Feasibility analysis of substituting gutters in NFT system network for horticulture production with corrugated roof sheet

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Abstract. Hydroponic cultivation with nutrient film technique (NFT) is an alternative solution for problems in horticulture production, especially those related with land limitations and climate problems. However, high investment requirements often become obstacles in applying the technique. This paper discusses the feasibility analysis of substituting the commonly used gutters in NFT system network for horticulture production with corrugated roof sheet, i.e. tarpaulin-covered corrugated asbestos roof sheet. The technical feasibility analysis was carried out based on a number of parameters, i.e. the uniformity of nutrients solution flow rate at the inlet and outlet, the uniformity of nutrients solution concentration in the network, and the uniformity of produced plant weights. Meanwhile the financial feasibility analysis was carried out by Net Present Value (NPV) analysis, Net B/C analysis, and Internal Rate of Return (IRR) analysis of horticulture production. The results of the analysis were compared with those of NFT network system using gutters. The results indicated that uniformity of flow rate, the uniformity of nutrients solution concentration in terms of electrical conductivity and degrees of acidity, the uniformity of depth of flow and plant weight were close to 90%. This means that the proposed hydroponic technique can be applied. Using assumptions derived from productivity of tested horticulture commodities and the actual market prices of inputs as well as output, hydroponic techniques with NFT networks using tarpaulin-covered corrugated asbestos roof sheet was also financially feasible.

1. Introduction
Fruits and vegetables are parts of horticultural products that very important in a healthy diet. Vitamins, minerals and fibre contained in fruits and vegetables have a function as antioxidants that can reduce the emergence of non-communicable diseases (NCDs) caused by malnutrition. Meeting the needs of enough fruits and vegetables for the community is also very important in reducing the risk of micronutrient deficiencies.

Consumption of fruits and vegetables of the Indonesian people is still relatively low, with an average of 173 grams per capita per day [1], compared to the WHO/FAO recommended nutritional...
adequacy figure of 400 grams per capita per day. However, the increasing awareness of the need for healthy food slowly increases the consumption level of these fruits and vegetables. This in turns necessitates an increase in the supply of fruit and vegetables for the community.

The other challenge is conflict of interest in land use. Population and industrial growth has caused the conversion of agricultural land into residential and industrial areas, and then it forced agricultural production shift to marginal areas. A study has reported that in the period of 2007 to 2010 there has been a decrease of agricultural land area in Java Island from 4.1 million ha to 3.5 million ha [2]. In such situation, vegetable production using hydroponic techniques is one solution.

There are various hydroponic techniques that have been developed, one of which is nutrient film techniques (NFT) [3]. NFT is a hydroponic technique where plant roots are placed in a shallow water layers containing all the dissolved nutrients required for plant growth. The nutrient solution is circulated in a very shallow stream in a watertight gully, also known as channels, passing the bare roots of plants. Hydroponic cultivation with NFT implemented in green house is an alternative solution for horticulture production with land limitations and climate problems. The hydroponic farming systems reduce dependences on land, the hydroponic approach that emphasizes the function of water helps plants to find minerals and other intake more easily, the flexibility of the NFT system has enabled it to be adapted to a wide range of crops, setting the nutrition supply properly allows plants to get a better intake compared to agriculture that relies on the soil as a growing medium, and a greenhouse system allows plants to grow throughout the year regardless of the season. However, high investment requirements often become obstacles in applying the technique.

To reduce the investment cost, Joy Farm, a small scale enterprise in Depok City, has been substituting the commonly used gutters in NFT system network with corrugated roof sheet, i.e. tarpaulin-covered corrugated asbestos roof sheet, for their horticulture production. The idea is not in line with recommended practices, i.e. using specially made channels/gully for NFT systems that have flat bottoms with grooves running lengthwise along the channel. This paper discusses the technical feasibility as well as financial feasibility analysis of this substitution.

2. Materials and methods
A cultivar of water spinach (Ipomoea aquatic Forsk) and red spinach (Amaranthus tricolor Linn) were used in this study. They were grown in an NFT irrigation network with nutrients reservoir and nutrients solution in a 1.000 m$^2$ green house. There were 64 plant beds in the green house that were made from corrugated roof sheet, i.e. tarpaulin-covered corrugated asbestos roof sheet, each with an area of 11 m$^2$, from which 40 beds were used to cultivate water spinach and 24 beds for red spinach. Figure 1 shows the layout of the beds in the NFT system while figure 2 shows plant bed made from tarpaulin-covered corrugated asbestos roof sheet. Styrofoam sheets were placed on plant beds to support the plants. A portable electrical conductivity meter (EC meter) and pH tester were used to measure EC and pH value of the nutrient solutions.

