The Investment Order Tool

Horticultural investment selection in Jordan and Spain
June 2016 to June 2019

Chris Blok[1], Esteban Baeza Romero[1], Geert Franken[1], Romain Leyh, Maarten Coelen[2], Pieter Mol[3], Wouter Bakker[4] and Kees van der Kruk[5]
1. Wageningen University & Research, Greenhouse Horticulture, 2. Rockwool Grodan, 3. Ludvig Svensson, 4. Bakker Brothers, 5. Priva

Report WPR-891

WAGENINGEN
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Referaat
In 2015 bracht Wageningen Universiteit & Research, Business Unit Glastuinbouw een groep Nederlandse tuinbouwtoeleveringsbedrijven bijeen rond het creëren van een investeringsvolgorde tool. De betrokken ondernemingen waren de meststof producent SQM (tot 2018), de producent van steenwol teeltmateriaal Grodan, Priva voor automatisering van klimaat, voedingsstoffen en arbeid, het zaad en veredelingsbedrijf Bakker Brothers en de schermproducent Ludvig Svensson. Twee regio's, Jordanië en Spanje, werden gekozen als model voor de investeringsvolgorde tool. De vergelijkingen betroffen in Jordanië de traditionele half-tunnel kas versus een multi-span kas en in Spanje de traditionele platte parral kas versus een multi-span kas. In Jordanië en Spanje omvatte de verbeterde kas automatisering van irrigatie, bemesting, ventilatie en scherming. In beide gebieden zijn klimaatmetingen verricht. In Almería is de tool getest in gesprekken met telers, voorlichters, onderzoekers en de bank Cajamar. De tool toont de meest winstgevende volgorde van alternatieve investeringen. De tool helpt telers om niet winstgevende keuzes te vermijden en bleek nuttig om risicomijdende keuzen te identificeren. De tool helpt toeleveringsbedrijven om onverwachte motieven van telers te leren kennen. De tool helpt lokaal onderzoek om aandacht te besteden aan risicobeheersing. Tenslotte helpt de tool lokale autoriteiten om effectieve ondersteunende acties te organiseren.

Abstract
In 2015 Wageningen University & Research, Business Unit Greenhouse Horticulture gathered a group of Dutch supply industry companies around the idea of creating an investment order tool. The companies involved were the fertiliser producer SQM (until 2018), the rockwool producer Grodan, Priva for automation of climate, nutrients and labour, the seed and breeding company Bakker Brothers and the screen producer Ludvig Svensson. Two regions, Jordan and Spain, were chosen to serve as pilot areas for the investment order tool. In Jordan the comparison was between the traditional single tunnel greenhouse and a multi-span greenhouse, in Spain the comparison was between the traditional flat roofed parral greenhouse and a multi-span greenhouse. In both, Jordan and Spain, the improved greenhouse used automation of irrigation, fertilisation, ventilation and screening. In both areas climate measurements were performed. In Almería, the tool was tested in discussions with growers, advisors, researchers, authorities and the Cajamar bank. The tool shows the most profitable order of investment alternatives. The investment tool can help growers to avoid non-profitable investments and to identify choices based on risk aversion. The tool helps supply companies to identify unexpected motivations of growers. The tool helps researchers to focus on some topics around risk control. Finally, the tool helps local authorities to organise effective support actions.

Reportinfo

Report WPR-891; Projectnumber: 3742217800, DOI number: 10.18174/499619

This project/research has been made possible, in part, by the contribution of:

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Address

Wageningen University & Research, BU Greenhouse Horticulture
Violierenweg 1, 2665 MV Bleiswijk
P.O. Box 20, 2665 ZG Bleiswijk
The Netherlands
+31 (0) 317 - 48 56 06
glastuinbouw@wur.nl
glastuinbouw@wur.nl
www.wur.eu/greenhousehorticulture

Inhoud

Summary

In 2015 Wageningen University & Research, Business Unit Greenhouse Horticulture gathered a group of Dutch supply industry companies around the idea of creating an Investment Order Tool. The Investment Order Tool was meant to offer growers the means to weigh alternative investments. Investment choices by growers are part of an emotional rather than factual process involving weighing conflicting advice from family, other growers, advisors and technical companies. An Investment Order Tool might help growers to avoid bad choices. The tool could also empower supply companies to effectively cooperate and the tool could assist research and local authorities to organise effective supportive actions.

Two regions, Jordan and Spain, were chosen to validate the investment order tool. Both areas were visited by the consortium partners in six trips during the project run time.

The goal was:
1. To get an impression on the technical level of the primary producers in Jordan and Almería.
2. To create an investment order tool for both regions with some 20 investment alternatives quantified in terms of economic advantage and costs involved.
3. To check the willingness within the area to use the tool to speed and direct investments.

Producers in Jordan were actively interested in multi-span and substrate growing. Two growers have, with co-financing from the Dutch embassy and many willing supply companies, realised two times 7000 m^2 of such improved greenhouse concepts. Jordanian growers needed a lot of detailed on site communication on the advantages of the solution offered over the existing half tunnels and some multi-spans already offered. The investment in Jordan is only of interest with a generous subsidy as long as the blocked export through Iraq/Syria is keeping vegetable prices extremely low.

