# DIRECTING FARMER'S GREENHOUSE CONSTRUCTION DECISIONS

*IRENE TZOURAMANI (*) - KONSTADINOS MATTAS (**) - MAVRIANOS GRAFIADELLIS (***)*


## Abstract

**In the Mediterranean region, protected cultivation is considered as one of the most important agricultural enterprises. The availability of plastics and the low cost of frame materials contributed to the rapid development of protected cultivation. In Greece many types of greenhouse can be found, either constructed by specific industries of by farmes. The construction cost of the greenhouse plays an important role in the decision of the investor, as construction expenses constitute a very significant part of the greenhouse production costs which are very much determinant of the greenhouse economic effectiveness, notably in a world where available funds to agricultural investment are greatly limited. The Net Present Value (NPV) criterion was used to assess the economic effectiveness of a greenhouse structure. It has been proven that cheap greenhouse constructions are the most preferable, probably due to the Mediterranean weather conditions, and they can be recommended as the most appropriate structure for cultivating off-season vegetables.**

## Résumé

***Dans la région méditerranéenne, la culture sous abri est une des enterprises les plus importantes. La disponibilité de matériaux en plastique et le faible coût de la charpente ont contribué au développement rapide de ce type de culture. En Grèce, il existe de nombreux types de serres, soit construites par des enterprises spécialisées soit par les agriculteurs. Le coût de construction des serres joue un rôle clé dans la décision des investisseurs, vu qu'il représente une partie importante des coûts de production des serres qui sont déterminants pour la rentabilité économique des serres, notamment dans un monde où les fonds pour les investissement agricoles se sont fortement réduits. La rentabilité économique de la serre a été évaluée en appliquant le critère de la Valeur Actuelle Nette (VAN). Il a été démontré que les serres de moindre coût sont les plus préférables, probablement en raison des conditions climatiques méditerranéennes, et qu'elles sont les plus adéquates pour les cultures maraîchères hors saison.***


Greenhouse enterprises are considered today as one of the most important agricultural enterprises not only in terms of the magnitude of the value of the gross output but also in terms of the required size of investment. Greenhouses have been classified according to their shape, cultural purpose, or even according to the plants growing inside them and the used temperature control. In the Mediterranean region, protected cultivation is practically synonymous with cultivation under plastic. The availability of plastics and the low cost of frame materials (generally wood) contributed to the rapid development of protected cultivation in the Mediterranean region. In the 25 years of existence of cultivation under plastics, the area of greenhouses has increased by more than 2000ha per year (FAO, 1990).

Farmers living in a very competitive world produce off-season agricultural products and sell them in a very competitive market, hence the lowest the production cost, the largest the profit margins (Salem *et al.*, 1994). Greenhouse construction constitutes a significant part of the production cost and any strategy that alleviates or curbs construction cost contributes greatly to industry's profitability. There is no doubt that decisions on the absolute type of greenhouse bear risks and uncertainty and must be taken with much care and awareness.

Various types of greenhouse constructions are at the disposal of any Mediterranean farmer, and he ought to select the most appropriate for his enterprise. Greenhouses can be classified according to their glazing (glass houses and the plastic greenhouses), frame (wooden, steel and aluminium), shape (single span or multi span) and environmental control (heating or not heating greenhouse). The most common structural materials for greenhouses are wood, steel, and aluminium. Wood still plays a significant part in greenhouse construction, especially for the "do it yourself" grower and some large commercial greenhouse operators who have looked closely at the economics of construction (Hanan, 1986). Wood is easy to work; the prob-

(*) Graduate student of MAICH Chania. (**) Professor of Agricultural Economics at the Aristotle University of Thessaloniki. (***) Director of Agricultural Research Centre of Northern Greece.

lem is that high greenhouse humidities and constant exposure to water mean that wood requires more maintenance service than metal (Roberts, 1984). Depending on the geographical location, the most common construction woods are Douglas fir, hemlock, spruce, pine and some cedar. Trusses, columns, beams or purlins made of these materials have different load bearing capabilities and in most instances, if maintained, will remain sound for many years (Hanan, 1986).

