Rooftop water collection, drip irrigation and plastic mulching in home garden conditions in drought prone areas of Cambodia

SUMMARY:

In Cambodia, drought can have different impacts: delay of rainfall onset in early wet season, erratic variations of rainfall onset, early ending of rains during wet season, and longer dry spell in July and August. This technology describes three different technologies and analyses the costs and benefits of their combined application: rooftop water harvesting, drip irrigation and plastic mulching in home garden conditions. As a result of the combined application of those good practices (GPOs), the resistance against drought is increased and a second cropping period is possible. The GPOs have been tested and validated in 19 Farms in the Kampong Speu (3) and Oddar Meanchey (16) Provinces in Cambodia.

KEYWORDS:
Rainwater [1]
Drought [2]
water supply [3]
Water harvesting [4]
Water conservation [5]
food security [6]

CATEGORY:
Climate change and disaster risk reduction [7]

COUNTRIES:
Cambodia

DESCRIPTION:

1. Introduction

Cambodia is highly vulnerable to natural hazards, primarily floods and drought, which heavily impact the agriculture sector. As a result, the lives and livelihoods of many smallholder farmers are severely affected. Through livelihood diversification, home gardens help to reduce the adverse impacts of natural hazards. Families are able to grow different fruits and vegetables to supplement their unbalanced diets, which currently mainly consist of consuming staple foods such as rice. When combined with rooftop rainwater harvesting, drip irrigation and plastic mulching, water is used effectively and efficiently, and provides considerable time savings especially for women and children often responsible for water collection. The water from the rooftop containers can also be used for various household needs, freeing time for other activities. Home gardening can help farmers, and women in particular, to reduce the impact of dry spells and drought, which enables them to generate additional income, diversify their livelihoods and contribute to the food and nutrition security of their families. In the following chapters, the good practices rainwater collection, drip irrigation and plastic mulching are being presented with a cost-benefit analysis of their combined application.

2. Rooftop rainwater harvesting to reduce risk during the dry spell and drought

Rainwater collection has been practiced to sustain Cambodian families through the dry season in the past, and traditional methods were improved to ensure sufficient access to water in order to reduce the impact of drought and dry spells. The water is collected using a rooftop rainwater system, where rainwater falls on metal or tiled roofs and is then collected in containers at the edge of the roof or channeled to a storage system via gutters and plastic pipes. The rainwater is channeled into a covered storage tank which protects the water from contamination . The storage has been improved to include assembled cement rings that could store in capacity such as 2,000, 3,000 and 5,000 liters of water.

Through the use of rooftop rainwater collection, families are able to collect enough rainwater in the rainy season and conserve it for the dry season or an unexpected drought.. This technique reduces adverse impacts of dry spells and droughts and enables farmers to increase and diversify the crop and animal production to generate additional income.

2.1 Identification of a suitable storage

2.1.1 Determination of the size of the tank

The size of the storage tank depends on the utilization purposes which include household consumption or household consumption plus vegetable or animal production. Based on experience, it is recommended that for household consumption, the calculation to determine the size of the tank is based on the number of household members, assuming a consumption of 15 liters per person per day. For vegetable production, 1 m^2 of garden needs an average of 2 liters of water each day under the climatic conditions of the tested area.

2.1.2 Choosing the right tank

There are various options available for the construction of these tanks with respect to the shape, size and the material of construction. Currently, three types of tanks are available in Cambodia: the Jumbo Jar (see Picture 1), the Cement Ring Tank (see Picture 2), and the Ferro Cement Tank. The Jumbo Jar tanks are the most popular ones due to their lower prices. Cement ring jars are the second favorable ones.


[8]

Picture 1. Traditional water containers called Jumbo jars


[9]

Picture 2. Modern water collection tanks, also called ring tanks.

Jumbo Jar	Cement Ring Tank	Ferro Cement Tank
• Storage Capacity: 1,000, 2,000, 2,500, and 3,000 liters • Prize: USD 165 plus installation	• Storage Capacity: 1,000, 2,000, 2,500, 5,000, 10,00 liters • Prize: USD 20 - 160 plus installation	• Storage Capacity: 2,500, 3,200, 3,800, and 4,600 liters • Prize: USD 800-1500 plus installation

[10]

Table 1. Characteristics of the different water container solutions

2.2 Construction of the rainwater harvesting system

The rainwater harvesting system may be constructed as per instruction below. The construction requires techniques and skills in the Water and Sanitation (WATSAN) sector.