Producers in Spain are not particularly interested in multi-span and substrate growing as they regard improved parral and enarenado as viable alternatives. They need a lot of detailed on site communication on the advantages of the solution offered compared to fragmented outcomes of local research. The investment in Spain is within the reach of individual growers if they are convinced of the return on investment. A major reason for Almerían growers not to invest is a high-risk aversion.

The Investment Order Tool now offers some 20 investment alternatives quantified in terms of economic advantage and costs involved. The tool allows for uniform comparison of very different investments just as designed, and allows for a structured discussion with growers, often resulting in more detailed information on prices and considerations given by growers than otherwise possible.

Growers and advisors perceive the Tool as reliable and indicative but this does not always lead to investments. The risks growers perceive should be convincingly addressed before growers will act on the results of the Investment Order Tool.

Growers and advisers have a real desire to use their own data on prices for investments too. This functional addition on the one hand increases trust in the tool but on the other hand could lead to too optimistic scenarios. At present, this extra flexibility is offered to Cajamar in Almería. If Cajamar decides to order this addition, the project Investment Order tool will have a direct sequel.

1 Introduction

1.1 Background

Group
In 2015 Wageningen University & Research (WUR), Business Unit Greenhouse Horticulture gathered a group of Dutch supply industry companies around the idea of creating an investment order tool. These companies were the fertiliser producer SQM (until 2018), the rockwool producer Grodan, Priva for automation of climate, nutrients and labour, the seed and breeding company Bakker Brothers and the screen producer Ludvig Svensson. The companies were chosen to cover a wide range of possible technical investments excluding conflicts of interests between group members and excluding greenhouse builders and propagators who were thought to be area specific.

Concept
The concept of the Investment Order tool was born in Egypt where it was found that the advice to use heating in a sweet pepper nursery was proven to cost considerably more than it could possibly deliver in increased yields (Blok *et al.* 2016). Subsequent rough calculations showed that heating could be feasible if some other – directly feasible – investments were made first. At that time, it was also found that the order in which feasible investments were adopted influenced the overall profitability. In other words: the return on investment for A, B, C for year 1, 2, 3 was usually not equal to B, C, A or C, A, B etc.

Application
The investment tool can help growers to decide on the choice of investments. This choice by growers is a highly emotional rather than factual process involving weighing conflicting advice from family, other growers, advisors and technical companies. An investment order tool might help growers to avoid bad choices. The tool could also empower supply companies to effectively cooperate and the tool could assist research and local authorities to organise effective supportive actions.

Pilot regions
Two regions, Jordan and Spain, were chosen to first validate the investment order tool.

As stated in the initial project text, Dutch product has a reputation as technically very good, but is also perceived as expensive and not sufficiently adapted to local requirements. Furthermore, companies are often reluctant to involve other supply companies for fear of losing sales opportunities. The proposed investment order tool is hoped to clarify why it makes sense to choose e.g. a screen first and substrate later. Such knowledge might help Dutch companies to always advise the most profitable product, even if it is not their product, knowing that soon their product will be the most profitable investment.

1.2 Goal

The goal was:
1. To get an impression on the technical level of the primary producers in Jordan and Almería.
2. To create an investment order tool for both regions with some 20 investment alternatives quantified in terms of economic advantage and costs involved.
3. To check the willingness within the area to use the tool to speed and direct investments.

1.3 Approach and definitions

The project focused on two regions, Jordan and Spain, where the current situation of greenhouse horticulture was described and where the most beneficial technological investments for the development of local greenhouse horticulture were identified.

Within the areas chosen, the following actions were executed:
a. Describe the current situation of greenhouse horticulture.
b. Identify logical investments for the development of the greenhouse horticulture.
c. Measure climate data in an old and in an improved greenhouse to check on the climate and yield assumptions made in the process of tool definition.

The subsequent development of the investment tool included the following steps:
- Develop an input template to gather the user’s basic choices for a specific case.
- Choose a set of relevant investments to be considered by users.
- Create a data set for yield per month and a percentage of extra yield in the input template for each investment considered, which was done by:
  - Using the model KASPRO coupled to a tomato crop growth model or
  - Using simple rules to evaluate the yield effects not properly simulated by KASPRO e.g. those of irrigation and fertigation and new varieties.
- Create a data set for prices and depreciation rates for selected investments by:
  - Using the Economic Model.
- Prepare a set of calculations to calculate the financial outcome of:
  - A basic scenario for a credible starting situation.
  - A freely chosen investment order for 2-5 investment choices.
  - A comparison with two optimised scenarios and the basic situation.
- Develop an output template to present graphs and tables with relevant remarks and warnings.

Investments order tool: A spreadsheet like program allowing the user to –within a given case- choose scenarios and to compare the financial consequences of alternative scenarios with an optimum order suggested by the tool.

Input template: A uniform but flexible template to gather and present data for a case.

Case: A specific combination of region-climate-crop-technology.

Scenario: A freely chosen investment order for 2-5 investment choices.

Investment order: The order in time of various technical investments.

Technical investment: A description of a specific technology in terms of costs, i.e. investment costs and running costs, but also of the yield effect in percentage of yield increase.

1.4 Organisation

The project applicant and main contact was Rockwool Grodan. Kees Struijk and Vincent Kuijvenhoven were the initial contacts. For the trip to Spain Maarten Coelen became involved and later took over from Kees Struijk.