The increased desire for more light energy in greenhouses and for covering more ground area with one "clear span" unit, led to the development of the steel structures (Hanan, 1986). Metal frame is a poor insulator, so these frames lose heat more rapidly than wood frames (Roberts, 1984). Aluminium components for greenhouse constructions were introduced in the early 1950s. Aluminium is light in weight, easy to handle and is not adversely affected by most greenhouse conditions; nevertheless, corrosion of aluminium can occur.

The shapes that appear most frequently in the Mediterranean region are the following: saddle-roof (a), shed-roof (b), round arch (c), round arch with vertical side wall (d), pointed arch with sloping side-walls (e), and pointed arch with vertical side-walls (f) (**figure 1**)(FAO, 1990).

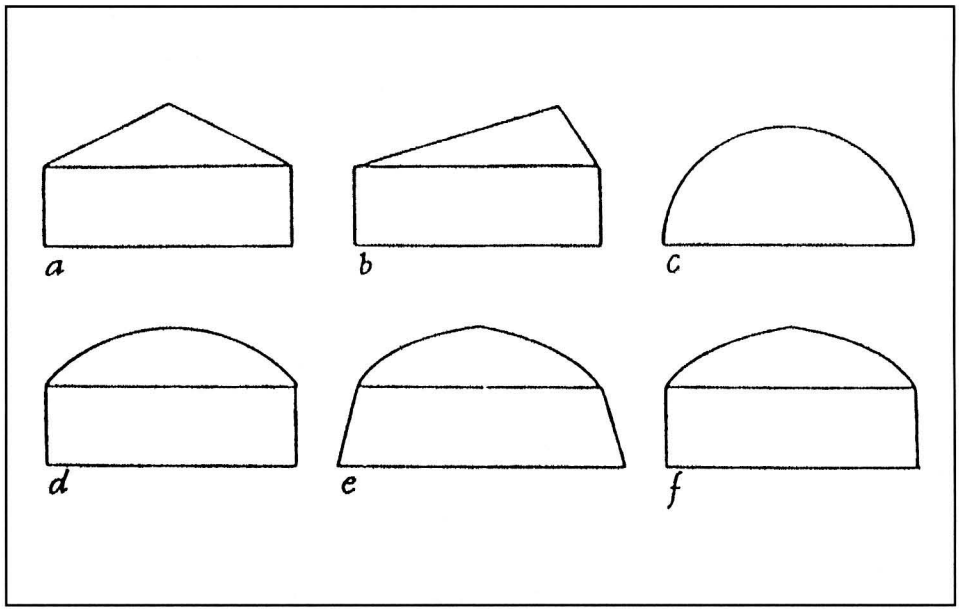



***Figure 1 - Possible shapes of greenhouse. Source: FAO, 1990.***

## Plastic greenhouse types in Greece

The most common types of plastic greenhouses in Greece are divided in two categories: 1. Plastic greenhouses constructed totally in factories (A), and 2. Plastic greenhouses constructed by farmers (B). Both categories (A) and (B) can be grouped into three common types: (i) round arch type, (ii) round arch with vertical side-wall and (iii) saddle roof.

Today, in Greece, the trend is towards the construction of prefabricated greenhouses which can maintain better environment and achieve higher production. Greenhouse construction industry has increased its share on the greenhouse area by 57.1% over the last five years while the share of greenhouses constructed by farmers was only grown slightly (5.1%) (**table1**).

**Round arched type** is the simplest type of the plastic greenhouse. This type is constructed either in single span type (**figure 2**), or in multi-span type and either imported or constructed by the farmers since domestic construction industries do not produce and sell such type of constructions. The dimensions of this structure are, height: 3-3.50m, distance between tubes: 2-3m, width of span: 5-9m. The ventilation is less effective (5-10%) and there is no rolling-up system at the sidewalls.

