Annex 1 for 'Improving rural livelihoods by rainwater harvesting in the lowlands of Mt. Kilimanjaro, Tanzania'.

Feasibility of rooftop rainwater harvesting for domestic and drip irrigation use

Introduction

Quantitative assessment of the feasibility or profitability of rainwater harvesting from rooftops for domestics and irrigation use is not easy. There are very many variables and options. However, it is a useful exercise in that it demonstrates that there are options which give rise to very considerable benefits. It also reveals some of the variables that have most impact on performance of the system.

Some of the unknowns in the system are a consequence of the nature of the project, which aims to (a) introduce new tree and crop options which have not previously been grown in the area (b) encourage households to explore options for water harvesting and use, rather than dictate a standard system. The results should therefore be seen as examples of what could be achieved, with the expectation that some households will realize different, likely greater, benefits.

Two irrigation system types

The most efficient small drip irrigation system is a bucket system. The system can irrigate 10–20 m^2, depending on the length of the drip tube and plant spacing, using 30-60 l water per day. The cost of such a system is about US$ 15-20. These small systems are called bucket systems. A bucket kit system comprising two 15 m long drip lines can be used to grow 50 plants such as tomato, egg plant and similar crops requiring a spacing of 60 cm along the plant rows; 100 plants of spinach, cabbage, kale, pepper and similar plants requiring a spacing of 30 cm along the plant rows; or 300 plants of onion, carrot and similar plants requiring a spacing of 10 cm (Sijali, 2001[1]).

For bigger catchments such as school or church roofs, a drum system could be considered. An area of up to 1,000 m^2 can be covered by a drum system. This presents an economic advantage because of the number of plants per drum system. A typical drum system covering 5 beds each 1 m wide and 15 m long can be used to grow 5 times more plants than the bucket system can support, but uses 5 times as much water. To install a drum system costs slightly over US$100 (Sijali, 2001).

Rainfall, tank size, roof area and water for domestic use and drip irrigation with a small-scale bucket irrigation system

An MS Excel based model was used to evaluate the feasibility of both domestic and irrigation water use. There are many variables in such a system, and we started with typical values of a 40m^2 roof area, 80% efficient collection and a 10,000 l tank. Studies by Soini (2005) in the area showed a household size of 6.2 persons. However,

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[1] Sijali, Isaya V. 2001. Drip irrigation, Options for smallholder farmers in eastern and southern Africa. Sida's Regional Land Management Unit, Nairobi.

5 persons per household was used in the calculations on the assumption that small children may use less water than the average water usage for adults. The input was monthly average rainfall values for Moshi (average annual 879mm), shown in Figure 1. The irrigation water modelled the amounts that might be used to supplement or fully irrigate a typical small plot managed by bucket drip system. Different scenarios and the sensitivity of the system were studied by varying the parameters.

Households are able to collect almost 29,000 litres of water with a 10,000 litre tank and roof area of 40 m^2 in a year. This is an enormous benefit. The domestic water (about 25,000 l) was earlier carried to the homestead but this amount and the additional water for irrigation (about 5000 l) is now available from the homestead itself.

It is not our intention to tell farmers how they should use the water for domestic consumption and irrigation. Different options and the consequences will be explained, but the choice is theirs. The scenarios described below are included to show that there are viable options, and to show a range of possible benefits.