For SQM Harmen Tjalling Holwerda and Katja Hora coordinated the efforts while in Jordan Majed Samawi from SQM, and Mr. Ghassan Haddad from Debbane assisted and in Spain José Andres Cayuela and José Maria Ureta were involved. As the anticipated advantages of combining the tool with a newly introduced fertiliser system were not met, SQM left the project at the start of 2018.

For Ludvig Svensson Maarten Oostenbrink initiated and coordinated the efforts while Pieter Mol, Elin Nasstrom and Verónica Cortés supported the process and Nelson Perez was the local contact for the company.

For Priva the project was initiated by Frans-Peter Dechering but the coordination was transferred to Maren Schoormans and later Kees van der Kruk. For Spain Patrick Dankers and Patricia Haverkamp were involved and later Josefine Krepel. Kees van der Kruk supported the delivery of technology.

For Bakker Brothers Wouter Bakker initiated the process and he was assisted by Kamal Joudeh (Jordan) and Piet Grobler (Jordan and Spain)
Wageningen University & Research, Greenhouse Horticulture delivered the basic idea for the investment order tool. Chris Blok initiated and coordinated the project. Erik van Os (Jordan) and Esteban Baeza Romero (Spain) were involved in planning the field trips and technical support. Various specialists helped to develop technical investment data: Apart from the people already mentioned these included Caroline van der Salm, Elias Kaiser, Cecilia Stanghellini and various others. Romain Leyh (later Geert Franken) and Esteban Baeza Romero programmed the tool in visual basic in Excel and tested and improved the outcomes as well as the presentation of the tool. Esteban Baeza Romero supplied invaluable support in establishing contacts with local growers, cooperatives, research and the Cajamar bank as well as in organising the various visits to the area.

2 Methods of tool development

The investment order tool is an off-line spreadsheet allowing the user to choose a combination of region, crop and greenhouse type before choosing investment scenarios. The investment order tool then calculates and shows the financial consequences of alternative investments with an optimum order suggested by the tool. To create the tool various steps were taken (in Figure 1).

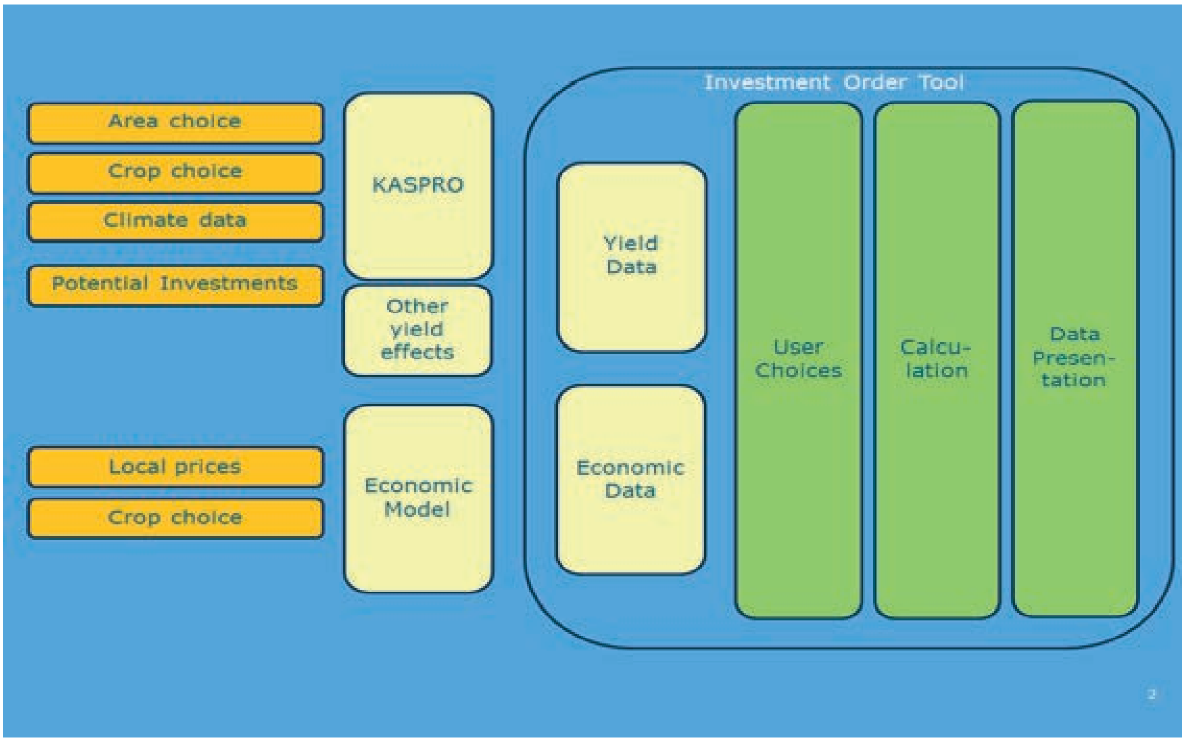

Figure 1 *Relation between the complex and fully dynamic existing WUR-GH tools KASPRO and Economic Model with the simple static and stand-alone Investment Order tool.*

2.1 Area and crop choice

The regions of choice had to be established concentration areas of plastic house horticulture with an evolving technological level as opposed to areas of disruptive development (turnkey projects). Using these criteria, Almería in Spain and the Jordan Valley in Jordan were selected (Garcia-Garcia *et al.* 2016; Blok *et al.* 2016). Within these regions, scenarios were developed for two greenhouse types, the most traditional type and a simple multi-span type. The multi-span was included because it allows for a wider range of climate related investments whereas the traditional types can be upgraded only to the point on which it becomes cheaper to convert to a multi-span.

