# Economic of low-cost multi-stack cubical and semi-cylindrical shape stacked protected farms on marginal lands

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**Abstract:** Multi-story protected farms require a very high initial investment which is beyond the capability of poor farmers. The initial investment in a single story stacked protected farm is very low which would be within most poor farmers. In this paper, the economics of a low-cost single storymulti-stack, naturally ventilated, insect proof, and net house equipped with gravity drip irrigation system for vegetable production in marginal lands in Tripura state in North Eastern India was evaluated. The construction cost of a three-layered stacked protected farm of size 10 m (length) × 10 m (width) ×6 m (height) is estimated to be $480 but the operating cost is very low (less than one-tenth of the construction cost) mainly comprises the cost of water, nutrient, substrate, and seeds. The crop grower self shall manage the works of planting seeds, irrigating to crops, harvesting matured crop, and selling in the local market. The annual average crops yield from a three-layered stacked protected farm size 10 m (length) × 10 m (width) × 6 m (height) for: all green spinach (*Spinaciaoleracea* L.), sweet tomato (*Solanumlycopersicum* L.), chili pepper (*Capsicum annuum* L.) and fresh-market cucumber (*Cucumis sativus* L.) areestimated to be 144, 1380, 190, and 2430 kilogram respectively. To get back the total investment on fixed cost of the construction of the one story three-layered stacked protected farm in Tripura state of North Eastern India, one crop grower has to cultivate crops for 43.6 years if only cultivates only all green spinach, 0.6 years if only cultivates only sweet tomato, 2.4 years if only cultivates chili pepper, and 0.4 years fresh-market cucumber respectively. The profit of growing crops in a three-layered stacked protected farm on land size 10 m×10 m area over open field farming is estimated to be five times for all green spinach, two times for sweet tomato, two times for chili pepper and three times for fresh-market cucumber. Protected cultivation is the best option for sustainable enhancement of crop yield in marginal lands to meet growing local food demands of growing populations.

**Keywords:** protected cultivation, greenhouse, marginal farmer, gravity drip irrigation, crop yield

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## 1 Introduction

As populations grow land is taken from open field agriculture. Most mechanization and other management practices are uneconomical in marginal and small land holdings. Despite heavy rainfall area (average annual rainfall>2000 m) in undulating areas, the soil has poor water holding capacity due to poor soil and water management practices (Singh and Gupta, 2002). Protected culture includes the use of a controlled environment to grow vegetable crops in mineral nutrient solutions or specially designed growing media. Protected culture is a method of growing vegetables in a location where the climate, or the soil, is not conducive, or land area is limited (Despommier, 2009). A gravity drip irrigation system is preferably adopted in small-size cropland where the supply of available water is limited. Meeting increasing food demand of a growing population is a serious concern. Fast growing nearly all leafy greens are grown well under multi-stack protected farms (Jensen, 2012).Enhancing agricultural productivity is one of the key challenges for the future. The global food demand is rising as the population is growing exponentially. Food production will need to be doubled by 2050 to meet the

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United Nation's Millennium Development Goals on hunger. The world is facing more and more extreme weather events from climate change; there will likely be impacts on agriculture (Mellino, 2015). Optimal water requirement of different crops is different. Installation of a high-tech irrigation system in small-size protected farms will be expensive and not affordable at all by the marginal farmers. Gravity drip irrigation system for a small plot system is very simple and cheap. No special training or skill is required to operate the system. No pump is required for applying water to the crop growing stacks in small-size protected farms. Water can be filled in the water tank manually using either a bucket or directly from a water supply tap. The system provides judicious and uniform quantity of water to each crop root zone thereby uniform crop growth is an important advantage of this system. The major agricultural problems such as pesticides, pests, deforestation, and soil erosion would be minimal because of controlled farming (Han, 2014). A key aspect that has made protected farms efficient is the usage of natural light. Protected farming is environmentally friendly as it eliminates the use of mechanical plows thus reduces the burning of fossil fuel. It is human health friendly as it reduces the occupational hazards such as accidents in handling farming equipment. About 70%of water is saved in comparison to open field farming (Bareja, 2011).

