# Farm Management and Economic Drivers for Implementation of Soilless Cultivation of Field Vegetables in The Netherlands

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**Abstract**

**Current field vegetable production in the Netherlands has difficulty to meet the requirements of the EU directives on water quality and to meet the market requirements on food safety, product quality and predictability. Therefore, a multiannual research program has been carried out to develop new soilless systems for field vegetables next to other outdoor horticultural crops. Profitability is a precondition for widespread implementation of these systems and to achieve a significant sustainability impact. This paper focuses on the potential of Deep Flow cultivation systems for vegetables to improve farm management and economics for growers. Results show that these crops give a yield increase on the soilless systems with respect to the soil bound system, mainly by faster growth and higher plant densities. At this moment, the cost prices for vegetables cultivated on this soilless system on a small scale are higher than conventional outdoor vegetables, because of the high capital costs for the soilless system in comparison with the costs for tractors and agricultural machinery and the higher energy requirement for water circulation. We expect that growers are able to make the system profitable for leek, lettuce and spinach by up scaling, optimization of production, mechanization and automation of the system. Product differentiation to high value market segments also offers perspectives to profitable systems, although the thus achieved cultivated area and sustainability impact on a national scale will be limited. The large investment costs in the systems may be a barrier for growers to change over to the soilless cropping system.**

## INTRODUCTION

### Background and Aim

Many outdoor horticultural cropping systems in The Netherlands do not meet the requirements of the EU Water Framework Directive and EU Nitrates Directive mainly because of high nitrate emissions. In addition, these cropping systems have difficulty in complying with new market requirements on food safety, product quality and predictability of the production, while crop yield and quality are threatened by soil borne pests and diseases. Within the current cropping systems, there are a few options for further improvement to comply with these regulations and demands (De Haan et al., 2009, 2010). Soilless cropping systems for outdoor horticultural crops can give the opportunities to tackle these challenges. A research program has been carried out from 2009 to 2013 to develop new soilless systems for nine groups of crops: leafy crops like lettuce, leek, cauliflower, strawberry, blue berries, apple, tree nursery crops, flower bulbs and summer flowers. The research program was cooperation between government, research, growers, trade and industry.

One of the main questions in the research is to find the key success factors for this innovation to promote the implementation of these new systems on a larger scale. We expect that economic perspectives are a main factor. Therefore, this paper focuses on the potential of outdoor Deep Flow cultivation systems for vegetables (leafy crops, leek and cauliflower) to improve farm management and economics for growers.

**Current Field Vegetable Production in The Netherlands**

Current field vegetable production is stable in area. However, the number of farms is decreasing and logically the average farm size is increasing (Table 1; Anonymous, 2012a). Most important vegetable crops in the Netherlands are brassica, strawberries, asparagus, leek and leaf crops like lettuce (CBS, 2013). There are several large farms, specialised in one or more crops on an area over 100 ha. These farms have to rent or exchange land for crop rotation. These farms produce together the largest share of national production. On the other hand, there are also small farms growing a range of vegetable crops in rotation. According to LEI's Farm Accountancy Data Network the net operating result for outdoor vegetable growers is generally negative over the last 10 years (Table 1). Important factor is the high labour costs. Because of concentrations of retail, competition from farmers from other countries, selling prices are under pressure. Meanwhile it is difficult to make product differentiations to get a higher price.

Conventional vegetable crops are seeded or planted in the soil, whereby the number of growing cycles is limited by the needed crop rotation and logistic aspects and irrigation is needed in dry periods. Mechanisation has been improved (in particular by large and specialized vegetable growers) by increasingly better machines for planting and harvesting over the last years. However, labour demand is still large (between 150-700 hours per hectare, Anonymous, 2012b) and the labour conditions can be improved.

**Deep Flow System for Vegetable Cropping**

For crops like lettuce, leek, cabbage and spinach with short growing cycles (2-4 cycles per year) Deep Flow (DF) systems are developed. DF systems consist of a water layer of 10-30 cm with floaters in which the plants are planted (Fig. 1). This type of systems use no or only small amounts of substrate and provide a clean production system. DF systems are robust as failure of the system does not directly lead to plant loss.

Besides, DF systems offer possibilities for easy logistics by transport over water. Main disadvantage of the system is the large water volume, making disinfection of the water practically impossible and giving high emissions when discharge of water is needed. Another disadvantage of the system is the high energy use for pumping of the water (De Haan and Van Dijk, 2013).