2.2.1 Catchment surface

The catchment surface of a water harvesting system is the surface which directly receives the rainfall and flows water to the container. The catchment surface is usually the roof of the house or animal shed. To ensure clean and safe water, the collection area of roofs can be constructed with a range of materials, including galvanized corrugated iron, aluminum cement sheets, tiles and slates. It is recommended to build the catchment surface adjacent to the home garden if farmers want to combine with drip irrigation system.

2.2.2 Gutters and down piping

Gutters and down piping serve to get the water from the roof during raining to the storage container. Gutters should be installed under the roofing on both sides of the roof and channeled with pipes to the tank. The most commonly used material for this purpose in Cambodia is plastic piping, which costs approximately USD 30 for a water harvesting system covering the roof of one farm house or similar building.

2.2.3 Cover of the water tank

It is also very important to cap or cover the water storage tank at all times. Wooden or cement covers are commonly used. Covering the tank prevents debris and dirt from contaminating the water and also keeps out mosquitoes and other pests that may contaminate the water and provide health risks to humans and animals. Therefore, the cap or cover should closely fit on the opening of the tank to avoid small animals such as lizards or mice to fall into the water tank. It is useful to install chicken wire before the inlet pipe to avoid animals that enter the pipe from the roof to end up in the water tank.

2.2.4 First-flush System

The ?first-flush? system is used to ensure clean water. During the dry season dirt and debris may collect on the roof and wash into the storage tank. The first-flush system discards the first bit of flowing water and ensures that the water being collected is clean. A simple first-flush system is made from attaching a vertical pipe to the down pipe that delivers water into the tank. A valve is put in place below the junction where the pipes come together. This way, the initial water may be sent out through the extra pipe and will not send dirt and debris into the tank. It is important to regularly check and clear the pipes and make sure that the first rain will be washed out to avoid dirty and contaminated water.

Drip irrigation systems require maintenance to prevent the clogging of gutters. Key maintenance interventions include periodic inspection of gutterlines, flushing of the system as well as the application of an orderly irrigation plan.

2.3 Capacity building

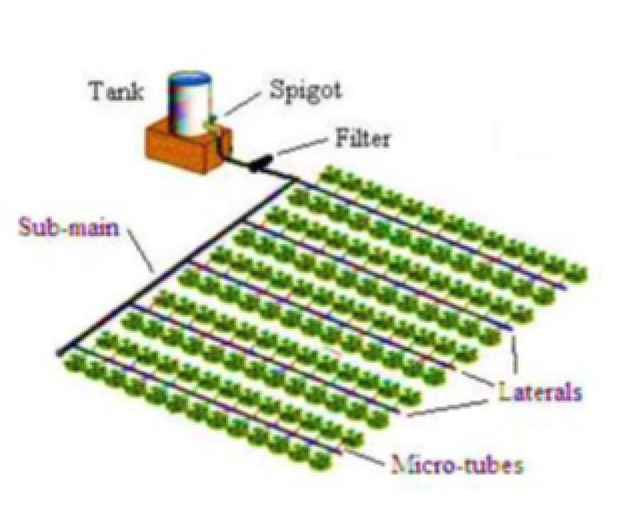
It is important to train families in the use and maintenance of the system to ensure sustainability. The training may also include how to manage water usage and sanitation techniques to ensure families have sufficient and clean water throughout the dry season. Additional trainings on farming technique may be required for them if the system is installed for the purpose of increasing agricultural production and livelihood diversification.

3. Drip Irrigation a drought resilient technique for vegetable cultivation

Irrigating crops can be a challenge for farmers during the dry season or in times of drought. Crop failure has detrimental effects on the livelihoods of families and their food and nutrition security. Access to sufficient as well as efficient use of water resources is highly important, in particular during the dry season. Lack of water increases the work burden of women and children, who have to travel sometimes long distances to meet the household water needs. For households without stored water, water shortages in the dry season limit the production from homestead vegetable gardens. Unlike many other irrigation techniques, drip irrigation enables a watering regime that provides slow, regular and even soil wetting. In drip irrigation, water is directed through a series of plastic pipes directly to the plant roots, enabling plants to effectively use most of the available water, thereby limiting the amount of water lost to deep drainage, evaporation and runoff. In addition to efficient and effective use of water, less fertilizer is washed away and as a result, the cost of inputs needed is lower. The more controlled water release also results in fewer weeds, which means less labor is required also for watering to raise crops. Time is saved not only from collecting water, but also in having to water the crops. Therefore, drip irrigation holds promise as a means for increasing water use efficiency, reducing labor requirements, and improving harvest quality and quantity. The use of rooftop rainwater collection as a valuable water source for drip irrigation can help farmers cultivate vegetables around the homestead. Vegetable cultivation is often done by women. As a result, this can help them to reduce the impact of drought and enable them to increase numbers of crops grown a year, which helps to generate additional income, diversify livelihoods and contribute to food and nutrition security.

