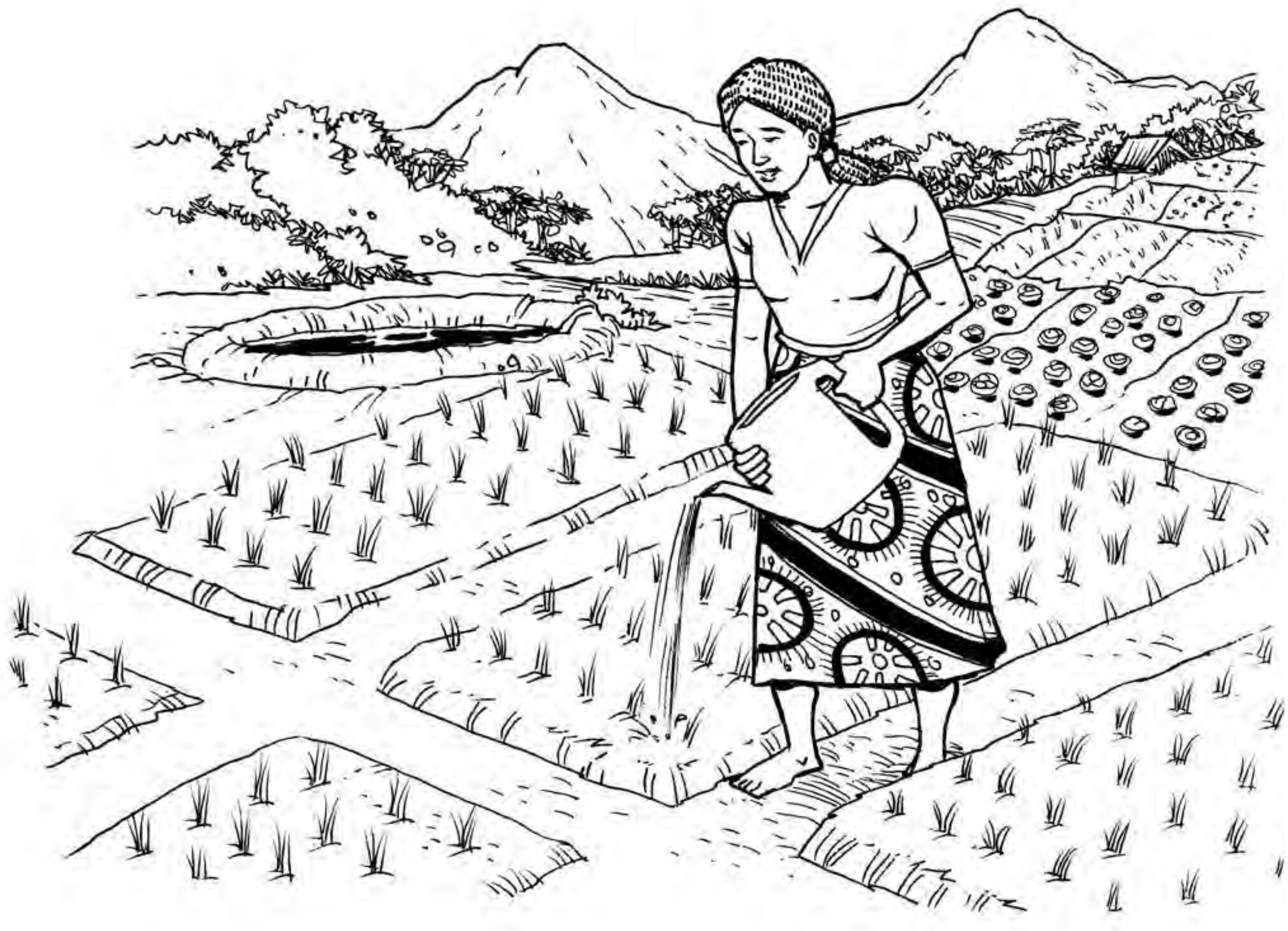
Economic Benefits of Rainwater Harvesting Technologies to Farmers:

Evidence from Minjar Shenkora District of Amhara Region



Over the last three to four decades, farmers in sub-Saharan Africa (SSA) have experienced weather-induced problems such as drought, prolonged dry spells, erratic rainfall, and floods. The average incidence of severe drought has been on the increase, with seven serious droughts occurring in Africa from 1980 to 1990 and 10 others between 1991 and 2003. The result is that drought-induced crop failures are prevalent in the region (FAO, 2005). There is broad agreement that one of the biggest climate change impacts will be on rainfall, making it more variable and less reliable (Lenton and Muller, 2009).

To counteract such problems, various agricultural water management (AWM) technologies can be used by smallholder farmers to improve production and productivity (Mati, 2007). Rainwater harvesting (RWH), which is about collecting, conserving, storing, and utilizing rainwater for various purposes, is one such technology. Rockström *et al.* (2007) indicated that rainwater harvesting has great potential to contribute to poverty reduction efforts by improving land productivity and profitability in rainfed areas in Africa. Rainwater harvesting interventions could also be useful as an adaptation method responding to climate change.

In Ethiopia, massive RWH structures were constructed in 2003–04. For example, 14,976 structures were constructed in the Amhara Region alone (BoWRD, 2005). Nearly 88% of the structures were built in moisture-deficient districts. However, the returns on investment and socioeconomic impacts of this investment remain largely unquantified and, thus, unknown.

The objective of the study was, therefore, to determine the impacts of RWH on agricultural productivity, household income, return on family labor and, overall, to assess the viability of the investment. The study explores the potential value of RWH in the transformation of smallholder agriculture and rural livelihoods but also warns against the dangers of inappropriate use of RWH not only in Ethiopia but also in SSA.

Study context

This study was undertaken in Minjar Shenkora District of the Amhara Region, Ethiopia, where uneven and erratic rainfall is a common occurrence. The lack of potable water near homesteads increases the workload of women and children who have to travel long distances to fetch water as there are no permanent rivers in the area (MSWoARD, 2008).

Rainwater harvesting in the area started in 2004 initially involving 308 households. By 2008, the number of those adopting the technology had expanded to 7,618 households. Some farmers even own more than one pond. About 45% of the harvested rainwater was used for onion seedlings and fruit production, 50% and 5% went to farm households' consumption and livestock, respectively. Pond size and water-holding capacity differed from one agroecology to another due to water evaporation and seepage losses. The net water volume harvested was estimated to be 95 m^3, 90 m^3, and 80 m^3 in the highland, mid and lowland areas, respectively. On average, 100 m^2 of land was cultivated with one RWH pond.

Study approach

The impact of the technology was evaluated by comparing the situation with and without (control) RWH schemes. Farmers, stratified into three categories based on altitude, (highland, midland, and lowland), were identified with the assistance of technical staff from the district office of agriculture. One peasant association (PA) from each stratum and 30 farmers per PA were then randomly selected. Field data were collected through farm visits and interviews. Data such as yield (kg/ha/year), farm-gate prices (US$/kg), amount and cost of all agronomic inputs, costs of husbandry practices, harvesting, handling, and marketing, and establishment and maintenance costs were collected. In total, 90 farmers were interviewed and their ponds assessed. In addition, group discussions were held with experts and leaders of the respective PAs.

The average prices of inputs and outputs for the year 2007 were used as the basis for calculation. A profitability analysis was done using the average cost of inputs and farm-gate prices of produce. Return to family labor was determined by dividing the net income or profit, excluding the costs of family labor with the number of family labor inputs in adult-days.

Evaluation criteria for financial feasibility such as the net present value (NPV), internal rate of return (IRR), and return on investment (ROI) determined whether the technology was profitable or not. NPV compares the value of a dollar today to the value of that same dollar in the future, taking inflation and returns into account. The difference between the sum of all discounted benefits and costs represents the NPV. IRR is the discount rate under which the discounted benefits are equal to the discounted costs—i.e., where the NPV is exactly zero. ROI is also a performance measure used to evaluate the efficiency of an investment. It is the ratio of money gained or lost on an investment relative to the amount of money invested.