## MATERIALS AND METHODS

A structured approach was used to design and develop these new soilless cropping systems for each crop group, followed by three years of experimental development at experimental farms in Zwaagdijk and Vredepeel and at some commercial farms. The program started with explorations per crop in working groups to get an overview of important opportunities and threats for the development of the new systems. Each working group made a crop description and a problem analysis for the conventional cropping systems in the soil and drafted system requirements for a soilless system. Most promising systems were selected crop specific, designed, engineered and tested on a small scale during several years. An overview of the experiments can be found in Blind (2013a, 2013b) and Van Os et al. (2013).

The sustainability and profitability aspects of the soilless system were assessed in detail by comparison of the new cropping system with the conventional system on these different aspects (Breukers et al., 2014). The profitability analysis is done for leek, head lettuce, spinach and cauliflower and is based on the achieved yields and experiences from the small scale tests and estimated costs for constructing the new system at larger scale. Prices and conventional cultivation measures are based on standards according to KWIN (Anonymous, 2012b).

Most important system requirement concerning farm management and economics is cost price. The cost price of a product from the DF system has to be equal or lower than expected selling price of the product. As investments costs are expected to be rising, other costs have to go down. Labour cost per unit of produce have to go down as they are now a large share of the total costs. The other important factor to compensate for higher cost is the need for increase in yield levels per area and per season.

Besides, the product quality has to be equal or better compared to the conventional grown vegetables. Vegetables from DF system have the general advantages to be free of soil. This gives advantages as well for labour concerning cleaning as for the quality of the marketable product. On this basis higher selling prices may be possible. However, based on comparable experiences and the current quality of soil-bound production we do not expect them to last long.

## RESULTS AND DISCUSSION

Results show that the vegetables can be grown on the chosen soilless system with higher yields. Soil-bound leek production for example yields on average three crop cycles in two years on the same area. Based on trial experiences, continuous leek cultivation in a pond is possible with main supply during the winter, whereby a four times higher yield than soil bound cultivation is achievable (Table 2). Most promising in terms of yield increase is head lettuce. Continuous planting in the ponds from April to October followed by continuous harvesting a month later shows a four times higher yield than conventional cultivation with an average of two cultivation periods per year. For spinach, due to a controlled germination phase, which is needed for cultivation on water, a yield increase of 10% was estimated in comparison with conventional spinach. Besides, through more efficient utilization of the growing surface a four times higher yield must be achievable for spinach too. Cauliflower has a longer growing period, whereby the mentioned advantage is smaller than for lettuce and leek. The cauliflower yield in a DF system is estimated to be almost twice as high as in a soil bound system.

However, despite the higher yields calculated cost prices for any of the analysed crops are higher on DF systems than in conventional production (Tables 3 and 4; Fig. 2). Except for leek we used the same selling price for products of both systems as we expect no higher prices can be realized. Calculated cost price for leek and head lettuce production in the DF system are close to the conventional system. Calculated cost price for cauliflower production in the DF system is much higher than the soil bound systems because of the relative low yield increase compared to leek and lettuce and the relative high capital costs for the soilless system in comparison with the costs for tractors and agricultural machinery in conventional production. The capital costs of the DF systems per year and unit of product are more than a factor 20 higher for cauliflower compared to the conventional soil-bound system (Table 4). Also for the other crops the capital costs in the DF system are higher than in the soil-bound system. The capital costs of the DF systems per year and unit of product are about double for leek, a fourfold for lettuce and a tenfold for spinach compared to the conventional soil-bound system (Table 4).

Possibly, the investment costs can be reduced over the years by further introduction of this system on a larger scale. Besides, optimization of the system could lead to at least 10-20% higher yields.

Labour costs per kg leek are lower in the DF system compared to the soil-bound system, especially because harvesting and planting is much more efficient (Fig. 3). Further mechanisation of the system can reduce the labour need in the DF systems. At the moment, mechanization is in the first large scale system is still limited. Additionally energy saving is an important point for improvement for the DF system. Energy costs for the DF system are relatively high with respect to the soil bound system caused by the high power consumption for the pumping of the water compared to the diesel consumption by tractors (Table 4).

Product quality was varying but on general equal or better than soil bound cultivation except for cauliflower where quality problems did often arise at the end of the growing period. However, with specific selection of cultivars for DF systems, we assume that product quality can be increased.

The calculated cost prices for the vegetables shown here and grown for bulk production are higher than conventional systems. When vegetable crops are chosen for niche markets as specialty lettuces (Lollo Rossa, Lollo Bionda, rocket and baby leaf) or mini cabbages the system can be profitable. However, few growers and few acreage will be involved.

