Sustainable Development of the Flemish Greenhouse Industry

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ABSTRACT

This paper addresses the sustainable development of the Flemish greenhouse industry by investigating the optimal size, structure and location of its firms. It emphasizes the importance of a square shape of the greenhouse as optimal structure. Using Data Envelopment Analysis an optimal farm size that varies between 1.7 and 3 hectares has been found, depending on the method used. Location factors that matter in the future Flemish greenhouse industry include temperature, light, transportation costs, air pollution and land prices, while rainfall, wind, output price differences, soil and infection risk do not differentiate between regions.

INTRODUCTION

Although the greenhouse industry is a dynamic and innovative sector with a strong international market orientation, both for flowers and for vegetables, the institutional environment for the cultivation of flowers and vegetables in greenhouses has changed considerably. The greenhouse industry faces increasing competition from abroad, an increasingly concentrated retail sector and increasing demands from the consumer. On top of that, the pressure to realize other social objectives, such as a clean environment and an attractive landscape, increases. Finally, the shift in EU agricultural policy from market support to rural policy will also have an impact on the greenhouse industry through substitution effects in other sectors.

In summary, the Flemish greenhouse industry is a sector confronted with considerable problems. To keep her market share, while at the same time taking into account the conditions imposed upon her by the environment and the consumer, the sector has to react as rational as possible, assisted in this process by appropriate government action. For this, the attributes of the present structure—more particularly, firm size and location—need to be evaluated, and compared to an optimal situation. Only in this way, an optimal (policy) environment can be created to support the sustainable development of the Flemish greenhouse industry.

While sustainable development involves the simultaneous achievement of economic, environmental and social goals, the analysis that follows will show that economic sustainability often results in environmental sustainability. This analysis focuses on the factors related to farm size and location. The next section will address some theoretical issues. Then, farm size and structure will be analysed. Consequently, various location factors and their relation to profitability will be discussed. The paper concludes with some recommendations.

THEORETICAL BACKGROUND

To determine the socio-economically and ecologically optimal structure for the Flemish greenhouse industry, the project will use insights from the theory of the firm, environmental economics and location theory.

The theory of the firm suggests that most economic sectors are characterized by a U-shaped average cost curve, from which an optimal firm size can be derived. This optimal firm size determines the competitiveness of firms in an international context. A recent study on the Dutch greenhouse industry confirms the existence of such a U-shaped average cost curve and reveals that the optimal size of a greenhouse farm is between 3 and 5 hectares, depending on the type of production (Alleblas and Mulder, 1997).

However, an approach that only looks at the existing average cost curve does not take into account the externalities produced by the greenhouse industry and will hence not result in a social optimum. Such externalities include in the first place the negative side effects from productive activities that harm society, such as the pollution of the environment (air, water and soil). However, also positive externalities may exist and should be taken into account. For example, electricity plants produce residual heat that can be used for heating purposes by surrounding firms. This ecological dimension needs to be included in the economic calculus by internalizing the externalities, i.e. by incorporating them into the cost of production. Only in this way a social optimum can be realized (Coase, 1960).

Cost minimization not only implies that a firm has an optimal size, but also that it is located there where costs are minimal. In the beginning, classical location theory emphasized distance (and hence transport costs) to the markets as the most important determinant of firm location.[1] Later, all costs of production (production factors, marketing, technology) were considered into the study of optimal location (Smith, 1966), including all environmental factors influencing these costs (policy, climatic conditions, infrastructure).[2] Insights from international economics have led to a better understanding of the factors determining firm location. For example, the concentration of firms into agglomerations has been explained by assuming imperfect competition in industrial sectors (Krugman, 1991). More recent research has emphasized the negative feedbacks of externalities produced by firms on their optimal location (Abdalla et al., 1995). Congestions of e.g. traffic or pollution in agglomerations have negative effects on the profitability of firms that consequently move to the periphery (Brakman et al., 1996).

OPTIMAL SIZE AND STRUCTURE

Greenhouse structure

Firm structure plays an essential role to optimize profitability in the greenhouse industry. A square-structured firm displays better economic and environmental results for several reasons. First, the paths and corridors necessary to allow men

[1] Refer to the models developed by von Thünen (1826) for the location of farms, Weber (1929) for industrial location, and Sangers (1969) for an application to horticulture.
[2] Refer to e.g. Smith (1971) for an overview of economic-geographic theories on optimal firm location.

and machine to reach all corners of the firm take up least size (table 1). Hence, more space remains to cultivate crops.