Results

Viability for improving productivity and profitability

Results of crop productivity and profitability are presented comparing 'with' and 'without' scenarios. Under the 'without' scenario, farmers were mostly reliant on field crops—i.e., teff and wheat. After the introduction of RWH, farmers grew vegetables in small gardens as well as in the fields. Of special interest were onions, which have been dealt with in the analysis. Onions were important because the availability of harvested rainwater enabled farmers to grow onion seedlings during the dry season, making them available for planting at the onset of the rains. This, in turn, made it possible for onions to be grown as a rainfed field crop by more farmers, including those without storage ponds. The area became a source of onions as a marketable crop. In the 'before' scenario, the average yields of teff and wheat were 1.85 and 2.84 tons/ha, respectively. Teff is considered a cash crop, earning an average farm gate-price of US$ 0.4708/kg compared with wheat at US$ 0.282/kg. Consequently, although wheat has higher yield, the gross incomes from teff and wheat were US$ 871/ha and US$ 801/ha, respectively (Table 1).

On the other hand, onions are a bulky cash crop, yielding, on average, 13.36 tons/ha and an average farm-gate price of US$ 0.169/kg, which translates into a gross income of US$ 2,258/ha. In addition, onion seedlings were also sold as cash crops, produced on plots measuring 100 m^2 (0.01 ha) and using about 40 m^3 of water from the pond. Onion seedlings earned a gross income of US$229 (Table 1) when farmers sold extra seedlings. As a result, the gross incremental income due to RWH for onions alone adds up to US$ 2,487/year per household. The average net income of rainfed teff, wheat, and onion was US$ 523, US$ 525 and US$ 1,848/ha/year, respectively. On the other hand, the average net income of onion seedlings was US$ 155/100 m^2 per year. Similar results were found by Mulinge *et al.* (2010) in Lare Division, Nakuru District, Kenya, where the increment in net income with supplementary irrigation was US$ 110, US$ 625, US$ 1,428, and US$ 4,603/ha for cabbage, kale, tomato, and onion, respectively, against rainfed agriculture.

Profitability analysis was done using the average prices of inputs and outputs, excluding family labor (Table 1). The average net income excluding family labor was US$ 2,100/ha for rainfed bulb onions, while teff and wheat, also rainfed, earned US$728 and US$685/ha, respectively. The average net income of seedling production with RWH ponds was US$ 118.13/year from a 100 m^2 area of land. The costs of production are generally low since farmers use family labor and low levels of inputs. About 72% of the total cost of seedling production with RWH was family labor. It also comprised the largest share of input cost for rainfed field crops.

Total family labor and gross economic returns to family labor are presented in Table 2. The return to family labor of RWH is determined by subtracting all costs from total revenue, excluding family labor inputs. Dividing this net profit with the number of family labor in man-days gives the gross return to family labor. Thus, the family labor used in the production of bulb onions, teff, and wheat per hectare was 150, 120, and 90 man-days, respectively. Meanwhile, onion seedling production used 13 man-days per 100 m^2 while production of bulb onion crop used 163 man-days per ha.

The study indicates that the gross return to family labor from onion seedlings under RWH was US$ 13.6 per man-day, while incremental return to labor due to the rainwater harvesting intervention was US$ 15 per man-day. By contrast, the returns to family labor for rainfed wheat and teff were only US$ 7.6 and 6 per man-day, respectively. This indicates that the returns to labor with RWH are significantly higher than those in rainfed systems.