## CONCLUSIONS

Deep Flow (DF) systems are technically a promising solution to grow outdoor vegetables with low emissions. DF systems are clean, robust, have a low substrate use and offers easy logistic possibilities by transport over water. Moreover they can realize large yield increases compared to conventional production, mainly for leek, spinach and lettuce. However, profitability is a precondition for widespread implementation of DF systems for vegetables to achieve a substantial sustainability impact.

The calculated cost prices for vegetables cultivated on DF systems on a small scale are however higher than conventional outdoor vegetables. Main reasons are the high capital costs for the soilless system in comparison with the costs for tractors and agricultural machinery, insufficient yield increase and insufficient increase of labour efficiency. We expect that growers are able to make the system profitable for leek, lettuce and spinach by up scaling, optimization of production and mechanization and automation of the system. The calculated cost price for leek on a DF-system is already close to the cost price of the conventional production because of large production increase and decrease in the needed labour. For cauliflower, we expect that a profitable system is not possible in a few years. Product differentiation to high value market segments also offers perspectives to profitable systems, although the thus achieved cultivated area and sustainability impact on a national scale will be limited. The large investment costs in the systems may be a barrier for growers to change over to the soilless cropping system.

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## Tables

Table 1. Cultivated area, number of farms, farm size, net income and profitability outdoor vegetables in Holland, 2005-2011 (CBS, 2013; Anonymous, 2012b).

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|
| Cultivated area | 22,000 | 24,460 | 24,416 | 24,857 | 24,096 | 23,986 | 24,270 |
| Number of farms | 980 | 970 | 910 | 930 | 900 | 900 | 890 |
| Average farm size | 17,3 | 19,1 | 21,4 | 22,0 | 22,7 | 22,3 | 23,6 |
| Net farm operating income | -46,9 | -39,3 | -11,4 | -48,2 | -76,7 | -25,6 | -29,5 |
| Profitability (return per € 100 costs) | 89 | 88 | 97 | 88 | 82 | 93 | 93 |

Table 2. Yield of vegetables in conventional soil bound systems and in DF water systems.

| | Soil bound | DF system | Unit |
|---|---|---|---|
| Leek | 65 | 285 | tons/ha/year |
| Head lettuce | 163 | 684 | 1.000 head/ha/year |
| Spinach | 52 | 229 | tons/ha/year |
| Cauliflower | 21 | 40 | 1.000 head/ha/year |

Table 3. Selling price, cost price and profitability of vegetables in conventional soil bound systems and in DF water systems.

| | Soil bound | | | DF system | | |
|---|---|---|---|---|---|---|
| | Selling price | Cost price | Profit-ability | Selling price | Cost price | Profit-ability |
| Leek (per kg) | € 0,47 | € 0,49 | 95% | € 0,49 | € 0,56 | 87% |
| Head lettuce (per head) | € 0,15 | € 0,17 | 90% | € 0,15 | € 0,20 | 75% |
| Spinach (per kg) | € 0,35 | € 0,35 | 100% | € 0,35 | € 0,52 | 67% |
| Cauliflower (per head) | € 0,55 | € 0,52 | 106% | € 0,55 | € 1,74 | 32% |

Table 4. Composition of cost price of vegetables in conventional soil bound systems and in DF water systems.

| | Leek | | Head lettuce | | Spinach | | Cauliflower | |
|---|---|---|---|---|---|---|---|---|
| | Soil | DF | Soil | DF | Soil | DF | Soil | DF |
| Starting material | 0,111 | 0,124 | 0,024 | 0,021 | 0,087 | 0,100 | 0,053 | 0,067 |
| Fertilizing | 0,008 | 0,017 | 0,004 | 0,004 | 0,015 | 0,015 | 0,024 | 0,024 |
| Pesticides | 0,015 | 0,001 | 0,005 | 0,000 | 0,009 | 0,002 | 0,022 | 0,008 |
| Energy | 0,015 | 0,044 | 0,006 | 0,011 | 0,007 | 0,034 | 0,016 | 0,161 |
| Transport costs | 0,113 | 0,113 | 0,073 | 0,073 | 0,180 | 0,180 | 0,144 | 0,144 |
| Labour | 0,120 | 0,085 | 0,026 | 0,020 | 0,021 | 0,016 | 0,152 | 0,077 |
| Land | 0,016 | 0,002 | 0,012 | 0,001 | 0,019 | 0,004 | 0,048 | 0,025 |
| Capital | 0,089 | 0,170 | 0,018 | 0,071 | 0,017 | 0,170 | 0,055 | 1,226 |
| Cost price | 0,492 | 0,562 | 0,167 | 0,202 | 0,354 | 0,524 | 0,518 | 1,734 |

**Figures**

Fig. 1. Deep Flow system for lettuce.