**Round arch type with vertical side walls** consists of steel pipes which have to be dipped in hot galvanising. This type is constructed either in single span type

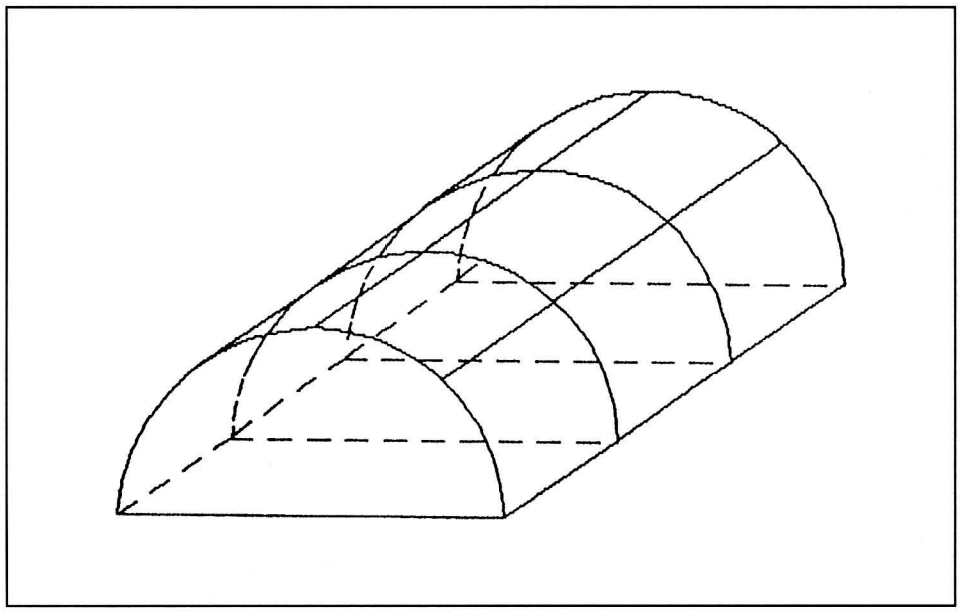


***Figure 2 - Round arch type (single span). Source: Agricultural Bank of Greece, 1986.***

**Table 1** ***Greenhouse area in Greece (in ha).***

| Year | | | 1967-68 | 1977-78 | 1988 | 1992 |
|---|---|---|---|---|---|---|
| Glass houses | | | 8 | 2.1 | 28.78 | 40.4 |
| Plastic Greenhouses | Constructed by Industry | Saddle type | - | - | 770.9 | 1,285.1 |
| | | Round arch type | - | 49.6 | 186.3 | 223.7 |
| | Constructed by Farmers | Saddle type | 447.1 | 1,364.2 | 1,557.6 | 1,579.9 |
| | | Round arch type | - | 802.5 | 789.7 | 688.9 |
| TOTAL | | | 455.1 | 2,218.4 | 3,333.3 | 3,818 |

Source: Greek Ministry of Agriculture (1968, 1978, 1988, 1992).

(**figure 3a**) or in multi-span type (**figure 3b**). The dimensions of the structure are height by the gutter: 2.60m, height of the ridge: 3.50m, width of the span: 8m at least; distance between the pipes: 2-3m and is mainly constructed by industrial firms. This type is covered by plastic sheets in the roof and in the sides. Ventilation is efficient by the sidewall openings and in the multi-span types, wider by 15m, by roof openings as well. Today only about 5% of greenhouse area is covered by round arch type with vertical side wall but the area is increasing rapidly.

**Saddle roof type** is very common in Greece. **Table 1** illustrates that the largest greenhouse area in Greece is covered by saddle roof type either constructed by industries or by farmers themselves. Most of them are wooden structures but also there are steel constructions (new trend nowadays) or combinations of wood and steel (the purlins are wooden beams and bars steel pipes).

This category can include the plastic greenhouses constructed from farmers i.e. the Ierapetra type (wooden construction), Timbaki type and Macedonian type (combination of wood and steel). The saddle roof type is usually a heavy construction and is preferred in areas with strong wind (like Crete) because of its high resistance. The dimensions of the structure are as follows height: 2.60m, distance between trusses: 2-3m, width of the span: 5-15m. The saddle roof type is constructed either in single span type (**figure 4a**), or in multi span type (**figure 4b**).

