Training for Rainwater Harvesting[1]

1. Context

Land degradation and water stress are significant threats to agricultural productivity and food security in the context of climate change, especially in arid regions like the Sahel. In sub-Saharan Africa, growth in agricultural output has relied on increased land use on increasingly marginal soils and shorter fallow periods (1, 2, 3, 4, 5, 6). This approach will be hard to sustain, especially in a context with more frequent climate shocks (1, 2, 3).

The lives and livelihoods of the estimated 135 million people of the Sahel–eighty percent of whom depend upon agriculture for their income–are affected by drought, land degradation and desertification (1, 2). Drought affects up to 50 percent of arable land in any given year in the Sahel. Approximately 80 percent of agricultural land in the Sahel suffers from nutrient depletion and poor soil fertility (1, 2). Severe degradation of land can contribute to desertification and land erosion, leaving land unsuitable for agriculture, and increasing pressure on natural vegetation. Desertification and other sources of land degradation affect 494 million hectares of land in Africa–approximately 17 percent of the continent's total land area (estimation based on UNEP 2015). In addition to effects on incomes, food security, and health, climate change can increase the risk of conflict (1, 2).

2. Training for Rainwater harvesting

On-farm rainwater harvesting techniques reverse land degradation, increase agricultural yields and revenues, sequester carbon in the soil, and combat desertification. Agronomic trials demonstrate that rainwater harvesting can help to retain soil moisture and replenish soil nutrients while reducing the risk of crop failure. It is particularly useful where irrigation is unfeasible and chemical input use is limited.

Micro-catchments, including demi-lunes (half-circular bunds) and zai or tassa (soil pits), are often a particularly appropriate type of on-farm rainwater harvesting for smallholder farmers because they do not require specialized equipment and can be implemented

[1] This is a draft document that will be updated periodically until the publication of the Innovation Commission final report

after harvest when the opportunity costs of family labor and local wages for paid labor are lower. Demi-lunes are suited to the sloped land with severely degraded soil, known as glacis, that is estimated to cover 40 percent of degraded land in the agro-pastoral zone of Niger.[2]

Despite the effectiveness of rainwater harvesting and substantial investment in promoting demi-lunes in Niger, adoption remains low. Only around 10 percent of farmers in Niger adopt demi-lunes on any part of their private land. Simple awareness of techniques may be insufficient to achieve widespread adoption, requiring more nuanced and detailed training than existing government extension agents may typically provide.

3. Impact and cost-effectiveness

Simple training sessions cost-effectively increase the adoption of on-farm rainwater harvesting techniques, which would benefit farmers across severely degraded areas of the Sahel and in other arid and semi-arid farming regions. In Niger, the Ministry of Environment tested strategies to increase the adoption of demi-lunes and found that a simple training increased adoption by over 90 percentage points and increased field coverage by 20 demi-lunes per hectare, despite a majority of farmers already being familiar with the technology (estimation based on Aker and Jack 2023). The training provided instructions on constructing demi-lunes without special tools, encouraged adoption on private as well as communal land, and distributed instructional reference booklets for farmers to reference at home. The training increased specific technical knowledge about how to construct demi-lunes, such as the recommended depth or number to construct per hectare, by 8 to 21 percentage points. Demi-lune adoption in Niger increased per-farmer agricultural revenue by USD 34-37 per year and improved soil quality and land usage over multiple years while increasing farmers' costs by USD 30 in the first year and USD 4 in subsequent years. Financial incentives did not lead to increased adoption of demi-lunes after three years relative to farmers who only received training. Farmers who adopted demi-lunes were also able to bring previously unproductive land into cultivation—on average, an additional 0.3 hectares. The training was cost-effective, with an average cost of USD 9 per participant. There is some evidence that demi-lunes continue to provide benefits at least five years after construction. Another example of on-farm rainwater harvesting is pit planting, which involves planting seeds in a shallow pit to help retain moisture.

[2]Glacis lands are impermeable soils, whereby rainwater runs off or evaporates, further depleting the soil biome. Moreover, this type of degraded soil is frequently too dry to absorb the rainfall: as a result, destructive river floods and numerous flooding episodes have been observed.

In Malawi, randomized trials found that pit planting adoption increased agricultural yields by 19 to 44 percent (1, 2) and reduced labor costs relative to traditional ridge planting methods.

Knowledge from training on rainwater harvesting diffuses among farmers and also benefits farmers who have not received the training. In Niger, households in villages where others received training on demi-lunes were 18 percentage points more likely to have constructed demi-lunes three years after the training. In Malawi, incentives for farmers to train others on pit planting increased adoption by about 7-14 percentage points. Targeting farmers who are better connected in social networks increased the diffusion of pit planting techniques, possibly because farmers need to learn from multiple people before adopting themselves. Extension agents could achieve most of the potential gains in diffusion by asking a few farmers in each village with whom they talk about agriculture most frequently to identify and target well-connected farmers for training.