### 1.1 Objectives

The objective of this study is to the economic evaluation of low-cost cubical and semi-cylindrical shape multi-layered stacked protected farms in marginal lands in Tripura state in North Eastern India that having a gravity drip irrigation system. This study is expected to help marginal landholder for growing getting maximum crop yield and maximum return round the year with minimal investment.

## 2 Detail methodology

Most of the open fields farming activities are carried out on scattered marginal lands. Larger machinery is uneconomical in the hilly and marginal. A gravity drip irrigation system is an ideal irrigation system for growing crops in areas where water becomes scarce in lean periods. three-layered stacked cubic and semi-cylindrical shape protected farms both having 6 m height one story each was constructed on 10 m×10 m area land. The cubic and semi-cylindrical shape structures are equipped with a gravity drip irrigation systems shown in Figure 1 and Figure 2 respectively. The major components of the structure are galvanized iron pipe, polythene sheet for the roof; shade net for sidewall and stacks (Table 1). The major components of the gravity drip system are water tank (plastic make), ball valve (plastic made), polyethylene tubes, micro-tube, drippers, pot and substrate (Table 1). The roof of the cubic structure has two span frames and semi-cylindrical shape roof both are covered with UV stabilized 200 micronpolyethylene. A 60 liters capacity plastic made water tank is placed slightly (15 cm) higher level to the pot root zone in the stack. Water flows under gravity through polyethylene tube (16 mm from diameter) and branch micro-tubes (6 mm diameter) the water tank due to gravity force to each pot root zone through drippers (discharge rate of 2 liters per hour) (Panigrahi et al., 2015). It can be a plastic barrel, one or two or more than two drum or concrete made a tank. Water is field either manually using a bucket or through a pipe of water supply. Always clean water is used for watering. Usually, the water filter is not required when filtered tape water or groundwater is used.

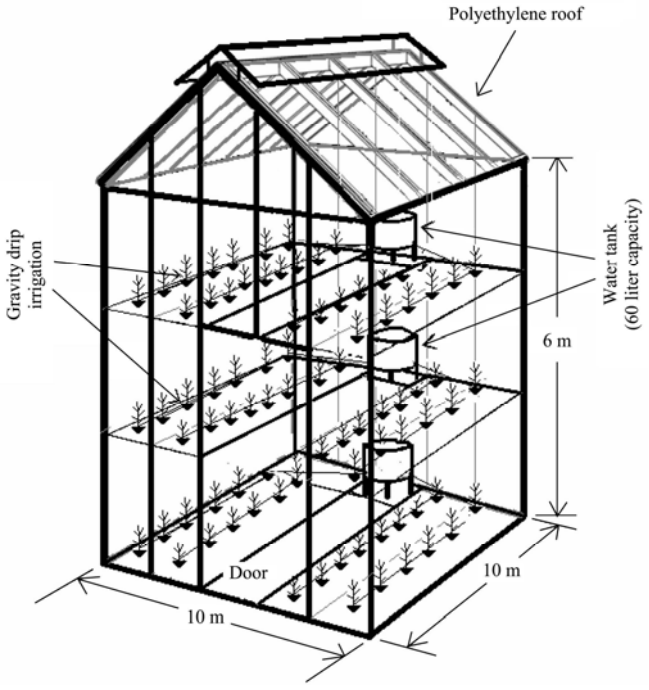


Figure 1 Model design of a cubical shape three-layered stacked protected farm with gravity drip in pot system