According to the Greek specifications the single or multi-span plastic greenhouses, which are up to 15m wide, are required to have only side ventilation of a rate of 22%. The wider greenhouses which are constructed by the growers are required to have 10% side and 10% roof ventilation and those constructed by industry, 7% side and 18% roof ventilation. The slope of the roof of the Greek greenhouses is about 20° to 25°, according to the industry. The slope of the greenhouses which are constructed by the farmers is much smaller.

## The cost of greenhouse construction

With the numerous options available and the differences in prices for greenhouse frames, it is extremely important for a greenhouse operator to study the available information and perform the appropriate cost analysis (Nelson, 1985). The investor is interested in reducing the cost of construction as much as he can in order to reduce his total cost. On the other hand, he wants to have better environmental control and less problems with the possibility of greenhouse reduction in order to increase the production and to improve the quality. In Greece many types of greenhouses can be met, either constructed by specific industries or by farmers. Nowadays, in Greece greenhouse constructions have improved significantly achieving an overall increase in farm income, a considerable decrease in production costs and a considerable improvement of the quality of the produced products.

A survey was undertaken in 1993 involving a large number of Greek greenhouse construction industries (17 out of 25). The main aim of the survey was focused on finding the cost of the structure in various types of greenhouses, and determining the most appropriate investment strategy. Greenhouse construction industries are primarily concentrated in Crete, where climatic conditions are favourable for the protected cultivation (45% of the Greek

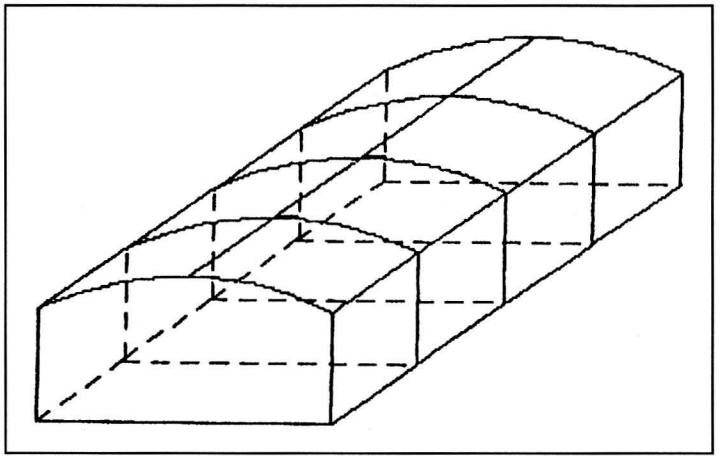


*Figure 3a - Round arch type with vertical side walls (single span). Source: Agricultural Bank of Greece, 1986.*

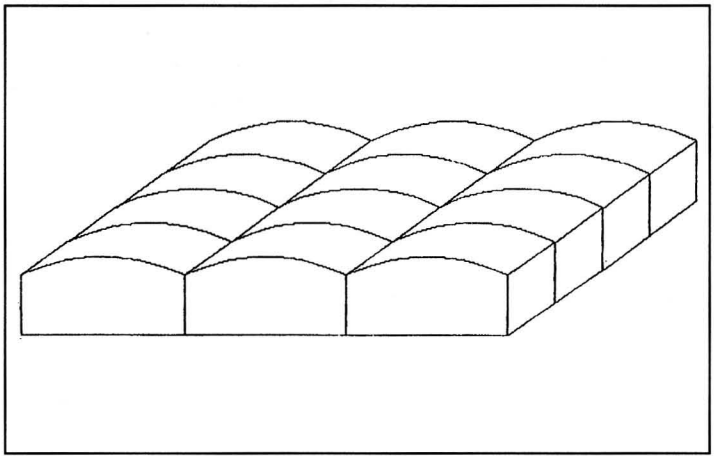


*Figure 3b - Round arch type with vertical side walls (multi span). Source: Agricultural Bank of Greece, 1986.*