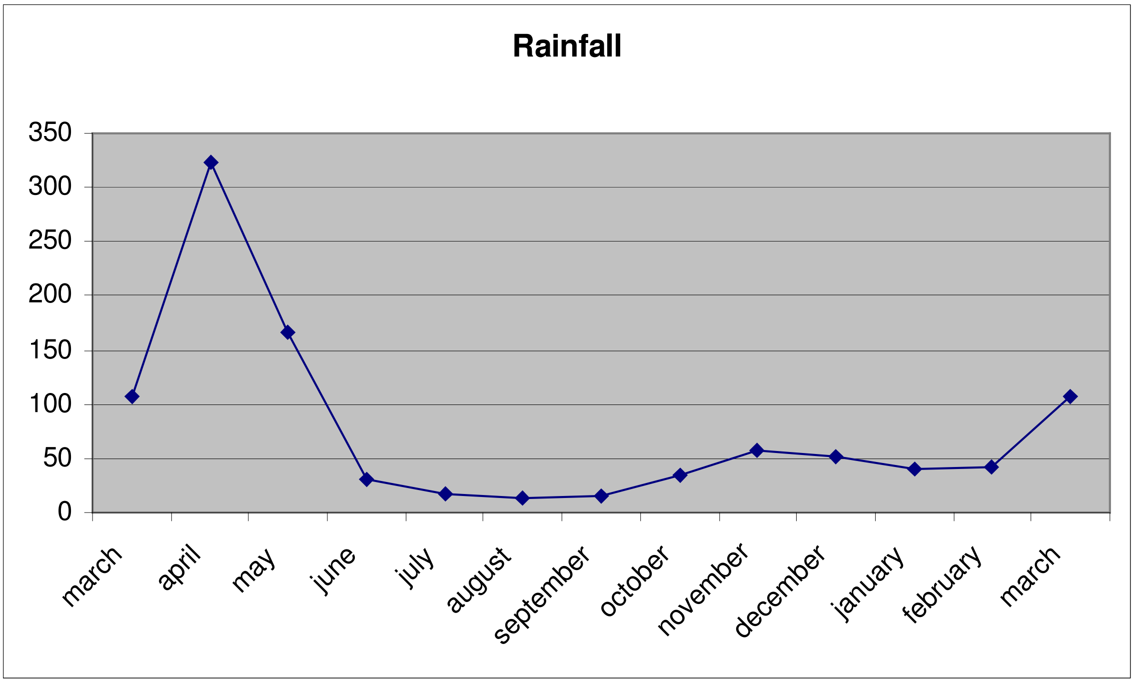

Figure 1. Average monthly rainfall in Moshi (1930-1988). Annual total = 879mm, standard deviation 265.

Different water use scenarios were visited and are shown in Table 1.The first line summarises a scenario with a domestic water usage of 23,850 l/year with a regime of 20 l/person/day in March-May and 11 l/person/day (Rwehumbiza et al. 2000[2]) in June-February. Land is irrigated during all months (total 5100 l) other than during the long rains (March, April, May): 28 l/day is used for four months to supplement rainfall of the short rains (Nov - Feb) to obtain a second harvest. 10 l/day is used for irrigating a small area (e.g. tree seedlings) during the four driest months (June-

[2] Rwehumbiza, F.B., Mahoo, H.F. and Lazaro, E.A. 2000. Effective utilization of rainwater: more water from the same rain, in Hatibu, Nuhu & Mahoo Henry F. (eds.), Rainwater harvesting for natural resources management: A planning guide for Tanzania.

October). Figure 2 shows the tank water content for this example. As an alternative, the main irrigation time can follow the long rains to extend the cropping season. The tank content diagram would be similar but with content decreases more quickly after the long rains. The seasonal adjustment of water use is based on experience in Kusa, where farmers have adjusted their water use according to availability (Odhiambo et al. 2005[3]).

If the second crop irrigation season (short rains) is reduced from four months to three months and the domestic consumption level is kept the same (March-May 20 l/person/day; June-February 11 l/person/day) it is possible to raise the daily irrigation level to 34 l/day. This would allow permanent irrigation of a kitchen garden with the bucket system. Reducing the number of months from four to three with the regime of 28 l /day irrigation, only marginal increase in domestic use per person is obtained (0.5 l per person / day).

Table 1. Examples of water use regimes with tank sizes of 8,000 and 10,000 litres and the roof area of 40 m2 and 80% efficiency in water collection.

Tank size (l)	Domestic use	Irrigation	Water deficit (l)
10,000	Total: 23,850 l/year March-May 20 l/person/day June-February 11 l/person/day	Total: 5100 l March-May: no irrig Nov-Feb **(4 months): 28 l/day** June-Oct (5): 10 l/day	0
10,000	Total: 23,850 l/year March-May 20 l/person/day June-February 11 l/person/day	Total 4,860 l March-May: no irrig Nov-Jan **(3 months): 34 l/day** June-Oct, Feb: 10 l/day	0
10,000	Total: 23,850 l/year March-May 20 l/person/day June-February 11 l/person/day	Total 5,850 l March-May: no irrig Nov-Jan **(3 months): 45 l/day** June-Oct, Feb: 10 l/day	972 Jan-Feb
10,000	Total: **28,890 l/year** March-May **22.8 l/person/day** June-February **13.8 l/person/day**	No water for irrigation	0
8,000	Total: 23,850 l/year March-May 20 l/person/day June-February 11 l/person/day	Total: 2,880 l March-May: no irrig Nov-Jan **(3 months): 12 l/day** June-Oct, Feb: 10 l/day	2 Feb
8,000	Total: 23,850 l/year March-May 20 l/person/day June-February 11 l/person/day	Total: 4,320 l March-May: no irrig Nov-Feb **(3 months): 28 l/day** June-Oct (5): 10 l/day	1442 Jan-Feb
8,000	Total: 23,850 l/year March-May 20 l/person/day June-February 11 l/person/day	Total: 5,850 l March-May: no irrig Nov-Feb **(3 months): 45 l/day** June-Oct (5): 10 l/day	2,972 l Dec-Feb
8,000	Total: 23,850 l/year March-May **22.1 l/person/day** June-February **13.1 l/person/day**	No water for irrigation	0

[3] Odhiambo, Orodi J., Oduor, Alex R. and Maimbo M. Malesu. Impacts of Rainwater harvesting. A case study of rainwater harvesting for domestic, livestock, environmental and agricultural use in Kusa. Technical Report No. 30. Regional Land Management Unit (RELMA-in-ICRAF) and World Agroforestry Centre (ICRAF), Nairobi.