2.1. Technical feasibility analysis
The technical performance of NFT systems is an important factor in determining the feasibility of the system to be implemented. In this system, the concentration of nutrients solution is one of the parameters that determine the quality and yield of plants. The concentration of the nutrients solution is represented by the value of electrical conductivity (EC), i.e. an index of salt concentration and an indicator of electrolyte concentration of the solution. EC of the nutrients solution is related to the amount of ions available to plants in the root zone [4]. The presence of these ions which allow electrical conductivity in nutrient solutions be measured by an EC sensor. EC values of nutrient solutions that are too high result in slow growing plants and high production costs. Contrariwise, concentrations of nutrient solutions that are too low will cause crop productivity to decrease [5]. Degree of acidity pH is also important factor since it influences nutrients uptake by plants. Therefore, efforts are needed to control the concentration of the solution and pH so that the cultivation results
from the NFT technique can reach the maximum level. In general, EC is maintained between 1 and 3 dS/m, and target pH is between 5.5 and 6 [6].

**Figure 1.** The layout of plant beds in the NFT system

**Figure 2.** Plant bed made from tarpaulin-covered corrugated asbestos roof sheet; (a) tarpaulin-covered corrugated asbestos roof sheet, (b) Styrofoam sheet placed on top of plant bed.

Uniformity of irrigation/nutrient absorbed by plants is parameters that must be considered in a hydroponic cultivation system and its value must be in accordance with the growing requirements of the plant since it will determine the quality of crop produced. Besides, uniformity of irrigation/nutrient also determines the level of efficiency of the cultivation system applied, so that it can be known whether the system is feasible or not to be applied [7]. General parameters used to evaluate uniformity of water distribution is the coefficient of irrigation uniformity (CU/coefficient of uniformity) suggested by Keller and Bleisner [8] as the following. Coefficient of uniformity equal or greater than 90% is considered as feasible.

\[
CU = \left[ 1 - \left( \frac{\sum |X_i - X_{\text{r}}|}{n \times X_{\text{r}}} \right) \right] \times 100 \%
\]  

(1)

Where,

- \( CU = \) coefficient of uniformity (%)
- \( n = \) number of observation points.
\( X_i = i^{th} \) observation value \((i = 1, 2, 3, \ldots, n)\).
\( X_r = \) mean value of measurement

Referring to [9], evaluation of the technical feasibility of the NFT network was undertaken based on parameters such as the uniformity of nutrients solution flow rate at the inlet and outlet, the uniformity of nutrients solution depth in the NFT network, the uniformity of nutrients solution concentration in the network, and the uniformity of produced plant weights. Debit and depth of nutrients solution were measured in four points of four beds’ inlet and outlet every three days. Nutrients solution concentration, in terms of EC and pH of nutrients solution, were measured in four beds’ inlet and outlet every hour (from 08:00 am – 04:00 pm) every three days. Plant weight were measured from four beds of each production cycle.

2.2. Financial feasibility analysis

Financial feasibility analysis was carried out based on investment cost, operational cost and projected revenue for five (5) years planning time. The investment costs comprise of those related with green house (wooden framed covered by vinyl), NFT system network with plant beds made by tarpaulin-covered corrugated asbestos roof sheet, electricity and generator set, workspace and storage, farming tools, and vehicle. The operational costs comprise of those related with seeds, nutrients, wages, electricity bills, fuel, maintenance, and security cost. All prices were referred to 2018 figures. With all of those information, analysis were made to obtain net present value (NPV), net B/C ratio, and internal rate of return (IRR) of horticulture production.

3. Results and discussion

3.1. Technical feasibility analysis

The NFT network with plant beds made from tarpaulin-covered corrugated asbestos roof sheet has been used for cultivating red spinach \((Amaranthus tricolor Linn)\) and water spinach \((Ipomoea aquatic Forsk)\).

Measurement of nutrients solution flow rate at the inlet and outlet, nutrients solution depth in the NFT network, nutrients solution concentration in the network, and produced plant weights have been made, the results and its analysis of uniformity are shown in figure 3, figure 4, figure 5, figure 6 and table 1 for nutrients solution flow rates, nutrients solution depth, nutrients solution concentration (EC and pH), and uniformity of produced plant weights, respectively.