Simple, low-cost drip irrigation kits are available in Cambodia and are suitable for use by farmers with small or large plots of land. In general, two kinds are available and suitable for areas from 40 m^2 to 500 m^2. A drip irrigation system is composed of the following elements: a water container that aliments the system and a main tube that brings the water from the tank to the garden. Some farmers install cement rings as the water container as it is easy to set up and materials are locally available (see chapter 2). Five assembled cement rings have a capacity of 5 000 liters of water. The other option can be using simple water tanks or jars Water tanks or jars are placed near the plot of land, generally within 2-3 m. It is raised by 1 m to ensure water flow by gravity. Farmers generally have to purchase the cement container separately as they are not part of the irrigation kits. A tap controls the water flow from the water container. The water first passes through a filter to make sure debris is removed so that the pipes will not be clogged. The water then flows through the sub-main pipe to the lateral pipes in the garden. The lateral pipes are laid over the crops parallel to the rows. The water flows into these pipes and is then distributed to the plant roots via emitters (micro-tubes). This process is illustrated in Figure 1 below:

Component	Description
Tank	500-litre concrete water storage jar (*pieng*). Elevated approx. 1.0 m above ground level
Spigot	Low density polyethylene (LDPE) plastic
Filter	0.35-mm stainless steel mesh, LDPE plastic, in-line filter
Sub-main pipe	49-mm inside diameter, 0.7-mm wall thickness, LDPE plastic
Lateral pipes	12-mm inside diameter, 0.125-mm wall thickness, LDPE plastic, "lay-flat" pipe
Micro-tubes	1.2-mm inside diameter, 0.9-mm wall thickness, LDPE plastic, "spaghetti" tubing



[11]

Figure 1. Components of drip irrigation Source:

3.1 Preparation of the system

The land must be leveled and prepared in rows so that the watering pipes may be installed (see sample Picture 3). Then, the water container must be set up and holes must be made in the sub-pipes using a needle. In general, a kit covering 40 m2 takes about 2 hours to install. Along with the installation, the orientation on basic instruction of the installation and management of small scale drip irrigation systems should be provided so farmers will know how to maintain the drip irrigation system themselves. After installation, the same kit may be used for 3-4 crop production cycles. After 3-4 cycles, it will need to be removed to check the quality and replace the broken parts while allowing farmers prepare the land for next cropping.

 [12]

Picture 4. Drip Irrigation installation with elevated water containers

3.2 Possible water sources for a drip irrigation system

Any source of water such as rooftop rainwater collection container, pond or a well may be used for a drip irrigation system as long as it provides water pressure (for example through gravity) and has an attachment suitable to connect to the drip irrigation system.

3.3 System layout

The system's design needs to be done according to the crops to be irrigated as well as the spacing of the crops. An emitter will be placed close to each plant. Plants that require more water may need two emitters. These emitters are attached to the main water system.

3.4 Filling of the water container

The water container should be filled with rooftop rain water by gravity or with a pump tapping other water sources. For a water container with a capacity of 5000 liters a home garden of 40 m^2 can be irrigated for around two months during the rainy season and for 15 to 30 days during dry season. As the plants mature, water will need to be irrigated two times each day.

3.5 Testing of the drip irrigation system

Turn the valve on and ensure that the water successfully runs from the water tank to the emitters. Adjust the water flow to allow the emitters to slowly release the water as water should dribble onto the soil near the plants.

3.6 Check for leaks

After adjusting the water flow, turn the valve off. The water should stop running. If this is not the case, this means that there are leaks in the drip lines due to an incorrect adapter. Use only threaded hose adapters. It is possible to fix small leaks by wrapping thread seal tape around the area.

3.7 Perform regular maintenance

It is important to routinely check for leaks and clean the filter regularly about every two weeks.

