangements, and allow expansion of the system as the area of a grower's irrigated land increases.

The ability to expand drip operations is important since growers in the Kitui area, in general, presently rely on rainfall to grow crops on much of the land they have available for growing and desire to convert those areas to irrigation.

Fourth, the system must be easy to operate and to maintain. As with any technology, no matter how well it may work, if it is hard to manage, operate, and repair, it will likely fall into disrepair and become just another failed development artifact.

In regards to this aspect of the drip system, it would be best to purchase locally available parts or systems. Not only does this make installation and repair more practical and affordable, it injects money into the local economy and improves the economic status of multiple individuals.

There are some organizations that offer a complete bucket drip irrigation kit, or "bucket kit", that is sold as a package. Chapin Third World Products, a Division of Chapin Watermatics Inc., is one company that is well known in some parts of the world (~~www.chapinlivingwaters.org~~). Chapin offers a kit that is very affordable and, reportedly, very reliable.

Chapin helps growers purchase the systems through a subsidizing program. Some drawbacks of this system are that it is small, only providing for two 50 foot rows of drip irrigation and it is not manufactured locally, but is made in the United States. Also, some reports indicate that Chapin bucket kits may not be necessarily rugged enough for some applications.

The Kenya Agricultural Research Institute (KARI) also sells a complete, self-contained drip "kit". The kit they offer covers a larger area (about 1/8 acre) and sells for 20,000 Kshs (242 USD). The biggest drawback to this and other drip "kits" is the inability to increase the size of the area irrigated.

Improvements to the drip "kit" concept have been made and simple low-head drip systems can be designed and purchased that are up-scalable and constructed of locally available components.
The original bucket kit, with a 20 liter bucket as the water reservoir, placed at a height of about one meter, can be improved and expanded upon. If, for instance a 40-100 liter jerrican is used, more water can be delivered to a larger field. Instead of two rows of drip irrigation, the grower can now water eight or ten rows of plants.

The system can be even further expanded if a larger reservoir tank is used. "Drum" or "mini-tank" systems can range from 200-1500 liters with the reservoir raised to a height of 1 to 1.5 meters and able to cover more than ten to twenty rows of plants.

In the above systems, the component parts are locally available. Such parts include 2.5 cm polyethylene (PE) pipes and PVC connectors, filter and silt trap, "barbs" or lateral connectors, gate valve, end plugs, and drip lines (sometimes called laterals).

The below list (supplied by Raymond Lal, Agricultural Officer in Kitui) shows names of local suppliers that could possibly provide the needed components:

Shade Net - Thika
G. North &Son - Nairobi
Hortipro - Nairobi
Amiran - Nairobi
African Hydroponic - Nairobi
Agro-Irrigation - Nairobi

Information on pricing and availability would have to be determined from each of these companies in order to know the best supplier to purchase from.

It should be noted that the low-head drip systems above can be adapted to irrigate permanent tree crops that have irregular tree spacing. "Blank" drip lines (drip tubing with no drip emitters installed) can be fitted with "button" emitters that can be inserted anywhere along the drip line (i.e., at the base of each tree) where application of water is desired.

The table below shows the cost ranges of various drip kits in both USD and KShs. This table was adapted from a research paper authored by:

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| Specification of Drip Irrigation Systems | Area (sq. m) | Cost (US $) | Cost (Kshs) | Cost (Kshs/sq.m ) |
|---|---|---|---|---|
| ***20-liters bucket kit*: 2 laterals of 15m; 4 laterals of 7.5m; or 6 laterals of 5m; with 15-30cm emitter spacing** | 15-20 | 22 | 1,815 | 103 |
| ***50-liters jerrican kit*: 4 laterals of 15m; 6 laterals of 10m; or 8 laterals of 7.5 m; with 30-60cm emitter spacing** | 30-40 | 40 | 3,300 | 88 |
| ***70-liters jerrican kit*: 6 laterals of 15m; 8 laterals of 10m; or 12 laterals of 7.5m; with 30-60cm emitter spacing** | 50-60 | 62 | 5,115 | 93 |
| ***80-liters jerrican kit*: 8 laterals of 15m; 12 laterals of 10m; or 16 laterals of 7.5m; with 30-60cm emitter spacing** | 60-80 | 75 | 6,188 | 88 |
| ***100-liters jerrican kit*: 10 laterals of 15m; 16 laterals of 10m; or 20 laterals of 7.5m; with 30-60cm emitter spacing** | 80-100 | 93 | 7,673 | 85 |
| ***150-liters mini-tank kit*: 12-16 laterals of 15m; or 20 laterals of 10m; with 30-60cm emitter spacing** | 150-250 | 130 | 10,725 | 53 |
| ***200-liters drum kit*: 12-16 laterals of 20m, or 16-20 laterals of 15m; with 30-60cm emitter spacing** | 300-500 | 172 | 14,190 | 35 |
| ***500-liters tank kit*: 32-40 laterals of 20-25m; with 30-60cm emitter spacing** | 800-1,000 | 357 | 29,455 | 33 |

From surveys and inquiries mentioned in this paper, all indications are that the chief constraint that small-scale growers experience, in terms of improving their water management activities, is purely a monetary one.

Creative financing strategies, however, may be utilized to reduce or eliminate the burden on the grower to raise initial start-up costs for a conversion to drip irrigation. In interviews with individual farmers and groups of growers, they have been found to be enthusiastically willing to take on the financial responsibility of paying back a small loan if it means an opportunity to convert their plots to drip irrigation.

Financial tools like revolving credit with assistance from non-governmental organizations can help to initiate the introduction of drip irrigation to small plot farmers who may otherwise be reluctant to or unable to make that expenditure.