![Figure 3](image-url)

**Figure 3.** Uniformity of inflow and outflow debit of nutrients solution in 4 beds of water spinach; (a) inflow debit with average CU of 95.02%, (b) outflow debit with average CU of 92.96%.
Figure 4. Uniformity of inflow and outflow debit of nutrients solution in 4 beds of red spinach; (a) inflow debit with average CU of 87.53%, (b) outflow debit with average CU of 87.76%.

The inflow and outflow debit of nutrients solution in beds of water spinach and red spinach ranged from 2 ml/sec to 13 ml/sec. The coefficient of uniformity of flow in water spinach beds were higher than those of red spinach beds, ranging from 90.02% to 97.11% with the average in inflow was 95.02% and outflow was 92.86%. The coefficient of uniformity of flow in red spinach beds were ranging from 83.79% to 90.50% with the averages were 87.53% and 87.76% for inflow and outflow, respectively. The flow was influenced by the size of the inlet and outlet holes in the pipes that were not fully uniform due to its manual making method. Besides, the growth of plant roots in the plant beds will also affect the flow of the outlet. Although the uniformity of inflow and outflow debit were relatively better than that of NFT system with gutters [9], for better uniformity of nutrients solution flows, the holes in the pipes need to be improved.

Figure 5. Uniformity of nutrients solution flow depth in beds of water spinach (CU = 85.62%) and red spinach (CU = 88.00%).

The depth of flow in the NFT network will be the space for roots of the plants to absorb nutrients in the solution. The expected depth of solution flow is 3 - 4 mm. Measurement undertaken in the inlet and outlet of plant beds indicate that the depth of nutrients solution flow in water spinach beds were ranging from 2.8 mm to 5.8 mm while those in red spinach beds were ranging from 3.1 to 5.0 mm. Depth in outlet tended to greater than depth in inlet since the plant beds are slightly inclined to enable natural water flow. Coefficient uniformity of the flow depth were ranging from 85% to 88%. The measurement results indicated that the depth of nutrients solution as well as its coefficient of
uniformity were not met the standards, and they were not as good as those in NFT with gutters. The identified sources of problem were including the damming effect of plant roots, moss and dirt on the flow of water, and also the thin folds of tarpaulin coating the beds. Since the roots are literally lying in the nutrient film, they are more susceptible to nutrient lockout due to excess of salt accumulation. Therefore, cleaning plant beds and flushing the NFT network at transitional periods (between harvest and subsequent cultivation) are highly recommended. It is also good to flush the system about 7 days before harvest.

Figure 6. Uniformity of EC and pH in beds of water spinach and red spinach; (a) EC with average CU of 90.66%, (b) pH with average CU of 96.64%.

The EC values of nutrients solution in water spinach plant beds were ranging from 3 dS/m to 3.5 dS/m, while those in red spinach plant beds were ranging from 2.5 dS/m to 3.2 dS/m. The values were in the range of determined target although some points have values slightly higher than the target. The EC coefficients of uniformity were also good, ranging from 88.83% to 98.85% with the average of 92.34% in water spinach beds and 88.99% in red spinach beds.

Measurement on pH indicated that the pH of nutrients solution in water spinach plant beds were ranging from 5.6 to 7.2, while those in red spinach plant beds were ranging from 6.0 to 7.4, both with very good coefficient of uniformity of about 96%. The pH surpassed the targeted value of 5.5 to 6 and therefore need for adjustment. The solubility of macro and micro nutrients will be very good in the pH range of 5.5 to 6.5 so that its absorption by plants will also be very good. Therefore control of pH need to be undertaken, for example by adding nitric acid solution (HNO3, pH = 2) to the nutrients solution.

Business on cultivation with hydroponic system basically aims to achieve high results in both production quantity and quality. Uniformity of plant weight is one of the technical performance evaluation parameters. Hence crop production be seen from the weight of the plants produced and the uniformity of weights. Average weight of plants per bed is 17.4 kg for water spinach and 17.6 kg for red spinach. However, the weight of plants per hole highly varied as indicated by table 1 which shown coefficient of uniformity per bed at the range of 67% to 80%.