Greenhouse production is an economic activity. The income for the growers comes from selling their product. For the present study, we have chosen tomato as the target crop. The reasons to choose this crop are various:

- Tomato is highly representative in the two regions matter of study. For instance, in Almería almost 11.000 ha or 40% of greenhouses cultivated tomato on season 2015/2016.
- For tomato, Wageningen University & Research has one of the most accurate growth models (*Vanthoor*, 2011) that can be coupled to greenhouse microclimate data to obtain very accurate predictions of monthly yields.
- Tomato is a crop whose productivity can be greatly increased by incorporating technology in the greenhouse, as we can see in Figure 2, which shows how average productivity in The Netherlands improved in the last decades thanks to technological improvements and including variety improvement.

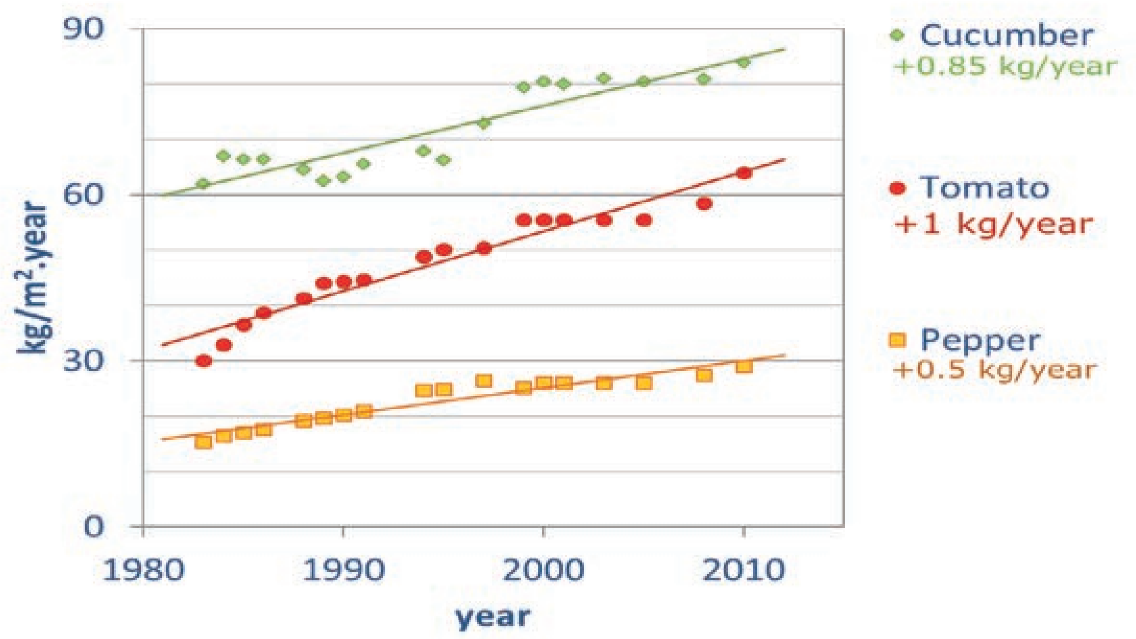

Figure 2 *Evolution average yields (kg/m²) in Dutch greenhouses for three major vegetable crops along the last 4 decades (KWIN, 1984-2011).*

2.2 Climate data

To get a static dataset from the existing models, a full set of local climatic data must be loaded into KASPRO as well as parameters for the greenhouse structure used. For Almería climate data were gathered from literature (García-García *et al.* 2016). For the Jordan Valley, a 2015 data set from a meteorological station from NCARE in Deir Alla was used. For the Jordan Highlands, data were retrieved from Amman airport for 2012 (Baeza-Romero *et al.* 2019). The technical description of the Almerían Parral, the Jordanian single spans and the multi-spans were found in reports (García-García *et al.* 2016; Blok *et al.* 2017b; De Groot *et al.* 2018). The Economic model was reduced to the information needed for the regions studied. For the Investment Order tool technical improvements were made operational by assigning to each investment a percentage of yield increase. These percentages were themselves output of dedicated runs with KASPRO. To avoid adding investment effects up to unrealistically high yield levels, the percentage increase was made to diminish towards a maximum yield level for each system. The maximum yield levels were based on prior KASPRO runs.

2.3 Potential investments

The investments included can be divided into those within the scope of KASPRO and those that had to be included in another way.

2.3.1 Investments within the frame of KASPRO

- Influence of light on yield. Relation light vs yield vs starting yield level.
  a. Transmissions of plastics and glass, thickness, age, UV-stabilisation and diffusivity including effects of dust accumulation.
- Influence of shading on yield.
  a. Input: Light sum transmission, climate data; radiation distribution over time. Hours of shading; critical levels for opening and closing.
  b. Output comparison fixed screening, movable screen, removable fixed screening. Yield advantage of movable over fixed screen.

- Influence of screens on temperature.
  a. Input: Light sum transmission, radiation loss to the night sky, climate data; radiation distribution over time. Hours of shading; critical levels for opening and closing.
  b. Output comparison fixed screening, movable screen, removable fixed screening. Yield advantage of moveable over fixed screen.
- Influence of temperature on yield.
  a. Input: Relationship with fruit pollination / setting. Climate data.
  b. Output: later to be specified later.
- Influence of ventilation on temperature / RH. To be specified later.
- Heating. To be specified later.
- Cooling by pad and fan / high-pressure mist. To be specified later.
- Carbon dioxide in relation to ventilation and in relation to substrate used.