Second, a square-structured firm has the smallest glass/content ratio. In this way, not only construction costs are lower, but also heat losses via the glass will be limited and less heating is necessary. Third, labor costs are significantly lower in a greenhouse with a length-with ratio of 1:1, as a result of the smaller distance that workers have to abridge.

In Flanders, considerable gains can be made. Looking at the length-width ratio of greenhouses in the four most important greenhouse regions, sub-optimal figures can be observed. In regions with recent constructions the situation is better than in regions with aged greenhouses, except for the region of Mechelen, that is characterized by a good length-width ratio despite the relatively old greenhouses.

Table 1

Length (m)	*Width (m)*	*Surface (m²)*	*Surface corridor (m²)*	*Cultivated surface %*	*Length/width relation*
100	100.0	10000	300	97.0	1.00
110	90.9	10000	330	96.7	1.21
120	83.3	10000	360	96.4	1.44
130	76.9	10000	390	96.1	1.69
140	71.4	10000	420	95.8	1.96
150	66.7	10000	450	95.5	2.25
160	62.5	10000	480	95.2	2.56
170	58.8	10000	510	94.9	2.89
180	55.6	10000	540	94.6	3.24
190	52.6	10000	570	94.3	3.61
200	50.0	10000	600	94.0	4.00
210	47.6	10000	630	93.7	4.41
220	45.5	10000	660	93.4	4.84
230	43.5	10000	690	93.1	5.29
240	41.7	10000	720	92.8	5.76
250	40.0	10000	750	92.5	6.25
260	38.5	10000	780	92.2	6.76
270	37.0	10000	810	91.9	7.29
280	35.7	10000	840	91.6	7.84
290	34.5	10000	870	91.3	8.41
300	33.3	10000	900	91.0	9.00

Note: the passageway is assumed to be 3 m wide and to reach along the entire length of the greenhouse.

Table 2: Length/width relation in greenhouses in the largest greenhouse areas

Greenhouse concentration area	*Length/width relation (95% confidence interval)*	*% farms < 10 years*
Gent-Lochristi	2.00 : 1 ←→ 2.30 : 1	31 %
Roeselare	1.63 : 1 ←→ 1.83 : 1	47 %
Hoogstraten	1.58 : 1 ←→ 1.77 : 1	55 %
Mechelen	1.48 : 1 ←→ 1.62 : 1	38 %

Firm size

Scale effects imply differences in returns and costs between firm sizes caused by size. These effects influence the optimal size of greenhouse farms in the short run. In the long run, also technological developments play an important role in the evolution of the optimal firm size.

In general, increase firm size first results in higher marginal returns and lower marginal costs. Beyond a certain size marginal returns will decrease and marginal costs will rise (but not necessarily simultaneously). Optimal size is reached when marginal returns equal marginal costs. Scale economies are usually a consequence of the better and more efficient use of production factors. As firm size increases, labor and machinery can be better adjusted.

We used Data Envelopment Analysis (DEA) to determine the optimal size of farms. DEA constructs, in a non-parametric manner, the convex hull around a set of observations. The distance to this production frontier is then a measure of technical inefficiency.[3] When assuming constant returns to scale (CRS), total technical efficiency is estimated, but total technical efficiency can be further decomposed into pure technical efficiency and scale efficiency. To calculate pure technical efficiency, the production technology is assumed to display variable returns to scale (VRS). Scale efficiency is then the residual between total and pure technical efficiency. As a result, a farm that displays pure technical

[3] A farm is technically efficient if it produces on the boundary of the production possibility set, i.e. it maximizes output with given inputs and after having chosen technology. This boundary or frontier is defined as the best practice observed in a sample of farms. An indicator for technical inefficiency hence measures the deviation from that frontier.

efficiency may not operate at an optimal scale, that is, its input-output combination may not correspond to the combination that would arise from a zero-profit long-run competitive equilibrium situation (Färe et al., 1985).