The low coefficient of uniformity of plant weight were caused by poor condition of surface flow that were not uniform due to tarpaulin folds that affect the plants’ absorption on nutrients. Besides, the number of plants planted in one hole was also causing the acquisition of nutrients in each plant was not good. Those reasons will ultimately have an effect on plant growth.
Table 1. Coefficient uniformity of plant weight

| Bed No. | Water Spinach (%) | Red Spinach (%) |
|---------|-------------------|-----------------|
| 1       | 73.24             | 73.24           |
| 2       | 71.94             | 67.94           |
| 3       | 75.78             | 79.95           |
| 4       | 67.94             | 73.24           |
| Average | 72.22             | 73.59           |

Based on the results above, in general the NFT system with plant beds made from tarpaulin-covered corrugated asbestos roof sheet can be applied, because the uniformity coefficients of the essential parameters were close to 90%, except the coefficient uniformity of flow depth and plants weight which were still not satisfying. To improve the value of uniformity routine care on the NFT network is indispensable. Need to be noted that nowadays corrugated roofs are no longer made from asbestos anymore, although in stores are still often called as corrugated asbestos. For the safety and health, it is recommended to substitute it with that made of fibre cement material. Another alternative is by using a corrugated plastic roof, then coated with black plastic or painted underneath with white, blue or green so that no light enters the water flow, which can cause the grow of algae.

3.2. Financial feasibility analysis

Financial factors are the main benchmarks of a business analysis, especially those related to cash flow that occurs during business activities. Calculation of costs, unit production cost, and projection of the profit earned is undertaken to know the indicators of the feasibility of a business.

The hydroponic crop cultivation business requires investment costs and operational costs. Investment costs are costs incurred before the plants produced, covering building and equipment costs while operational costs are costs that directly related with cultivation activities such as purchase of seeds, nutrients, wages of labours, fuel, electricity and maintenance cost. The harvest time was 15 days per cycle for water spinach and 22 days per cycle for red spinach. Two-days cleaning activity was allocated between cycles. Table 2 displays the details of the components of investment costs and operational costs.

Table 2. Components of investment costs and operational costs

| Investment Cost Components | Economic Life (years) | Amount (IDR) | Operational Cost Components | Amount (IDR/year) |
|----------------------------|-----------------------|--------------|-----------------------------|------------------|
| Wooden framed greenhouse   | 5                     | 480,000,000  | Seeds                       | 14,900,000       |
| Hydroponic System          | 5                     | 73,500,000   | Nutrients                   | 28,000,000       |
| Electricity and Generator set | 10               | 8,500,000    | Wages                       | 94,800,000       |
| Work Space and Storage     | 10                    | 6,000,000    | Electricity                 | 12,000,000       |
| Farming tools              | 5                     | 8,500,000    | Maintenance                 | 2,800,000        |
| Vehicle                    | 10                    | 110,000,000  | Fuels                       | 10,500,000       |
| Total                      |                        | 685,500,000  | Total                       | 163,000,000      |

Average weight of harvested plant per bed was 17.4 kg for water spinach and 17.6 kg for red spinach. By using interest rate of 7% per year, the production cost of each crops were IDR15,150 per
kg for water spinach and IDR 13,490 per kg for red spinach. Despite different unit production cost, the wholesales selling price of both crops was equal, IDR 18,000 per kg. The five years cash flow projection indicated that the NPV was IDR 303,205,000, the Net BC ratio was 1.44 and internal rate of return (IRR) was 21%. These results reveal that the business is financially feasible. Under current production scale and productivity level the breakeven point of wholesales price is IDR 14,500. The sizeable margin between the breakeven point of wholesales price and the actual selling price indicates that the cultivation business of the crops using the modified NFT system network is financially quite safe.

4. Conclusions
Tarpaulin-covered corrugated asbestos roof sheets have been used for substituting gutters as plant beds on NFT system network. The system was used for cultivating red spinach (*Amaranthus tricolor* Linn) and water spinach (*Ipomoea aquatic* Forsk). From the analysis undertaken it was concluded that the system was technically and financially feasible, indicated by coefficient uniformity of the essential parameters close to 90%, on 5-years cash flow projection the NPV was IDR 303,205,000, net BC ratio was 1.44 and internal rate of return (IRR) was 21%. The use of corrugated roof sheets made of fibre cement material or plastic material is suggested as alternative to cope up with unavailability of corrugated asbestos roof sheets.

5. References
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