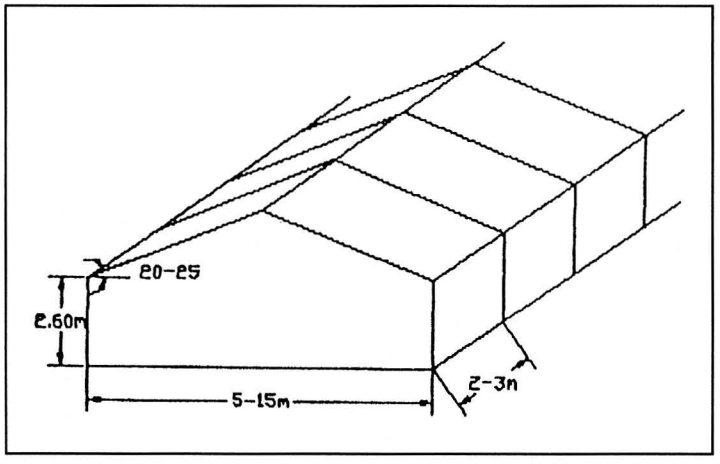



*Figure 4a - Saddle roof type (single span). Source: Agricultural Bank of Greece, 1986.*

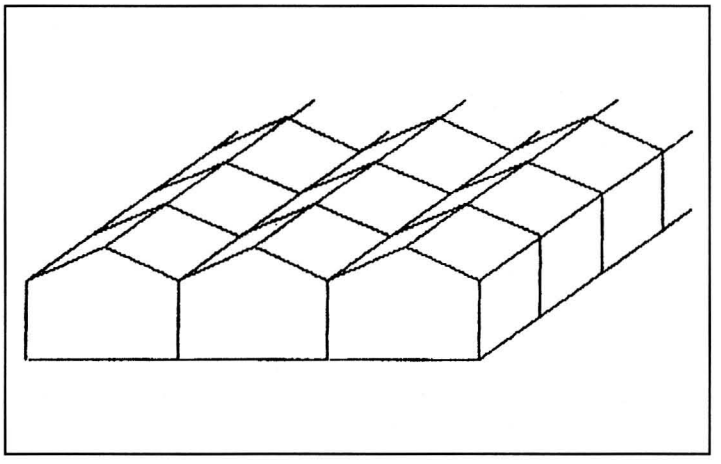


*Figure 4b - Saddle roof type (multi span). Source: Agricultural Bank of Greece, 1986.*

**Table 2** ***Cost per square meter of the most common greenhouse types in Greece.***[a]

| Types of the greenhouses[b] | Structure[c] | Single PE cover | Glazing | Erection | Total cost[d] | Variation[e] min | Variation[e] max |
|---|---|---|---|---|---|---|---|
| **Prefabricated types** | | | | | | | |
| Saddle roof type: wooden | 8.28 | 1.2 | 0.8 | 1.4 | 11.68$/m² | 10.01$/m² | 13.31$/m² |
| Saddle roof type: steel | 18.30 | 1.2 | 0.56 | 1.4 | 21.46$/m² | 20.76$/m² | 22.53$/m² |
| Saddle roof type: steel + wood | 15.74 | 1.2 | 0.72 | 1.4 | 19.06$/m² | 18.04$/m² | 19.32$/m² |
| Round arch with vertical sidewall | 10.80 | 1.2 | 0.48 | 1.2 | 13.68$/m² | 13.48$/m² | 14.08$/m² |
| Round arch type | 9.12 | 1.0 | 0.60 | 1.1 | 11.82$/m² | 11.62$/m² | 12.02$/m² |
| **Made by farmers** | | | | | | | |
| Saddle roof type: wooden | 3.60 | 1.2 | 0.8 | 0.9 | 6.50$/m² | - | - |
| Round arch type: steel | 3.00 | 0.9 | 0.5 | 0.6 | 5.00$/m² | - | - |

[a] Prices refer to year 1993 (exchange rate: 1$=250Drs).
[b] Further information on the different greenhouse types can be found on E. Tzouramani (1994).
[c] As structure is considered the frame of the greenhouse structure.
As single PE cover is considered the three years poly cover.
As glazing is considered the replacement of the poly cover every three years.
As erection is considered the establishment of the structure.
[d] Total cost here was computed as an average cost from the reported values by the various greenhouse construction firms and it can be viewed as a representative one.
[e] Variation in prices can be only in the structure of the greenhouse, because the greenhouse construction industries differentiate their prices on it.

greenhouse area is located in Crete). Also, important greenhouse construction industries operate close to big Greek cities (Athens and Thessaloniki).