As in Färe et al. (1985), we assume that production is characterized by a non-parametric piecewise-linear technology, so that simple linear programming techniques can be used to calculate efficiency. We further assume strong disposability of outputs and inputs and estimate the non-parametric deterministic frontier, expressed in terms of minimizing input requirements. Total technical efficiency can be estimated using the following linear program for each farm k that constructs the CRS frontier: $\{\min_{\lambda,z} \lambda$ *subject to* $z\, Y \geq Y_k;\ z\, X \leq \lambda\, X_k;\ z \geq 0\}$, where Y_k denotes the output of farm k, X_k is a vector of m inputs employed by farm k, and z is a vector of k intensities that characterizes each farm.

The inputs for the DEA were size, labor, infrastructure and variable costs. The proceeds were used as output. The DEA was carried out for 9 years (1990-1998). The scale efficiencies were plotted out in function of the firm size. An example for specialized vegetable farms in 1995 is shown in figure 1. A trendline was added and the crossing point of the trendline with the 100% scale efficiency line was calculated. This point was supposed to be the minimal size a firm needed to be sure it was working scale efficient. The results of this calculation are shown in figure 2. When the results in figure 2 are extrapolated to 2010, one can see that greenhouse farms will be scale efficient at 3 to 3.5 hectares.

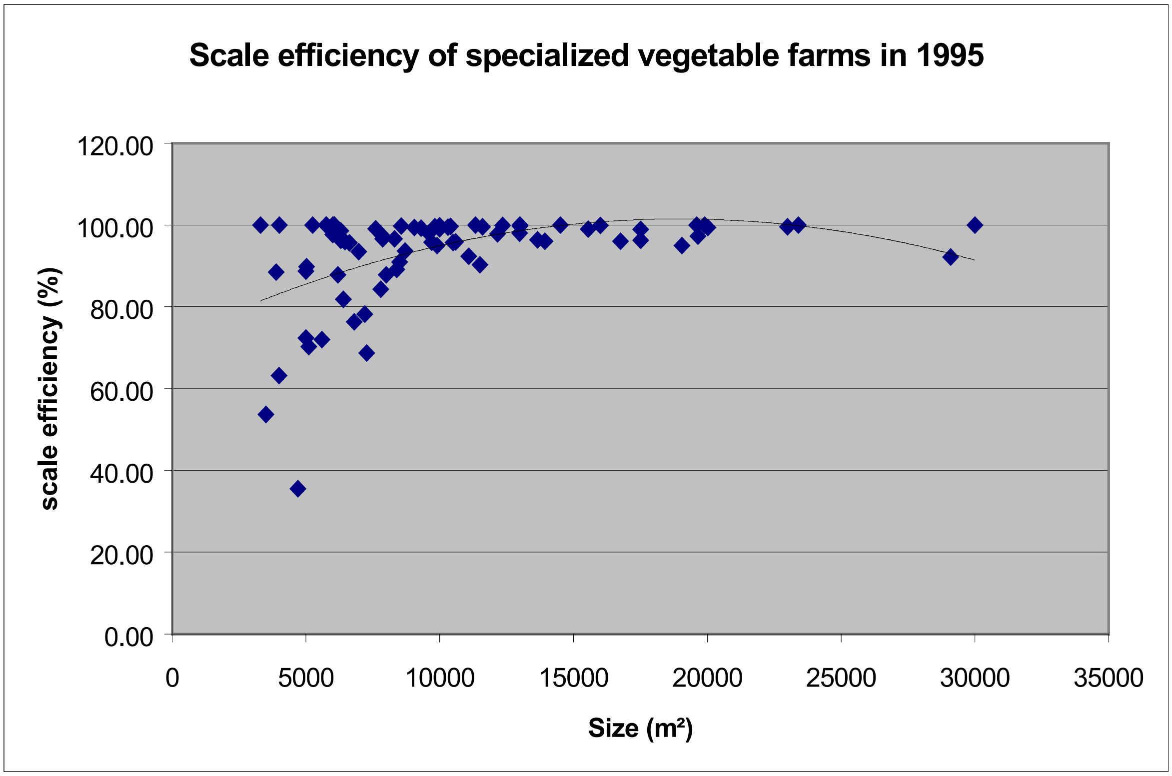

Figure 1: Scale efficiency of specialized vegetable farms in 1995

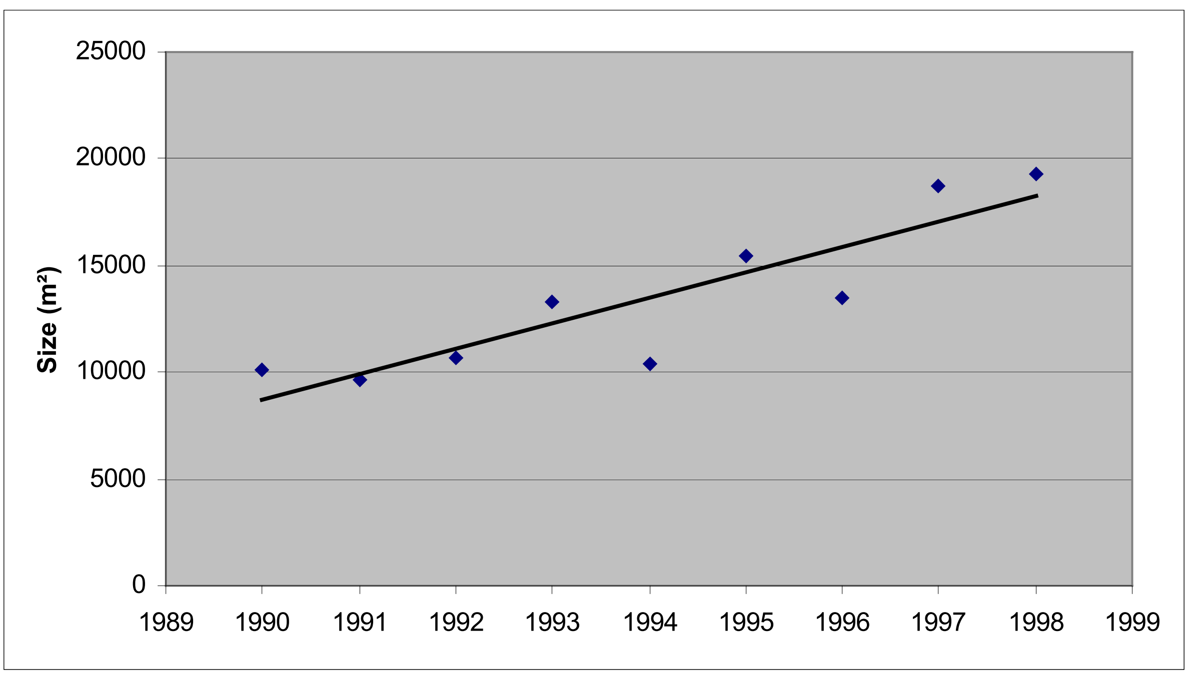

Figure 2: Optimal size

A second, more conservative analysis was carried out for three years: 1989, 1994 and 1998. The optimal size is defined being the size where 80% of the observed farms perform with a scale efficiency exceeding 95%. When this graph is produced for several farm types and several years, an increase in optimal size for each of the farm types can be observed. Optimal size hence increases and will increase in the years to come. In the example shown in figure 3, one can observe that the optimal size for specialized vegetable farms in 1989 was situated between 9000m² and 1 ha, in 1994 between 1 ha and 11000m² and in 1998 between 12000m² and 13000m². In that case one can assume that optimal size will be about 1.6 to 1.7ha in 2010.