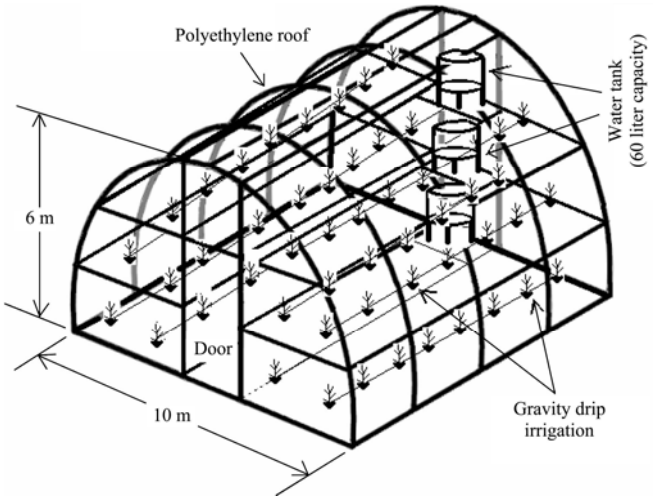


Figure 2 Model design of a semi-cylindrical shape protected farm with gravity drip in pot system

### 2.1 Cost of installation, operation and maintenance

The estimated cost of construction of a low-cost three-layered stacked protected farm structure of size 10 m (length) × 10 m (width) × 6 m (height) in Agartala city is shown in Table 2. The rate of materials for construction was based on the market survey of Agartala city. A low-cost single story stacked protected farm is considered to be constructed in the farmer's own land and the gravity drip irrigation system in the protected farm drips water to each pot root zone for 4 hours during Indian time 10:00 am to 2:00 pm every day.

The operating cost mainly comprises the cost of water, nutrient, substrate, and seeds. The crop grower self shall manage the works of planting seeds, irrigating to crops, harvesting matured crop and selling in the local market. Water controller is used for regulating the rate of flow of water to each crop root zone through drippers. The estimated cost of raw materials required for installation of gravity drip irrigation in a three layered stacked protected farm on 10m ×10m area is shown in Table 1. The farmer himself shall construct the three-layered stacked protected farm equipped with a gravity drip irrigation system in his/her own land with the help of 1 or 2 laborers. Estimated operating cost of the three-layered stacked protected farm and open field on area 10m ×10m in Tripura is shown in Table 2. Each installation lasts for about 20 years. A little care is sufficient to keep the system in good condition.Water can be filled either manually or by using a pump operated water supply through pipes. The water tank is always covered with one non-corrosive plate for protecting the inside water from evaporation and to prevent algae development. A water filter is not required when filtered water is used.

**Table 1 Estimated cost of construction of athree-layeredstacked protected farm in Tripura**

| Major item | Sub-items | Quantity | Specification | Rate | Total cost ($) |
|---|---|---|---|---|---|
| Structure | Galvanized iron pipe | 16pcs. | 6 m length, 40 mm diameter | $1.25 m$^{-1}$ | 120 |
| | Polythene sheet for roof | 2 pcs. | UV stabilized 200 micron, 10 m ×10 m | $0.40 m$^{-2}$ | 80 |
| | Shade net for sidewall | 4pcs. | 40 mesh, 10 m× 6 m | $0.50 m$^{-2}$ | 120 |
| | Stacks | 6pcs. | Plastic make, 10 m × 2 m | $0.75 m$^{-2}$ | 90 |
| Gravity drip system | Water tank (plastic make) | 3pcs. | 60 liters capacity | $3.00 per unit | 9 |
| | Ball valve (plasticmake) | 3pcs. | 20 mm threaded PVC ball valve | $1.33 per unit | 4 |
| | Polyethylene tubes | 100m | 16 mm diameter | $0.06 m$^{-1}$ | 6 |
| | Micro-tube | 100m | 6 mm diameter | $0.15 m$^{-1}$ | 15 |
| | Dripper | 120pcs. | Discharge 2 liters per hour | $0.05 per dripper | 6 |
| | Pot | 120pcs. | Earthenware | $0.15 per pot | 18 |
| | Substrate | 120 kg | Peat | $0.10 km$^{-1}$ | 12 |
| Total cost of the above system components = $480 | | | | | |