4. Plastic mulches in vegetable cultivation for enhanced resilience to drought and soil erosion

Mulching is a technique that has been used by vegetable growers for many years. Mulches are used to cover and to keep soil moisture for a better plant growth. Traditionally, natural mulches such as rice straw and water hyacinth have been used. However, since the creation of synthetic materials, plastic sheet has been introduced as a mean to provide the same benefits. Plastic mulches are impermeable and therefore, prevent the evaporation of moisture from the soil.

They limit losses of water and reduce soil erosion better than natural mulches do. In addition to conserving water, plastic mulches also help with weed control. That allows farmers to improve and maximize their production.

Plastic mulching is a good practice to ensure crop production during dry spells and droughts. This is especially true if plastic mulching is used in conjunction with drip irrigation (see drip irrigation above). This practice saves labor time (such as for weeding) and other resources (such as fertilizer, herbicide and pesticide input), increases yields and thereby contributes to people's food and nutrition security.

Furthermore, plastic mulches are easily acquired and provide flexibility for utilization. However, they are more expensive than natural ones. Plastic mulches can be used at least 3 crop cycles in terms of quality especially in combination with drip installation.

Plastic mulches require farmers to have skills in vegetable growing. The introduction of plastic mulching must, therefore, be accompanied with adequate training and/ or Farmer Field School in a package of vegetable production, including cleaning, land preparation, lime application, composting, harrowing, making beds, applying mulch, drip irrigation, and drainage.

4.1 Land preparation

Clean and plow the land to a depth of 30 cm. Remove all bushes, rocks, and weeds. Plow the soil into tiny pieces.


[13]

Picture 5. Cleaning and land preparation

4.2 Application of lime

The lime increases soil pH, corrects soil acidity and provides calcium and magnesium which are important for vegetable growth. In addition, it makes more nutrients available to plants. Lime will also help reduce soil borne diseases and pests. However, lime should not always be used especially when plants are grown on soils that are already high in pH/ alkaline. Therefore, if you are unsure about the pH of your soil, do a pH test first before applying lime.

Apply lime on the surface of the soil. Practically, use 5 to 10 Kg of lime for 100 m2 of land size. Spread the lime across the land covering it with an even thin layer of lime. When applying lime, put on a mask and wear gloves to protect yourself.

4.3 Compost and harrowing

Cover completely the lime with a layer of compost. Use 2 to 3 Kg of compost for every square meter of land (see compost fertilizer). Harrow or rake the compost twice into the land to ensure that the compost is well mixed into the soil. The compost is rich in nutrients, which helps to increase soil fertility as well as to retain moisture. Therefore, this mix helps crops grow healthy and strong.

4.4 Preparation of beds

Build the beds parallel to the land's longest side considering the slope of land, accessibility, and water source. Bed should be 30 cm high and 60-90 cm wide for rainy season; this is wide enough for most crops. Make sure the beds will drain effectively.

4.5 Application of mulch

Pull the plastic mulch, silver side up, tightly over the beds. Put some soil on the plastic mulch to hold it in place (see picture 6). Plastic mulch helps protect the soil against weeds and decreases the mobility of pests. If possible, use reflective plastic films, which can also repel certain kinds of insects. One vegetable bed of 10 meters length needs around 10.5 sq. meters of plastic sheet.

For commercial gardens from 500 to 2000 m2, it costs approximately USD 60 in Cambodia. For home gardens from 300 to 400 m2, it costs about USD 12.5. About USD 4.5 for 40 $m^{2.}$


[14]

Picture 6. Application of plastic mulch

4.6 Preparation of drainage

Next, dig 20 cm deep canals between the beds for irrigation tubes. Dig two primary canals towards the lowest point of the garden. To avoid soil erosion between the beds and to get a fast and shallow canal, dry rice straw, rice husks or rice ash could be used. They can flow off the land slowly.

5. Lesson learnt from demonstrations of rooftop rainwater collection systems

5.1 Economic and social feasibility

5.1.1 Benefits

- Rooftop rainwater collection is the most suitable practice for rural farmers and considered as the coping strategy for dry spells or drought
- Rooftop rainwater harvesting can assist household water needs with good quality water and more constant water supply in the dry season
- The combination of rooftop rainwater harvesting and drip irrigation can save water and time significantly, and also reduce the women's work burden to fetch water from large distances
- The combination of the technologies of rooftop rainwater harvesting, drip irrigation, plastic mulch and home gardening could save time, water and labor; and farmers can gain higher yields than with the conventional practices

5.1.2 ?Cost

- The initial investment costs are high, hence, low-income families may not be able to afford this system without support
- It is labor intensive to install cement rings

5.2 Increase resilience

5.2.1 Benefits

- Water is collected during the rainy season, and conserved to use in the dry season. Two cement stands (with 10 assembled cement rings) can store about 5,000 liters of water. This amount of water can last for at least one month for consumption and household use for an average five family members and irrigation of 60 m^2 home garden.