To be able to keep the same regime of domestic use with a 8,000 l tank, one can irrigate 28 l /day for only three months, and a water deficit of 1442 l is created.

The system is very sensitive to changes in domestic water use as the small changes in daily use per person are multiplied by five, the average household size. Family size will therefore play a major role in how much will remain for irrigation. In another scenario, if the domestic water use increases to 22.8 l/person/day for March-May, and 13.8 l/person/day for June-February (total usage of 28,890 l), the tank water is just enough to satisfy the domestic water needs of a family of five, but will not be sufficient for any irrigation at all.

By doubling the roof area but not increasing the tank size, 45 l per day can be used to irrigate for four months, the rest of the months water use remaining at 10 l/day and long rains remaining without irrigation. At the same time domestic water usage can be raised from 11 l/person/day to 17 l/person/day during June-February. Alternatively, one could keep the domestic water usage at the lower level and irrigate nine months of the year (all except the long rains) with 54 l/day rate. The larger collection area allows useful amounts of water to be harvested during small dry season showers.

In all the regimes January-February and early March before the long rains start are likely to be the months when water deficits emerge.

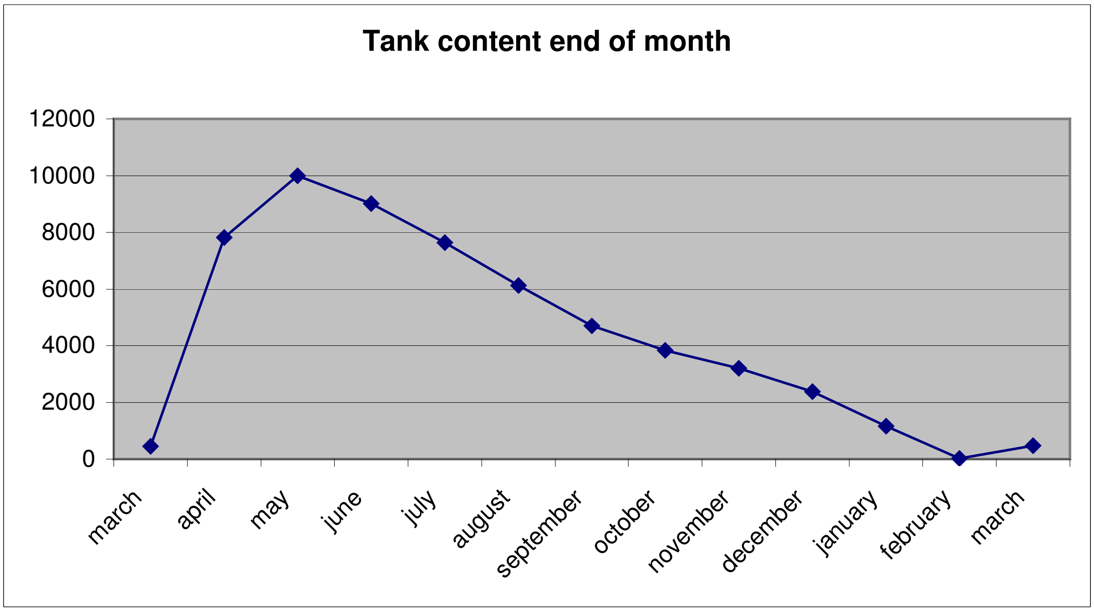

Figure 2. Diagram showing the water content in the 10,000 l tank with domestic water usage and a likely irrigation regime aiming at producing a second harvest during the short rains.

A further source of variation, which is important in the area, is the variation in rainfall amounts between years. Studying the effect of this will require a much fuller analysis. However it is clear that:
(a) years with above average rainfall will allow more water to be used for either domestic or irrigation, for example extending the cropped area during the dry season. Some crop options are able to exploit variable water availability.
(b) during years with below average rainfall the harvesting and tank will buffer families against the worst effects of drought.

Depending on the crops grown, 30 to 60 litres of water will be needed to irrigate an area of 15 m^2, a strip of 15 m long and 1 metre wide. As the calculations (above) show, irrigation water use in the project area (with a 5 person household) with a roof are of $40m^2$ and a tank size of 10,000 l can range between 28 l to 45 l over a three or four month period. About one third of the total area will be irrigated for 5 months of the year (e.g. to keep tree seedlings alive). To adjust to the varying area under irrigation, the system needs to be built in a way that allows size adjustments to be made.