The survey, as mentioned earlier, was conducted throughout Greece including the greenhouse types listed in **table 2**. The construction cost is expressed per square meter since comparison among different greenhouse types can be made easily and effectively. **Table 2** shows that prefabricated types are the most expensive greenhouses and they might be two or three times more costly compared with non-prefabricated constructions. The saddle roof type with steel is the most expensive type in the Greek market, which costs 21.46$/m² and the round arch type is the cheapest one (5.00$/m²) (**table 2**).

## Financial analysis

### Methodology

In this study an attempt was made to evaluate different types of greenhouses that are usually built in Greece, and are constructed either by industries or by farmers. Data were obtained from experiments conducted at the Agricultural Research Centre of Northern Greece in the region of Thessaloniki, a semi-arid Mediterranean environment with a cold variant: the summer is hot and dry, the winter is cold and rainy. The greenhouse types used for the evaluation were the prefabricated wooden type, the saddle roof type (steel), the saddle roof type (combination of steel and wood), the round arch type with vertical side walls, the round arch type and the wooden type which is constructed by farmers. The heating system of the diesel-fired furnace system (DFS) was used (Salem *et al.*, 1993).

The steel prefabricated types of greenhouses require to be replaced after twenty years in contrast with the wooden types which need replacement after twelve years (and only if the wood was treated by chemicals). The farmer's wooden type requires to be replaced after six years. The operational life of heating system (the diesel-fired furnace system (DFS)) is eight years. Maintenance cost applies especially to the wooden types of greenhouse as they require extensive maintenance work. The poly cover should be replaced every three years, regardless of the greenhouse type. Eight years' span life were used partly because more meaningful results can be obtained and partly because long run price changes cannot be predicted, resulting in misleading results. The real discount rate used in the analysis was set at 20% reflecting the greek financial market. Operating incremental costs are assumed to increase at the rate of inflation, the same rate at which output prices were assumed to increase. The result was to leave costs and benefits constant throughout the considered period. For the evaluation the Net Present Value was used as a measure of investment worth and also to permit comparisons with available investments alternatives. Incremental cash flows for each year of the investment's economic life were determined. The NPVs were determined by considering the monetary flows and referred to a base area of 0.1ha greenhouse. The unit of currency was the drachma (drs) (1$=250drs) (Bank of Greece, 1993).

Factors, having a major impact on the production benefit, were incorporated into the analysis like: (1) investment cost, which depends on the type of greenhouse and the type of the heating system; (2) fuel consumption, which depends on the type of heating system; (3) price of tomatoes, which varies over the harvest period, with generally higher prices earlier in the season; (4) yield of the crop, which varies with the heating system.

The specific expression of the NPV is the typical formula:

$$NPV = \sum_{t=0}^{8} \frac{CF^t}{(1 + R)^t} \qquad (1)$$

Where:

$CF_t$ = the cash flow (incremental benefits - incremental costs);
R = interest rate;
t = year of operation.