6. Lessons learned from the drip irrigation system demonstrations

6.1 Economic and social feasibility

6.1.1 Benefits

- Significant labor saving times for women of up to three hours per day.
- Water is applied only where needed, and is not wasted or lost through evaporation or runoff.
- Reduced amount of washed away fertilizers, so it helps to reduce the cost of inputs.

6.1.2 Cost

- Installation costs of around USD 60 for home garden from 300 to 400 m2 could be high for farmers.
- In case of damage or extension of the system, farmers may struggle to find locally available suppliers to support the installation or fix the damage.

6.2 Increase resilience

6.2.1 Benefits

- Efficient water-saving technique, uses four times less water than the conventional technique. For instance, a 10-metre long vegetable bed of 60-90 cm wide using drip irrigation requires around 15 liters of water/day, whereas conventional practices using water tanks may take up to 60 liters of water

6.3 Environmental suitability

6.3.1 Cost

- Drip irrigation systems and plastic mulch can have negative effects on the environment as they are made of plastic, and if farmers use big systems the waste may end up being discharged on landfills without proper management and with long-term threats to groundwater. It is, hence, suggested to train farmers on waste management and the supplier of the drip irrigation systems should collect the old drip kits for recycling purposes.

6.4 Additional considerations

- To combine drip irrigation systems with other practices such as rooftop rainwater collection, plastic mulch, compost and botanical insecticide to improve soil composition and soil moisture.
- Properly fence the farms to protect crops from animal encroachment.
- Be precautious of damages of the system while harvesting and make sure that the plastic tubes are stored in a safe place between crop cycles.

7. Lessons learned from plastic mulching demonstrations

7.1 Economic and social feasibility

7.1.1 Benefits

- Labor and time is saved: farmers, particularly women, have more time to monitor pest and diseases on vegetables and scale up the production.
- Reduces the amount of fertilizers washed away by rain, so it helps to reduce the cost of inputs

7.1.2 Cost

- It might be difficult for some farmers living in remote areas to have access to the plastic mulching suppliers and it might be expensive. In this case, organic mulches such as rice straw and water hyacinth can be a good alternative for farmers as they are cheap and easy to find after the harvesting of rice and vegetables, and the organic mulches buried into the soil additionally serve as organic fertilizers.

7.2 Increase resilience

7.2.1 Benefits

- Plastic mulches maintain soil moisture for longer than no-mulching. The plastic cover acts as an insulator to keep moisture from evaporation during hot times or dry spells.
- Plastic can also prevent weed to grow, hence it reduces the competition between weeds and crops for water and fertilizers.
- Can maintain the shape and level of vegetable beds in the rainy season. It also prevents vegetables from waterlogging, reducing the incidents of root rot and other diseases
- Works efficiently when combined with drip irrigation. The combination of these practices could save water up to four times.

7.2.2 Cost

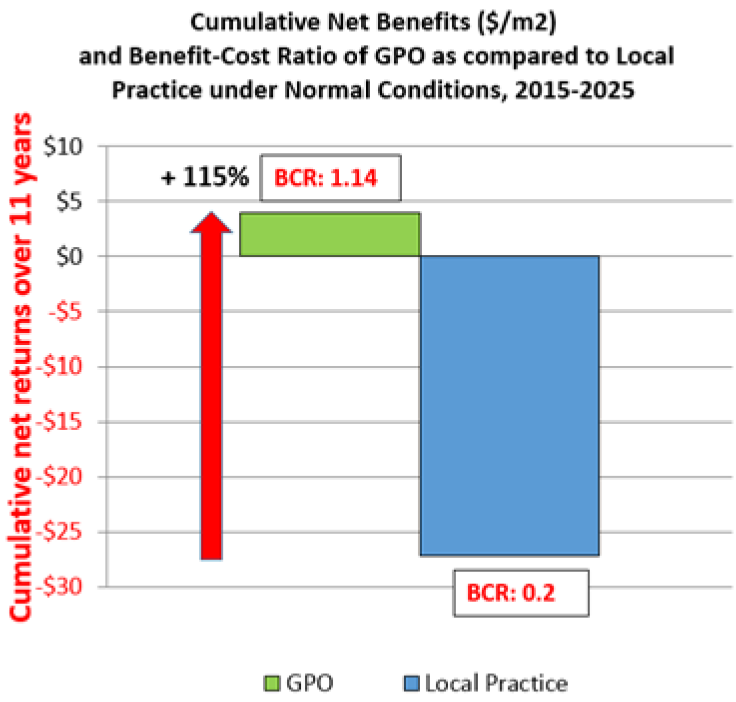
- Plastic waste has a negative effect on the environment if farmers use big amounts of plastic mulches and throw the waste on land without proper management. The environmental costs of producing plastic mulching sheets needs to be considered before shifting from traditional mulching materials to plastic. It is suggested to train farmers on waste management and the suppliers of the plastic mulch should collect the old plastic mulch for recycling purposes.