Benefits

Well-known benefits from rainwater harvesting in rural Africa include the following:

- Improved food security
- Time that was earlier used to carry water can be used for a productive activity
- Health benefits from reduced work, increased amount of vegetables in the diet, better water quality, better hygiene
- Saved cash when vegetables do not need to be bought for home consumption
- Reduced amounts of money needed to treat water borne diseases
- Cash from sales of vegetables and/or tree seedlings

It is difficult to calculate a monetary value for any of these. Some attempt was made to estimate income from vegetable crops grown in the area by few farmers living near to the few irrigation furrows (Table 2). Some of the weaknesses of the calculations include:

- Crop prices vary enormously within the year. For example, in 2002 maize prices varied from Tsh 9,000 to Tsh 30,000 per bag and tomatoes from Tsh 200 to Tsh 4,000 per debe (Soini 2002[4]). However, irrigation gives farmers the flexibility to produce during seasons when prices are higher, though increasing irrigation will tend to reduce the seasonality in prices. We do not know where new prices would settle.
- It is hard to estimate yield levels: for some crops like kales, literature gives only very rough estimates (Grubben and Denton 2004)[5]. This is due to variation caused by
    - different regimes of growing the crop, either harvesting once, or several times over several months
    - level of fertiliser/manure used
    - how the soil has been tilled
    - whether there is shade or not
    - levels of weeding
    - the water use regime of the household determining how much water is available for growing the vegetables etc.
- Soini (2002) found huge variation of crop yields (e.g. maize, beans, groundnuts) in this particular project site in locations just a kilometre apart.

[4] Soini E (2002) Livelihoods on the southern slopes of Mt. Kilimanjaro, Tanzania: challenges and opportunities in the Chagga homegarden system. Natural resources problems, priorities and policies Working paper series 2002-3. World Agroforestry Centre, Nairobi

[5] Grubben, G.J.H. and Denton, O.A. (eds), 2004. Plant resources of tropical Africa 2. Vegetables. PROTA Foundation, Wageningen.

For example, maize production on a lowland field varied from 350 $kgha^{-1}$ to 6,000 $kgha^{-1}$. However, we do know that kitchen gardens tend to have higher yields per unit area than fields because small areas can be managed well and kept fertile.

- The particular crops included in the table were picked because information on prices was available. However, while the crops in the table will be good for home consumption they may not be the best options for cash crops. One of the aims of the project is to diversify crop production by introduction of new crops. A market study will be needed before calculations can be made for such new crops.
- The exact area that can be irrigated by the available water depends on crop water use efficiency.
- Some of the crops and trees made available to interested farmers may bring income only after several years time lag (fruit trees), but may even become the backbone of the economy (like coffee once did for the highlands).
- The crops in the table might not be the ones farmers choose to grow. It is the individual choice of each household or a choice of a group.

Table 2. Examples of crop production and income derived from a 15m² irrigated kitchen garden.

Plants produced	Produce in one season (kg)	Price obtained Tsh/kg	Value of the crop in a year (TSh)	Value of the crop in a year (US$)	% of the per capita GNI
300 plants of onion	60	800	48000	43	13.1
300 plants of carrot	60	600	36000	33	9.9
100 plants of cabbage	200	300	60000	54	16.4
100 plants of kale	90	400	36000	33	9.9
100 plants of pilipili	54	800	43200	39	11.8
50 plants of tomato	90	800	72000	65	19.7
300 tree seedlings			30000	27	8.2

The gross national income per capita in Tanzania is US$ 330 (World Bank 2005[6]). To this the relatively modest cash incomes from irrigated production could make a substantial difference. Naturally the non-cash benefits must be added.

Cost sharing of the rainwater harvesting structures in the project

Table 3 gives the costs of materials and labour costs for construction of tanks and irrigation kits.

Table 3. Cost of water tanks and irrigation kits (sources: Sijali (2001), Mbugua (2004)[7])

Item	Cost (€)
8,000 l tank	395
10,000 l tank	475
gutters	50
bucket drip irrigation kit	20
drum drip irrigation kit	100

[6] World Development Report 2005. Washington: World Bank.
[7] Mbugua (2004) Rainwater harvesting systems are Pangani catchment Makania Tanzania. Final Report. RELMA/ICRAF/SEARNET, Nairobi

The project will pay the full costs of 6 demonstration tanks in locations chosen by communities. These will serve the additional purpose of training fundis. The project will pay 50% of the costs of 16 further tanks, again the community deciding on criteria for selecting tank locations.

In 4 locations drip irrigation systems will be installed for training purposes and the project will pay the cost of these. The project will pay 50% of the costs of bucket drip irrigation systems for other tanks.