### Financial analysis for different greenhouse types (with the DFS)

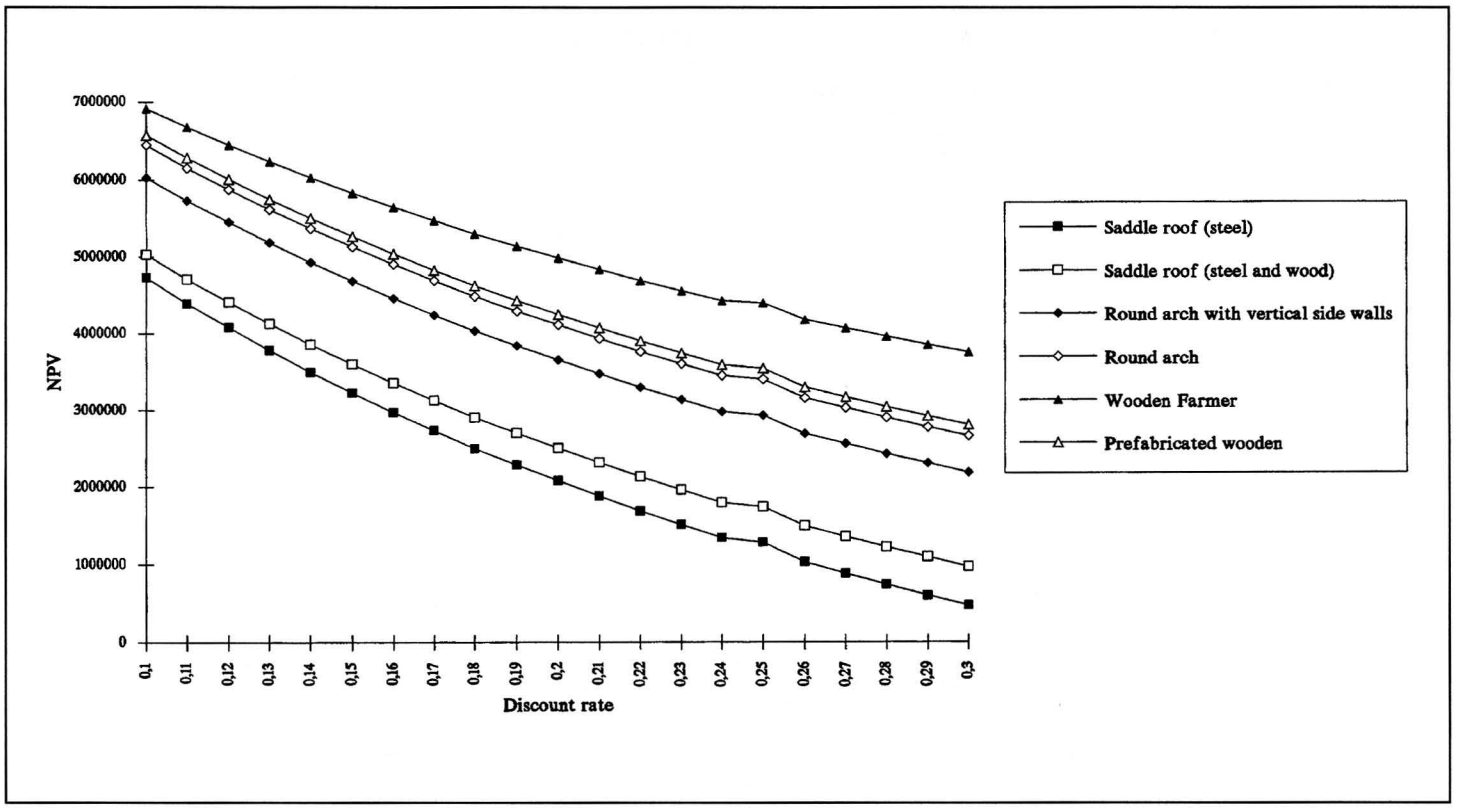
This evaluation is based on the application of the model (formula 1) as it was described in the methodology section. Variables considered in the evaluation of all

**Table 3** ***Parameters considered in the economic evaluation.***

| Investment | Variable |
|---|---|
| Structure | Seeds |
| Erection Glazing | Fertiliser-Chemicals |
| PE-cover | Fuel |
| Cost of DFS | Labour |
| | Insurance |
| | Maintenance |
| | Others |
| | Salvage value |

**Table 4** ***Financial analysis for different greenhouse types (with the DFS) - (0.1ha tomato greenhouse).***

| Type of greenhouse | NPV(drs) |
|---|---|
| Prefabricated wooden type | 4,055,014 |
| Saddle roof type (steel) | 2,082,111 |
| Saddle roof type (combination of steel and wood) | 3,822,791 |
| Round arch type with vertical side walls | 3,653,527 |
| Round arch type | 4,110,059 |
| Farmer wooden type | 4,982,376 |




***Graph 1 - The effect of a change in discount rate on the NPV in different greenhouse constructions.***

greenhouse types are depicted more analytically in the Appendix (**table 3**). The financial analysis was conducted assuming that greenhouses operate to produce tomato, a very common practice in the areas where data have been gathered.