7.3 Additional considerations

- Beware of possible damage caused by animals if the plot is not properly fenced
- Beware of damage to plastic mulch and tubes during harvesting
- Beware of the increased temperature of soil while using plastic mulch. It can scorch young plants.
- Remove the plastic mulch between production cycles and keep it properly for the next crop cycle.

8. Cost-benefit analysis

The results of the qualitative and quantitative analyses conducted based on field demonstration data are summarized hereafter.



[15]

Figure 2. Cummulative net benefit cost ratios of good practice and local practice($ per m^2)

The performance of the combined GPOs was assessed at farm-level in Cambodia based on quantitative data collected during the monitoring period. The net benefits obtained from the application of these practices were measured through a cost-benefit analysis (CBA), and compared to the net benefits obtained from traditional practices. The CBA projects the cumulative net present value of benefits obtained from 1 acre over a period of 11 years (10 percent discount rate is applied to express the future value of costs and benefits in present terms), as well as the benefit-cost ratio (BCR), which is the ratio between total discounted benefits and total discounted costs over the appraisal period.

The graph in Figure 2 shows that the net benefit over 11 years is 115% higher in farms that adopt the GPOs combination, as compared to non-adopters. The cost-benefit ratio of the good practice is higher than that of the existing local practice. Although the good practice requires more input and labor (especially for maintenance), the increase in yield due to a more balanced water supply, weed management and soil water retention more than compensated the additional input cost.

Figure 3 below shows the average annual costs and benefits per m2 of the good practice compared to the local practice.

Cost assumptions are as follows:

- Labor cost only includes hired labor. Family labor is not included.
- Seeds costs are considered as upfront capital costs, not seasonal costs (first purchase, then saved from cycle to cycle).
- Operation and maintenance costs are not included due to possible double counting with other costs such as labor.

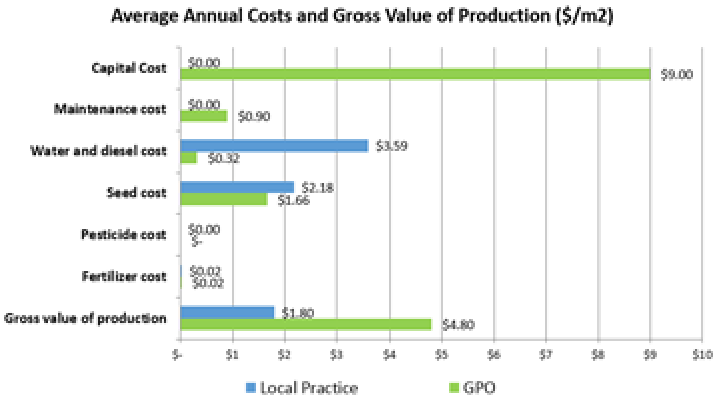


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Figure 3. Average annual cost and benefits per m^2 of the good practice compared to the local practice

Assuming a 10% discount rate, capital costs are fully repaid after 7 years. To overcome upfront investment barriers, access to credit should be facilitated.

From a strictly economic point of view, the GPO yields very limited benefits. However, relevant positive impacts of GPO implementation arise from qualitative evaluation:

- Food Security and Nutrition: the GPO allows two cropping cycles, hence, it enhances food security and diversification of diets
- Access to safe water: 70% of the farmers said that the GPO improved their access to clean and safe water
- Knowledge: All interviewed farmers considered that they acquired new knowledge by taking part of the project and implementing the GPO
- Sustainability: All interviewed said they would replicate the GPO in the coming seasons

Given the relatively high capital cost required to start the good practice, adequate access to credit for farmers would facilitate adoption.

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