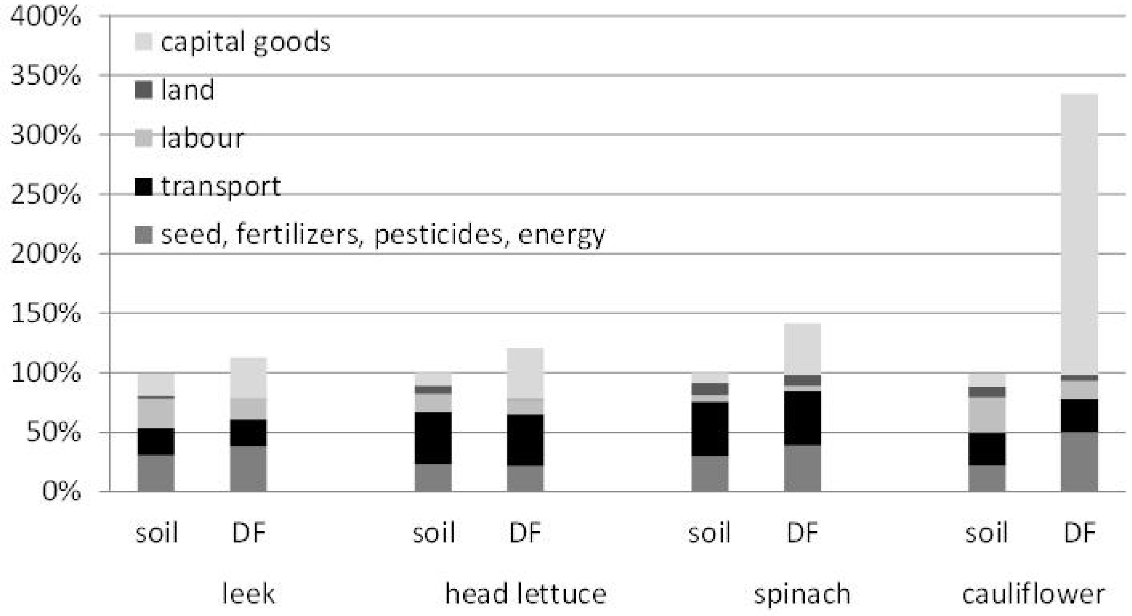


Fig. 2. Cost price leek, head lettuce, spinach and cauliflower DF system versus soil bound system (soil bound system is 100%).

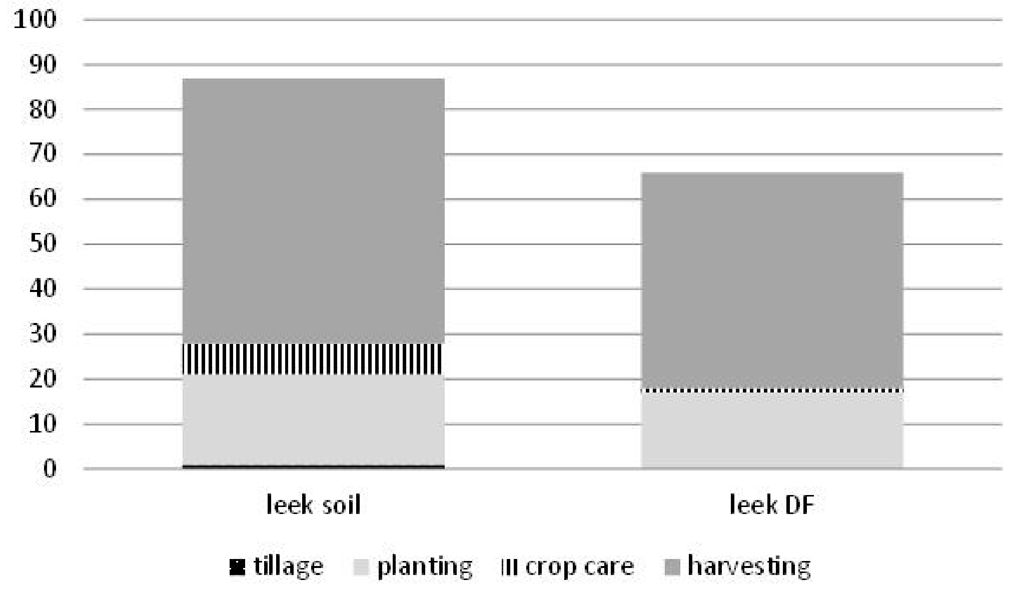


Fig. 3. Labour demand leek (per 10 ton) DF system versus soil bound system.