Introduction of drip irrigation to small-holder farmers currently utilizing bucket irrigation may be initiated and sustained through:

1. assistance in the area of financing,

2. assistance in the design, purchase, and installation of low-head drip irrigation systems,

3. appropriate training in the techniques of and the operation and maintenance of drip irrigation, and

4. follow-up monitoring and assistance.

In this way, small scale growers who make multiple trips to the sand dam to retrieve water, or who purchase water from a borehole and kiosk system, and who are presently laboring on unprofitable plots, and irrigating by methods that are less than conservative and efficient, may experience greater profitability, opportunities for growth, greater food security, and a higher standard of living.

**FOLLOW-UP**

As a follow-up to the discovery phase comprised of the surveys, interviews, and meetings mentioned above and leading to the above-stated conclusions, there are various "Next Steps" that could be taken to initiate and support small-grower conversions to drip irrigation and to promote the initiation, manageability, and sustainability of a grower assistance drip irrigation implementation program.

* Determine if initiation of a drip system assistance program for small-scale growers is appropriate

* Perform a cost/benefit analysis comparing cost and revenues from bucket irrigated crops with cost and revenues from drip irrigated crops. It would be important to collect hard data from growers who are using both methods of irrigation over at least one growing season, preferably more.

In making comparisons it will be necessary to compare cost and revenue of different farmsteads of different sizes, using different irrigation methods. It may, therefore be best to compare data on a per acre basis or even costs and revenue per square meter. It may also be helpful to analyze only vegetable and row crops and to not include tree crops in the cost/benefit analysis.

The process of data collection should begin early. Select farmers could be chosen and trained on what records to keep and how to keep them. Data concerning grower inputs of finances, water, labor, and time and their revenue earned could be compared in order to determine the actual monetary benefit to the grower of converting from bucket irrigation to drip irrigation.

This data will be important for translating observed benefits and perceived profitability into measurable and reportable values. Reporting these values would be of help during the search for funding and could provide real-world data that can be used in promoting the drip irrigation program and in writing grants and proposals.

* Secure grant funding to begin project

* Contact drip equipment suppliers to get most current prices of various drip components and systems

* Develop grower assistance/revolving credit program to meet the needs of growers and KDC

* Identify eligible growers according to prospects for success and grant requirements

* Interview, visit, and survey eligible growers to determine best drip system to suit their needs based on crop selection, size of area to be irrigated, grower aspirations

* Ensure that grower land is ready to receive drip irrigation (ground preparation, crop selection and placement, row orientation, slope of land, tank site selection, etc.)

* Conduct training on drip system installation, operation, and maintenance (including drip application to different crops, determination of irrigation timing and application, plant water relations and soil, weed, and pest management, etc.)

* Assist grower in developing a feel for their specific land, crop and system needs and challenges

* Develop and maintain a system of monitoring and assisting growers when issues arise with maintenance, repair, obtaining spare parts, answering questions, troubleshooting, etc.

* Maintain relationship with suppliers

* Assist growers in obtaining and installing components if they have a need to expand or change their drip system

**WATER HARVESTING, RECYCLING, AND CONSERVATION TECHNIQUES, AND OTHER SECONDARY RECOMMENDATIONS**

Water conservation and water harvesting are a constant concern in semi-arid Kitui county, Kenya. Sand dams that have been constructed in the area create, in effect, a localized artificial aquifer that stores water normally lost as streamflow. The sand that is carried down the stream during the times that it does rain is deposited at the sand dam.

This built-up sand settles and stores stream water that can be retrieved by digging a depression in the sand to the stored water level. Additionally, shallow wells are often constructed adjacent to the stream and the sand dams, since increased storage of water at the sand dam causes a rise in the water table adjacent to the stream.

Rainwater harvesting for domestic use and for supplemental irrigation is common. Large tanks are often situated next to houses with gutters for collecting rainwater from the roof and channeling it into the tank.

Additional water harvesting techniques may be useful. In addition to roof catchments for rainwater collection, ground catchments may also be used.

Ground catchments could be designed in a couple of ways. A slightly sloped parcel of ground of, say 100 square meters, could be cleared of all vegetation. Plastic lining could be laid down on the bare ground to make the ground surface impermeable. At the downhill end of the slope a small trench is dug just large enough to hold a 15cm or 20cm PVC pipe, slotted or perforated all along the length and halfway around the circumference.

The perforated pipe lays across the downhill edge of the catchment area with perforations facing up. Water runs down the hillside, into the perforations and runs down the length of the pipe into a collection tank.

Alternatively, a basin could be dug out and lined in the same manner as fisheries around Kitui dig out and line their fish basins. Rainwater could be channeled into and collected in these basins. A sun screen could be stretched over the basin to reduce evaporation.

Recycling greywater may be another way of conserving water for purposes of irrigation. Greywater is household water that has been used for washing dishes, laundering cloths, or bathing. It includes any water, other than toilet waste, left over from household activities. Greywater, although it may contain grease, food particles, hair, and other impurities, can be coarsely filtered and added to a drip system.

Water collected or recycled can be used as supplemental irrigation water, added to the drip tank, and providing additional water savings to the grower's operations.

Although sanitation facilities and practices were not part of this study, one practice that may be useful for small-plot farmers (and one that is being practiced by a few) is composting human waste material.

Compost latrines can be built that allow for the combination of waste material with other organic matter such as ash and plant material and composting them. The resultant material can be safely applied to crops as fertilizer for crops and organic matter for soil conditioning.

Further inquiry and investigation would be required to determine if compost latrines and use of the resulting compost would be culturally acceptable and practical for use.