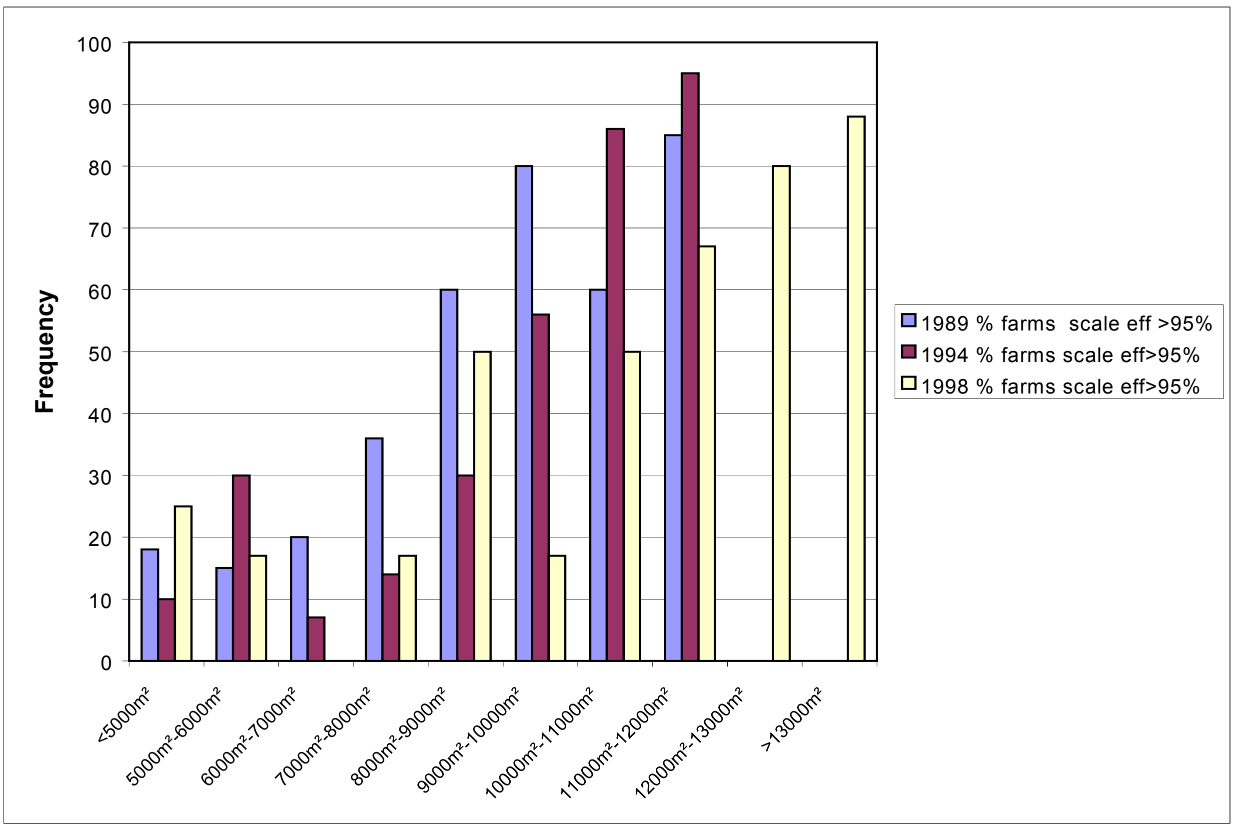

Figure 3: Percentage of specialized vegetable farms with a scale efficiency > 95%

Source: CLE

OPTIMAL LOCATION

Location theory predicts that firm location may have a significant impact on firm profitability. A location factor thus determines the economic attractiveness of a certain location. In the next, the location factors that will play an important role in the location of the Flemish greenhouse industry will be discussed and quantified where possible.

Climate

- Temperature

  Average year temperature is an important location factor that has an immediate influence on fuel costs and thus on profitability. In specialized vegetable production, such as tomatoes, fuel costs represents 15 % of total costs (Van Lierde; De Cock, 1999). With an average outside temperature of 2.5°C and a desired inside temperature of 18°C, one centigrade Celsius less means a decrease in fuel costs of 3 % or a decrease in total costs of 0.5 %. A cooler summer decreases the cooling needed ad saves labor.

- Rainfall

  The use of ground water in greenhouses will be forbidden from 2010 onwards. A specialized tomato farm needs approximately 1,000 litres of water per m^2. In an area where there is only 700 mm of rainfall per year, a manager of a 1 ha farm will have to purchase an additional amount of water of 3,000 m^3. At a price of 33,814 BEF/m^3, which is the rate for the industrial use of water in Flanders, this means an additional cost of a little over 100,000 BEF per hectare. Moreover, a basin will have to be built to store water from rainfall. This can cause problems in areas where there is a little room for expansion. This problem is expected to be less severe in Flanders than in the Netherlands.

- Wind

  Wind speed influences primarily energy use. A faster current alongside the greenhouse results in more cooling and increases fuel costs. Whether or not wind influences profitability depends to a great extent whether or not the greenhouse is being sheltered from the wind using hedges or screens. Hence, wind is less important as a location factor.