**Table 4** shows that all greenhouse types, over an eight year period, have produced a positive NPV. In particular, relative cheap greenhouse structures – like the farmer wooden type and the round arch type – demonstrate the highest NPV whereas the expensive greenhouse types -like the saddle roof (steel) – indicate a relatively small NPV. This definitely supports the practice followed by the majority of the farmers who continue to replace and expand greenhouses with cheap constructions.

### Sensitivity analysis

Sensitivity analysis relates a given change in an economic variable with the expected change in profitability. NPVs were estimated by assuming a wide range of values in discount rate. Therefore increases and decreases in the discount rate were examined in order to determine the effect of the discount rate on the NPV. The analysis was distinguished among different greenhouse types with DFS.

Thus, the NPV is closely related to the discount rate: when the discount rate decreased by 50%, NPV increased by 127% and 101% for saddle roof steel and saddle roof combination of wood and steel, respectively. However, the same decrease in discount rate caused smaller increase in NPV in other greenhouse constructions: 65% to the round arch with vertical side walls, 57% to the round arch type, 55% to the prefabricated wooden type, and 38.9% to wooden farmer type (**graph 1**).

When the rate increased by 10%, the NPV decreased only by 3-9% and a 50% increase in the discount rate caused a 25-77% decrease on the NPV. It is important to note that a change in the discount rate is more significant in the case of negative change, for example, when R=30% NPV decreases by 25-77%, but a decrease of 50% (R=10%) caused an increase of 127-38% in the NPV, giving an advantage to cases with low interest rates.

## Conclusions

In Greece, several greenhouse types, constructed either totally by farmers or by greenhouse construction firms, are in operation. Any investor in greenhouse business always faces the problem of what type of greenhouse is more profitable to invest in order to have significant profit returns. His investment decision affects not only the production cost of the vegetables enterprise but also the competitiveness of the greenhouse farms. Thus, it is extremely important an investment decision to designate and facilitate the most appropriate investing strategy.

The Net Present Value (NPV) criterion was used to assess the effectiveness of a greenhouse structure. Generally speaking, the evaluation of several types of greenhouses that are extensively built in Greece proves that cheap constructions are the most appropriate ones. Precisely, the wooden prefabricated type or the round arch type garner the most significant earnings regardless of the heating system used in. On the other hand, the expensive constructions, although manifest some advantages like strong and heavy structures, resistance to wind forces, better environmental control and less heat losses, due to particular Greek weather conditions are not recommended as the proper structures for cultivating off-season vegetables. ●

## References

Agricultural Bank of Greece, 1986, Technical Specifications for Greenhouses' Constructions, Athens.

FAO, 1990, **Protected Cultivation in the Mediterranean Climate,** Horticultural Crops Group, Plant Production and Protection Division, Food and Agriculture Organisation, Rome.

Greek Ministry of Agriculture, 1968, Construction Types, Department of Agricultural Information, Athens.

Greek Ministry of Agriculture, 1978, Construction Types, Department of Agricultural Information, Athens.

Greek Ministry of Agriculture, 1988, Construction Types, Department of Agricultural Information, Athens.

Greek Ministry of Agriculture, 1992, Construction Types, Department of Agricultural Information, Athens.

Hanan J., 1986, **Greenhouse management,** Univ. of Colorado State, U.S.A.

Nelson V. P., 1985, **Greenhouse operation and management,** Reston Publishing Company, Inc. Reston, Virginia, 3rd ed.

Roberts, W. J., 1984, Solar Greenhouse for the Home, Northeast Regional Agricultural Engineering Service.

Salem, A., Mattas, K., and Grafiadellis, M., 1993, Assessing low-cost input use in off-season tomato production, *ACTA HORTICULTURAE,* 340, 117-123.

Tzouramani, I., 1994, **Investment alternatives in greenhouse enterprises.** M.Sc. Thesis. Mediterranean Agronomic Institute of Chania, Greece.