Return on investment

A financial analysis (cost-benefit analysis) based on agricultural enterprises alongside RWH with storage ponds was done. Initial investment costs of RWH were US$ 154, 175, and 187 per pond in highland, midland, and lowland areas, respectively. The maintenance and production costs were US$ 48.8,

***Table 1**. Gross and net incomes (US$) from major crops at Minjar Shenkora.*

Crop type	Mean gross income	Cost of inputs	Net income
Teff rainfed	871	348	523
Wheat rainfed	801	276	525
Onion seedlings	229	74	155
Field onions rainfed	2258	410	1848

35.8 and 27.1 per pond in the highland, midland, and lowland areas, respectively. The gross incomes from seedling production were US$ 301, 212 and 174 in high, middle, and lowland areas, respectively.

The average discounted benefits and costs of RWH for onion seedling production were US$ 1,527 and 304, respectively. In general, assuming a discount rate of 10%, the average NPV of investment in storage ponds over 7 years was about US$ 1,223. (The economic life of a RWH pond is estimated to be around 7 years in the study areas). Moreover, the average financial IRR for the three agro-ecologies was 202%. The average ROI was also 483%. All these showed the financial variability of RWH ponds (Table 3).

The real benefits of RWH would have been much higher than the calculated values if the water amount used for domestic purposes and livestock (about 50% of harvested water) had been considered in the analysis. Rainwater harvesting reduced long distance travelling of animals to watering points and, thus, the energy wasted can improve the performance of animals in terms of more meat and milk. The work burden of women and children and the time required to fetch water from distant rivers and streams helped them engage in other productive farm activities such as watering onion seedlings.

The economic potential of RWH is very clear as seen in this study. However, the history of RWH in Ethiopia is dogged by many failed programs. To ensure the uptake and sustainable use of the technology, attention needs to be given to policy support for the technology to encourage farmers to adopt it. The technology is also only appropriate where there is water stress. The exact technological options chosen are also critical and need to be both cost-effective and durable. For example, the concrete domes have not been as successful as geo-membrane structures, which themselves have failed where inappropriately laid or not maintained. In addition, the right crops for cultivation need to be selected, i.e., ones that generate a quick and high return, such as onions.

Key limitations

Some health hazards associated with RWH and storage include pests, especially mosquitoes in lowland parts of the district. There were also safety concerns since the ponds are open, while contamination of the water reduces its value for domestic use. Many farm households fenced their water-harvesting ponds to prevent entry of animals and protect children from danger. Water treatment is also required if households use the water for domestic purposes.

Conclusion

Rainwater harvesting has positive multiplier effects—improving the productivity and income of smallholder farmers while addressing the prevailing problems of moisture stress in the area. In the study area, before RWH was introduced, high-value crops such as onions, which can bring about a quick and high return on investment, were not widely cultivated due to lack of water. With the advent of the RWH technology, it was possible for farmers to grow onion seedlings on about 100 m^2 in the dry season and sell or plant them during the rainy season. The results

Table 2. *The average total family labor inputs and gross return to family labor.*

Crops/system	Total family labor	Net income excluding family labor (US$)	Return to family labor (US$/man-day)
Teff rainfed	120 (man-days/ha)	728	6.0
Wheat rainfed	90 (man-days/ha)	685	7.6
Seedling production with RWH	13 (man-days/100 m^2)	118.13	13.6
Onion rainfed	150 (man-days/ha)	2100	14.0
Incremental labor due to RWH intervention (onion crop only)	163 (man-days/yr)		15.0

Table 3. Net present value, internal rate of return, and return on investment from onion seedling production.

Performance parameter	Highland	Middle	Lowland	Average
Discount factor	10%	10%	10%	10%
NPV (7 years)	US$ 1,477	US$ 1,158	US$ 1,033	US$ 1,223
IRR	256%	189%	163%	202%
ROI	514%	467%	468%	483%

showed that the average net income from onion seedlings was US$ 155 per 100 m^2 plot, while that from rainfed bulb onions, once transplanted, was US$ 1848 per ha, making the contribution to farmer incomes from onions alone to be about US$ 2,003 per year, which is higher than what they earned from rainfed teff and wheat combined. Due to such visible benefits, the RWH technology has the potential, when properly constructed and supported, to have a transformational effect on livelihood.

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