2.3.2 Investments included outside the KASPRO framework

- Influence of EC on yield.
  a. Input: Salinity yield decrease (SYD), costs of water and RO, price of crop, margins.
  b. Output: costs of Yield decrease versus EC and yield loss per EC versus treatment costs that are investment plus running costs.
- Influence of rainwater collection.
  a. Input: SYD, costs of water collection, price of crop, margins, rain data, evapotranspiration data.
  b. Output: costs of Yield increase versus reduced water costs versus water collection costs that are investment plus running costs.
- Advantage of low urea/ammonium fertilisers over high urea/ammonium fertilisers.
  a. Input: Marketable yield depression by pH and ammonium problems, costs of nutrients, price of crop.
  b. Output: Marketable yield decrease versus pH-ammonium and investment in low urea/ammonium fertiliser.
  c. Marketable is meant to keep track of quality effects like BER occurrence.
- Advantage of using resistant or tolerant varieties over the non-resistant standard varieties.
  a. Input: Yield decrease of using new varieties versus the risk and damage levels for specific diseases versus the costs of yield decrease and crop protection.
  b. Output: Break-even point of resistant /tolerant varieties versus disease risk index and versus number of plants effectively lost.
- The choice between soil and substrate and between free draining versus closed system.

2.4 Local prices and regional economic data

2.4.1 Almería

- The monthly average prices for the first and second category tomatoes have been obtained from the following official website of the Regional Government of Andalucía:
  - http://www.juntadeandalucia.es/agriculturaypesca/observatorio/servlet/FrontController
- The assumptions made for the percentage of fruits of first and second category and for non-marketable yield assumed for each scenario have been obtained from different studies performed in a Research Station of Almería along more than 30 years of scientific research: The Experimental Station of Las Palmerillas from Cajamar Foundation:
  - (http://www.publicacionescajamar.es/series-tematicas/centros-experimentales-las-palmerillas/) and also from personal experience with commercial growers.
- The production costs have been obtained from different sources:
  - The same website where prices were obtained: http://www.juntadeandalucia.es/agriculturaypesca/observatorio/servlet/FrontController
  - The yearly agricultural campaign analysis published by Fundacion Cajamar: http://www.publicacionescajamar.es/series-tematicas/informes-coyuntura-analisis-de-campana/

- The investment costs have also been obtained from the previous two sources plus the following report of 2015:
  - http://www.juntadeandalucia.es/agriculturaypesca/observatorio/servlet/FrontController?action=DownloadS&table=11030&element=1638582&field=DOCUMENTO

2.4.2 Jordan

- The monthly average prices for the tomatoes have been obtained from ECOCONSULT (Annex 1). For the analysis, the prices on the Wholesale Market have been used. For the moment, in the absence of real export prices for tomato, it has been decided to perform simulations considering a hypothetical export price 2 times larger than the wholesale market price. Since some of the simulations consider extended growing cycles for both the Highlands and the Jordan Valley, for the months where no selling prices are available for each location, prices of the other location for these months has been considered. For instance, in July and August there are no selling prices for the wholesale market for the Jordan Valley, then prices available for the Highlands for these months have been considered.
- For the simulations in which local market prices have been considered, it has been assumed that both first and second category product are accepted by the market at the same price, and for all scenarios, a 5% non-marketable yield has been assumed. Estimated export prices are based on assumptions made for the percentage of non-marketable yield for each scenario using information from different studies performed in semi-arid regions and from personal experience with commercial growers.
- The production costs have been obtained from different sources:

I. Fossil energy: it has been assumed that diesel would be used for greenhouse heating. Price of diesel is updated to May-2017 (http://www.globalpetrolprices.com/Jordan/diesel_prices/)
II. Electricity, plant material, labour costs, crop protection, and water (ground well water price has been used): obtained from ECOconsult (Annex 1). For labour costs, although a number of 12 workers/ha has been provided by ECOconsult, we have assumed that this amount of labour is only used on peak moments, and for the simulations a more reasonable average number of 6 workers and 1 manager has been assumed.
   i. Crop nutrition cost and other materials such as clips, wires, etc.: in absence of data from Eco-Consult, same value as that used for Almería has been used (http://www.publicacionescajamar.es/series-tematicas/informes-coyuntura-analisis-de-campana/)

- The investment costs have also been obtained from different sources plus:

I. Price of traditional tunnel greenhouse, including plastic cover: EcoConsult. Life span considered of 15 years.
II. Price of multi-span with fixed roof vents, including plastic cover: offer from Flora Engineering services. Life span considered of 15 years.
III. Price of multi-span with controllable double vents, including plastic cover: based on experience of prices in Almería. Life span considered of 15 years.
IV. Heating system, including boiler: KWIN, verified with offer from Flora Engineering services.
V. Screening system: offer from Bosman for Klein Karoo in South-Africa.
VI. Fogging system: KWIN
VII. Simple Fertigation system: EcoConsult.
VIII. Advanced fertigation system: offer from Bosman for Klein Karoo in South Africa.
IX. Covered basin for water storage: Almería study data.
X. Climate computer simple: KWIN
XI. Building: Almería study data.