**Table 2 Estimated operating cost of the three-layered stacked protected farm and open field on area 10 m×10 m in Tripura**

| Crops | Crop to crop spacing | Mean growing period | Growing frequency (number/year) | | Protected farm ($/year) | Open field ($/year) |
|---|---|---|---|---|---|---|
| | | | Protected farm | Open field | | |
| All green spinach | 1 m × 1 m | 80 days | 4 | 1 | 18 | 5 |
| Sweet tomato | 1 m × 1 m | 157 days | 2 | 1 | 42 | 17 |
| Chili pepper | 1 m × 1 m | 165 days | 2 | 1 | 16 | 11 |
| Fresh-market cucumber | 1 m × 1 m | 117 days | 3 | 1 | 12 | 6 |

## 3 Results and discussion

The crop yields from the three-layered stacked protected farm are estimated with reference to the average crop yield per plant under for all green spinach 0.3 kg (Pena, 2005) and sweet tomato 5.75 kg, chili pepper 0.79 kg, fresh-market cucumber, 6.75 kg (Rajasekar et al., 2013) are considered in this project. The crop growing frequency in a year under protected cultivation for all green spinach, sweet tomato, chili pepper and fresh-market cucumber are 4, 2, 2 and 3 respectively whereas the same under open field agriculture is 1for all these types of crops (Table 2). The annual operating cost is different for the four different crop varieties (Table 2). The cost of operation and profit from the three-layered stacked protected farm are estimated based on the crop market price of vegetables in the local Agartala city of Tripura state of North Eastern India on 28$^{th}$ June 2017 are shown in Table 1. The annual crop yield of all green spinach, sweet tomato, chili pepper and fresh-market cucumber from the from the 300 m$^2$ cumulative crop growing area (one story) of three-layered stacked protected farm are estimated to be 144 kg, 1380 kg, 190 kg and 2430 kg respectively; whereas the same from open field agriculture is 36 kg, 690 kg, 95 kg and 810 kg respectively (Table 3). The market price per kilogram of all green spinach, sweet tomato, chili pepper and fresh-market cucumber as per the local market price in Agartala city of Tripura state of North Eastern India on 28$^{th}$ June 2017are found to be \$0.20, \$0.64, \$1.16 and \$0.49 respectively. The total annual crop sale from the (one story) of three-layered stacked protected farm is estimated to be \$29 for all green spinach, \$ 883 for sweet tomato, \$220 for chili pepper and \$1191 for fresh-market cucumber. The annual investment to the (one story) three-layered stacked protected farm is estimated to be \$18 for all green spinach, \$42 for sweet tomato, \$16 for chili pepper and \$12 for fresh-market cucumber. Annual profit from the (one story) three-layered stacked protected farm is estimated to be \$11 for all green spinach,\$841 for sweet tomato, \$204 for chili pepper and \$1179 for fresh-market cucumber whereas the profit from the same land size open field agriculture is estimated to be \$2, \$425, \$99, and \$391 respectively. It is estimated that vegetable crop production from one story three-layered stacked protected farm on a land area of 100 m$^2$ viz., (10 m × 10 m) in Tripura state of North Eastern India is about four times higher for all green spinach two times higher for sweet tomato, two times higher for chili pepper and three times higher for fresh-market cucumber compared with open field agriculture. If a crop grower constructs one story three-layered stacked protected farm in grower's own land then the initial investment on fixed cost would be approximately \$480. To get back the total investment on fixed cost of the construction of the one story three-layered stacked protected farm in Tripura state of North Eastern India, one crop grower has to cultivate crops for 43.6 years if only cultivates only all green spinach, 0.6 years if only cultivates only sweet tomato, 2.4 years if only cultivates chili pepper, and 0.4 years fresh-market cucumber respectively. The profit from one story three–layered stacked protected farm over open field farming on land size 10 m ×10 m area is estimated to be five times, two times, two times and three times for growing all green spinach, sweet tomato, chili pepper and fresh-market cucumber respectively (Table 3). The initial investment of constructing the one story three-layered stacked protected farm in a cultivable or non-cultivable land is high may be affordable by most marginal land holders but it gives higher profit comparing to open field agriculture. Risk of crop damage involves minimum in protected cultivation comparing to open field agriculture. Multi-story protected farming is steadily becoming popular broadly in agricultural industrial communities viz., Vertical Farm (Levenston, 2011); South Pole Greenhouse (Cowing, 2011); Aero Farms (Nwosisi, and Nandwani, 2018); Sky Greens (Despommier, 2013); American Hydroponics (Shrestha and Dunn, 2010); Bright Farms, Sun Works, VertiCrop (Schnitzler, 2012); Thanet Earth (Caputo et al., 2017). Basic estimates of farm performance, calculated as profit per hectare, showed that smaller-scale farmers are substantially more profitable than larger ones (Kuo et al., 2006) Prices for organic herbs are incredibly high with soaring demand. In a multi-stacked crop production system, more crops can grow in less space as increasing the numbers of stacks vertically. A wide range of fast growing vegetables are able to be produced under multi-layered stacked protected