- Light

  Differences in light are less pronounced in Flanders compared to the Netherlands. Nevertheless, differences in the yearly sum of radiation can be observed between the various Flemish provinces and hence also the various greenhouse regions. The amount of light has a great influence on production. The general rules are that an increase of light with 1 % increases production with 1 % for vegetables, while 1 % more light results in 0.5 % more production for ornamental crops. However, some critical comments should be made concerning these rules. First, 'light' does not equal the 'total sum of radiation'. Data on light over a sufficient number of years are only available for a few locations. Further, the assumption of equal influence of light in winter and in summer should be questioned. In general, the influence of light is larger in winter (depending on CO_2 and water supply). (Alleblas; Mulder, 1997)

Economies of agglomeration

Research carried out by the Dutch LEI shows that particularly smaller firms (± 0.5 ha) can gain by establishing in an agglomeration of greenhouses (Alleblas; Mulder, 1997). They can benefit fully of all economies of agglomeration following a concentration of similar firms. When firms become larger, the impact disappears. Hence, economies of agglomeration will decrease in importance as location factor in the next 10 to 15 years as smaller firms will disappear.

Output prices and transaction costs

Following production, the manager has to decide about marketing channels and ways of transportation. This choice will be influenced by the level of output prices and by the level of transaction costs. Transaction costs involve the costs of transportation, packaging, cooling and auctioning.

The marketing of horticultural produce is changing rapidly following innovations in price formation and logistics. Facilitation, tele-auctioning, reference auctioning and sales outside the auction increase the potential marketing channels for the manager. In addition, instead of transporting all produce to the auction, increasingly, produce is transported directly to the buyer.

Following these developments, it is reasonable to assume that by 2010, prices will be the same throughout the country. As a result, price differences between regions will decrease in importance as location factor. Only transportation costs remain as major factor in the choice of marketing channel. Managers will sell their products to the closest buyer, such that firms located nearest to their point of commercialization will have lower transportation costs.

In some cases, auctions offer cooling and packaging services. Also membership contribution may differ, but the influence of such costs may not be exaggerated.

Land prices

Land price is a location factor that does not have a major impact on profitability, contrary to the Netherlands. This may change in the future, depending on the acreage made available for the greenhouse industry by the Flemish government. In theory, a greenhouse firm can establish itself on any piece of agricultural land, on the condition that both provincial and municipal authorities provide a license. In practice, however, it is very difficult to get such a license. In addition, it is difficult to predict where licenses will be made available and where not. As a result, there is only a small difference in land for intensive agriculture and land for extensive agriculture. This situation may change dramatically in the future as all provinces and municipalities are preparing new zoning plans. If little space is allocated to greenhouses, prices for greenhouse land will rise rapidly to Dutch levels. Hence, land price is a location factor that will play a prominent role in the future.

Soil

Not all soils are suited equally for greenhouses. Two types of greenhouse firms can be distinguished. In a first set of firms plants are cultivated under glass but rooted in soil. A second set of firms uses an inert substrate to grow plants and can be located on any kind of soil, as long as it has sufficient carrying capacity.

For firms using soil, such as organic farms, soil is much more important, although the quality of the soil can be controlled and upgraded more easily than outside. Nevertheless, soil improvement means additional costs and hence influences a firm's profitability.

Infection risk

In general, infection risk for pests and diseases is assumed to be greater when greenhouses are geographically concentrated. Research shows enormous differences in plant protection costs between individual firms. These differences can be attributed partially to accidental factors that cannot be influenced, and partially to the goals and quality of the management. A large acreage of the same crop generally increases the risk of infection than an equal amount of land with different crops. Research further has shown that infection risk is lower for smaller concentrations. The concept of size relates to the total size of the area. When the area is larger than 200 ha, the infection risks remains constant. However, in smaller areas, the differences are subtle.

Air pollution

As a result of the direct uptake by plants, air pollution can cause crop damage and yield losses. The nature and the intensity of the effect depend on the nature of the pollution, the level of exposure and the sensitivity of the crop. For example, in the whole of Flanders average ozone concentrations are high enough to have a negative impact on crop production. The concentrations of SO2, NO and NO2 vary between the different greenhouse areas (. Pollution is and will be even more in the future an important location factor (VMM, 1999).

CONCLUSIONS

This paper has addressed the optimal size, structure and location of firms in the Flemish greenhouse industry. It has highlighted the importance of a square shape of the greenhouse as optimal structure. Using Data Envelopment Analysis an optimal farm size that varies between 1.7 and 3 hectares has been found, depending on the method used. Location factors that matter in the future Flemish greenhouse industry include temperature, light, transportation costs, air pollution and land prices, while rainfall, wind, output price differences, soil and infection risk do not differentiate between regions.

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