2.5 KASPRO

In order to obtain the greenhouse microclimate parameters and the use of resources, such as energy, water, nutrients, etc., of the different technological packages selected for the investment order analysis on each target region, we have used a simulation model. For this purpose, we have chosen the KASPRO greenhouse climate model (*De Zwart*, 1996).

KASPRO consists of different modules based on the solution of the transport equations for heat, mass and momentum transfer in the greenhouse environment. The model has been extensively used in scientific research, and its description and applications can be broadly found (for instance, (Katsoulas *et al.* 2015; Luo *et al.* 2005a; Luo *et al.* 2005b) (Figure 3).

The use of a simulation model to predict the monthly tomato yields instead of harvesting average productivity data locally is based on the following reasoning:

- With models, it is possible to fix average technological and climate scenarios, and predicted yields validated with real data. Thanks to the use of models, it is possible to make multiple simulations for different technological options that would require long time to find in the field, or simply they would be non-existent.
- Repeatability of results for future works.
- Possibility to estimate the use of resources, a factor not always measured in commercial farms in low-tech greenhouses.
- Complex interactions of temperature, light level, humidity and carbon dioxide availability can be taken into account for any production level with fair accuracy that is not possible in any other way.

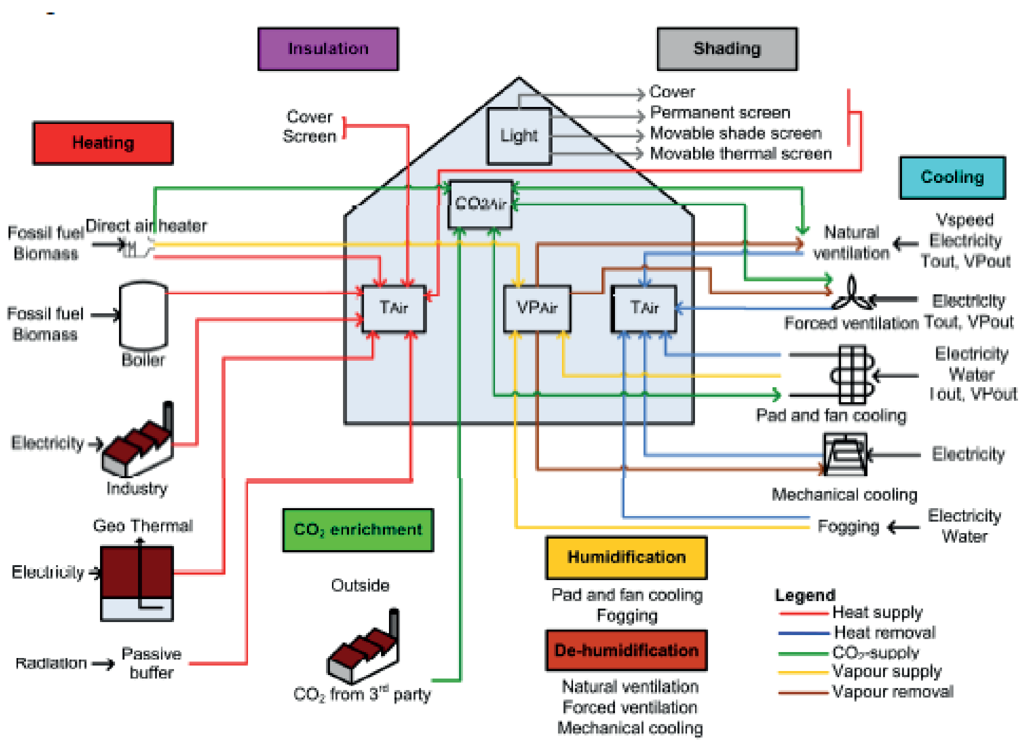

Figure 3 *KASPRO selected functions (coloured boxes), and design elements (text blocks and pictures below the accompanying functions), needed for the greenhouse design method to manage the greenhouse climate (transparent boxes inside the greenhouse). The coloured arrows represent the various energy and mass fluxes (legend at the bottom right).*

2.6 Economic Model

The yearly income is obtained by multiplying the monthly yields (kg/m^2) obtained for every scenario from the simulations using KASPRO coupled to Vanthoor´s crop growth model (2011) by the percentage of 1st and 2nd category fruits assumed for every scenario based on assumptions made from local experience with growers and trials performed in research centres, and this, multiplied by the price of 1st category and 2nd category fruits averaged for the last 5 years. The sum of the income obtained from selling the first and second category fruits represents the total income. Total income=sum of monthly total income.

The sum of the income obtained from selling the first and second category fruits represents the total income, and this value is in selected cases multiplied by a correction factor (0-1) that assumes a certain loss due to a learning curve when using a new technology by the growers for the first year. It was established as a value of 0.95 for all the technologies in the case of the multi-tunnel, as it is assumed that a grower with a multi-tunnel is already a more skilled grower and can learn to use equipment faster. For the parral, it was assumed 0.9 for the two types of screens (shading and thermal), 0.85 for the mist (in our experience growers over use the mist at the beginning which causes problems) and 0.95 for air heating (in our experience, air heating is managed without much problems).

2.6.1 Investment costs

For the calculation of the yearly investment costs, a percentage of depreciation and maintenance has been considered for each item for Almería (Table 1) and Jordan (Table 2).

2.6.1.1 Almería

Table 1
Summary of investment costs used for the economic calculations for Almería.