farms in hilly and marginal lands with limited water. Cost of installation and maintenance structure is minimal. Raw materials are available in most cities of the Tripura state of North East India. No skilled persons are required to operate the system. Clean water or filtered water needs to be applied to the crop through the gravity drip irrigation system. No water filter is required if clean water like supply tap water or groundwater is used. Judicious water conservation during the rainy season is very important for use during the winter season for growing fast-growing vegetable crops. The crop should be sown at the date of best timing based on the demand in the market. Similarly, the crop should be harvested in time to avoid loss in yield (Singh and Munda, 2008).

**Table 3 Estimated crop yield and profit of fresh crops from a three-layered stacked protected farm and open field on area of size 10×10 min Tripura**

| Crops | Annual production (kg) | | Market price ($/kg) | Annual sales ($) | | Annual investment ($) | | Annual profit ($) | | Profit in protected farm verses open field (times) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Protected farm | Open field | | Protected farm | Open field | Protected farm | Open field | Protected farm | Open field | |
| All green spinach | 144 | 36 | 0.20 | 29 | 7 | 18 | 5 | 11 | 2 | 5 |
| Sweet tomato | 1380 | 690 | 0.64 | 883 | 441 | 42 | 17 | 841 | 425 | 2 |
| Chili pepper | 190 | 95 | 1.16 | 220 | 110 | 16 | 11 | 204 | 99 | 2 |
| Fresh-market cucumber | 2430 | 810 | 0.49 | 1191 | 397 | 12 | 6 | 1179 | 391 | 3 |

## 4 Conclusion

A wide range of seasonal vegetables is able to be grown under protected culture from hilly, non-conductive and marginal lands. The construction of a three-layered stacked protected farm is simple and low-cost. The materials required for constructing a three-layered stacked protected farm structure are available in most of the cities of Tripura state of North East India. The operating cost is minimal if the crop grower self shall manage the works of planting seeds, irrigating to crops, harvesting matured crop and selling in the local market. Review of one story three-layered stacked protected crop production system revealed that the annual average crops yields from a three-layered stacked protected farm are found to be much higher compared with open field farming. The initial cost of construction of the farm is slightly high that can be affordable by the most marginal landholders but the crop yield is much higher compared to open field agriculture. Growing vegetables in multi-layered stacked protected farm especially in high-density urban areas reduce the length of transportation and environmental pollution. Multi-stacked protected cultivation is the best option for sustainable enhancement of crop yield from hilly, nonconductive and marginal lands to meet growing local food demands of growing populations. The initial investment of single story square and semi-cylindrical shape protected farms with multi-stack gravity irrigation system is within the marginal farmer's capability.

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