A one-time training is sufficient for years of sustained adoption of rainwater harvesting techniques, suggesting a path to long-run sustainability with relatively small ongoing costs. The training in Niger cost USD 9 per participant and had lasting impacts of a similar magnitude at least three years later, suggesting a high social cost-benefit ratio and that ongoing training need not happen frequently to sustain benefits.

Rainwater harvesting techniques including demi-lunes and *zai* or *tassa* soil pits increase carbon sequestration in soils. The FAO estimates that demi-lunes in Niger could sequester 0.32 tons of CO2e per hectare per year, and that *zai* or *tassa* soil pits could sequester 0.19 tons of CO2e per hectare per year.

4. Potential for further improvement

Transitioning this innovation to scale could involve adaptation to new contexts, including identifying appropriate rainwater harvesting techniques and updating training content to match local languages, crops, and existing practices. Implementers could investigate the possibility of providing training materials digitally and training a cadre of extension workers and local trainers. A staged scaling process, starting at a moderate scale while monitoring and potentially rigorously measuring impact, could include A/B testing to identify whether one rainwater harvesting technique achieves similar benefits at lower costs, or performs better than another on particular types of soil, in particular agro-climatic conditions, or for particular crops.

Integrating remote sensing techniques could help detect the adoption of rainwater harvesting techniques, which can be used to reward extension agents and lead farmers. Monitoring tools and performance incentives for extension agents and farmers could play important roles in ensuring the effective diffusion of information (1, 2). Innovations in remote sensing and other technological tools, such as drones or automated processing of geo-referenced photos from smartphones, could facilitate implementing such monitoring and incentives at scale. Remote sensing could also facilitate monitoring the persistence of adoption for quantifying carbon sequestration benefits.

5. Potential for scale

Training for rainwater harvesting techniques can be scaled through government delivery channels. The Ministry of the Environment in Niger partnered with researchers to conduct trainings on demi-lune adoption. The Ministry has now begun scaling the innovation, with plans to train more than 10,000 farmers in 400 villages by the end of 2023.

Many international organizations also have experience in training farmers on rainwater harvesting and could be useful scaling partners, especially in areas where government extension services are severely under-resourced. Organizations including ActionAid, Catholic Relief Services, Concern Worldwide, Islamic Relief, ICRISAT, Justdiggit, Save the Children, and the World Food Program have trained farmers in on-farm rainwater harvesting techniques in countries including Burkina Faso, Burundi, Ethiopia, The Gambia, Kenya, Niger, Senegal, Tanzania, and Uganda. These organizations could potentially implement the innovative training from the Ministry of Environment in Niger to improve the cost-effectiveness of their programming.

6. Potential path forward

Funding of USD 6 million could enable this innovation to reach about 75,000 households (or about 580,000 individuals) in Niger. In addition to reaching more farmers, this funding would support the addition of remote sensing to monitor innovation adoption and trainer performance. This estimate is based on inputs from the current implementers and accounts for the costs of training participants, training trainers, and new monitoring efforts. This would be expected to generate at least USD 8.3 million in increased income for participants over five years, and likely much greater benefits over time due to improvements in soil health and resilience. Based on estimates of knowledge transfers to neighbors of trained farmers, this investment could also generate at least USD 1,000,000 in additional benefits over five years for other farmers. This funding could also potentially generate substantial climate mitigation benefits by sequestering carbon in rehabilitated soil. The FAO estimates that demi-lunes sequester 0.32 tons of CO_2e per hectare per year, although more due diligence would be needed to understand the magnitude and permanence of sequestration in this context. Assuming a social cost of carbon of USD 190 per ton, the estimated annual social value of carbon sequestered by this funding in Niger is USD 2.3-8.6 million. Scaling this intervention in Niger has an estimated social benefit-cost ratio between 4 and 9:1, accounting for the marginal costs of training farmers, the costs to farmers to construct demi-lunes, the costs of monitoring and evaluation, and the suggested further improvements discussed above in Section 4.

A larger grant of funding could bring this innovation to farmers in more countries. Expanding to new countries could involve additional work to adapt training materials, identify target regions with highly degraded soils, and build in impact evaluation and A/B testing to confirm the techniques and training materials that are most appropriate and cost-effective for each context. Funding of about USD 21 million could enable this innovation to reach 225,000 households (or about 1.8 million individuals) in Burkina Faso, Mali, and Chad. This funding would be expected to generate at least USD 24.9 million in direct benefits for participants over six years, and potentially greater benefits over time due to improvements in soil health and resilience. Based on estimates of knowledge transfers to neighbors of trained farmers, this funding could also generate at least USD 3 million in additional benefits over five years for other farmers. Assuming again carbon sequestration of 0.32 tons CO_2e per hectare, and a social cost of carbon of USD 190 per ton, the estimated annual social value of carbon sequestered by this investment is USD 6.8-22.8 million. More due diligence would be needed to understand the magnitude and permanence of sequestration in each country's context. Scaling this innovation to three additional countries has an estimated social cost-benefit ratio between 3 and 6:1, accounting for the marginal costs of training farmers, the costs to farmers to construct demi-lunes, the costs of monitoring and evaluation, and the suggested further improvements discussed above in Section 4.