	€/m²	€/m²/year
Traditional raspa y amagado parral greenhouse (excl. cover)	7.95	0.56
15% Extra ventilator area for traditional raspa y amagado	2.40	0.17
Rainfall water collection system		
Enarenado system (special artificial soil of Almería)	4.53	0.45
Modern plastic film greenhouse (excl. covering, double vent per span)	18.00	1.20
Plastic film covering	1.50	0.50
Heating system in the greenhouse	6.35	0.44
Growing pipe in the greenhouse		
Heating system (boiler) 100 W/m², 2 ha	6.00	0.42
Screening system	8.00	2.00
Insect netting	0.32	0.06
CO_2 dosing (1ha)+ detection		
Fogging system	5.00	0.50
Fertigation system A B container and drippers	1.50	0.23
Water storage tanks		
Covered basin for water storage	0.96	0.07
Re-circulation and disinfection		
RO installation (50 m³/day)		
Artificial lighting (150W/m²)	60.00	9.00
Climate computer simple	1.00	0.27
Building (computer, canteen, storage, packaging etc.) 10% of greenhouse	0.66	0.05
Pure CO_2 enrichment system (rental, 6000 l, 12 times)+dosing & distribution	1.00	0.07

2.6.1.2 Jordan

Table 2
Summary of investment costs used for the economic calculations for Jordan.

	JOD/m²	JOD/m²/year
Traditional tunnel greenhouse (excluded. cover)	1.50	0.15
Multi-span fixed roof vents (excluded cover. Cover, insect screen)	15.20	1.01
Multi-span controllable double vents (excluded plastic, insect screen, etc.)	19.50	1.60
Rainfall water collection system		
Plastic film covering	1.50	0.50
Heating system in the greenhouse + boiler	6.35	0.42
Screening system	5.50	1.38
Insect netting	0.32	0.06
CO_2 dosing (1ha)+ detection		
Fogging system	5.00	0.50
Simple Fertigation system A B container and drippers	0.20	0.02
Advanced fertigation system (storage tanks, drainage system, etc.)	8.80	0.88
Covered basin for water storage	0.96	0.13
Recirculation and disinfection		
RO installation (50 m^3/day)		
Artificial lighting (150W/m^2)	60.00	12.00
Climate computer simple	1.00	0.10
Building (computer, canteen, storage, packaging etc.) 10% of greenhouse	0.66	0.03
Pure CO_2 enrichment system (rental, 6000 l, 12 times)+dosing & distribution	1.00	0.15

2.6.2 Variable costs

The resource use for each technological scenario simulated has been obtained from the KASPRO simulations and from experience and the data sources mentioned previously for the target region.

2.6.2.1 Almería
Table 3 shows the different variable costs used for the economic study for Almería, for a tomato greenhouse crop.

Table 3

Summary of variable costs used for the economic calculations for Almería.

	Costs variable [€/m²/year]
Energy from natural gas (price/m³)	0.580
Electricity [price/kWh]	0.160
Pure CO_2 [price/kg]	0.200
Plant material [price/plant]	0.450
Labour costs crop [price/h]	3.700
Crop protection [price/m²]	0.550
Crop nutrition closed cycle [price/kg tomato]	0.032
Water [price/m³] (water system, transpiration, fogging)	0.390
Plastic film, wires, clips	0.080
Transport, telecommunications [price/m²]	0.080
Insurance	0.250

2.6.2.2 Jordan

Table 4 shows the different variable costs used for the economic study for Jordan, for a tomato greenhouse crop.

Table 4

Summary of variable costs used for the economic calculations for Jordan.

	Costs variable [JOD/m²/year]
Energy from diesel (price/kg)	0.490
Electricity [price/kWh]	0.060
Plant material [price/plant]	0.120
Labour costs workers crop [price/h]	1.000
Labour costs manager [price/h]	3.800
Crop protection [price/m²]	0.300
Crop nutrition closed cycle [price/kg tomato]	0.032
Water [price/m³] (water system, transpiration, fogging)	0.200
Plastic film, wires, clips	0.130
Rent for land [price /m²]	0.200

3 Results and Discussion

3.1 Main performance indication

In Almeria the yield prediction by KASPRO for an improved parral was plotted against yield data supplied to us by IFAPA. The total yields were within 5% of each other but the production in the winter months was distinctly better for the practical data. This was interpreted as the effect of the winter variety common in Almeria but not yet part of the KASPRO simulation. This confirmed the reliability of the basic simulation. Besides that the data from Almeria was used to introduce the option for a winter variety in the tool, using the better results for temperatures between 12 and 15 degrees Celsius.

In Jordan the report on the yield in the HAED report was delivered too late to be incorporated in the tool (*Brunsting*, 2019). It however showed that the local yield in an improved greenhouse for Cherry tomato was equal to that estimated in a KASPRO simulation. This is interesting as the cultivation was a training situation and the crop was burdened by several problems including a virus infection. It therefore seems KASPRO might slightly underestimate the production in the Jordan Valley.

The yield confirmation of the basic estimates by KASPRO is perhaps not surprising as KASPRO has been validated for several climates. More debatable are the estimates the tool makes for various technical improvements. Part of the estimates is backed by KASPRO (generally those for light, heating, screens and ventilation). Other estimates are based on dedicated literature. Both estimates are discussed in the remainder of this chapter but they lack validation in the regions. In Jordan no reliable experimental data is available and in Spain despite an impressive experimental output, very few experiments were designed to deliver this type of comparison. The proposal of Cajamar people to do just that (paragraph 3.6) is therefore understandable.

3.2 Tool description

The Investment Order tool was tested for various scenarios and investment choices (Table 5).

Table 5
Examples of yield assigned to various scenarios and various investment levels.

Scenario	Greenhouse type	Max yield level Kg.m^{-2}	Investment
Almería,	Parral	9.9	none
Almería,	Parral	16.1	shade screen
Almería,	Multi-span	14.8	none
Almería,	Multi-span	23.2	shade screen
Jordan Valley,	Multi-span	23.5	none
Jordan Valley,	Multi-span	30.5	shade screen

In Figures 4-8, the Investment Order tool is described using the situation of a grower with an Almerían Parral plastic house with a winter variety tomato. The model starts by asking basic information for the water quality and irrigation system (Figure 4). The fresh water salinity is used to assess the yield improvement after investment in a rainwater basin or a reverse osmosis installation. The yield drop caused by specific EC's for specific crops is based on literature (*Sonneveld* and *Van der Burg*, 1991). The frequency of irrigation is used to determine the benefit of migrating from soil to substrate cultivation. Yields are allowed to increase 15% when the number of irrigation cycles increases from one to ten per day (Xu *et al.* 2004). The model also allows evaluating the possible effects of undesirable ammonium contents of specific fertilisers to avoid related pH risks (Dickson *et al.* 2016). After the basic information, the user can define a basic scenario, in this case cherry tomato in Almería in a multi-span greenhouse. The grower is then allowed to customize the reference situation by adding those investments, which were already present (Figure 5). In a next step, nursery yield and selling price for first and second-class products are shown and may be changed on a per month basis (Figure 6). Higher selling prices or higher yields both increase the net benefit of the reference situation and thus more technologies may become feasible (and appear in screen). The introduction of customized economic data creates a new temporary dataset with a new nursery specific reference.

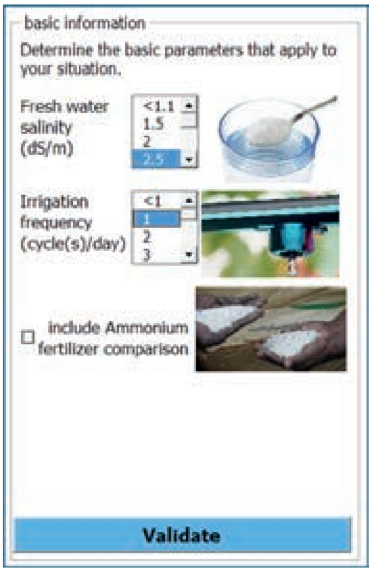

Figure 4 Consecutive basic input windows for salinity, irrigation frequency and ammonium fertiliser evaluation (left).

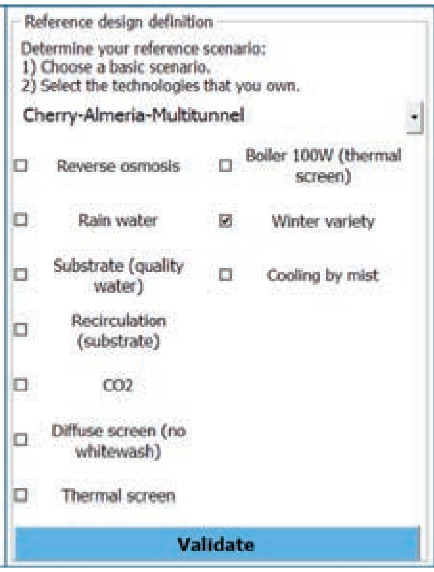

Figure 5 Choice of reference scenario, in this case Tomato-Almería-Parral and input of grower investments in this scenario (middle).

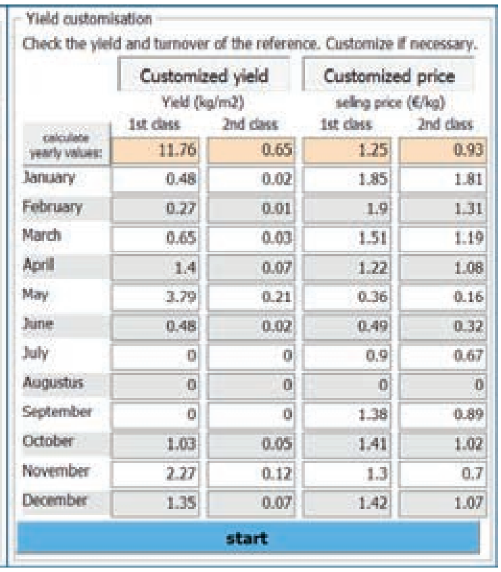

Figure 6 Definition of yield level and price level for two fruit quality classes per month (right).

The grower is consequently allowed to fill three investment alternatives by typing in the year of investment. His first choice was investing a diffuse screen (year 1), adding cooling by mist (year 3) and collection of rainwater (year 5). The second choice was cooling by mist (year 1), collection of rainwater (year 3) and adding a diffuse screen (year 5). The third choice was collection of rainwater (year 1), a diffuse screen (year 3) and cooling by mist (year 5). Based on the nursery specific reference, the Investment Order tool now calculates a "least investment" order in which the feasible technologies are selected in order of increasing depreciation cost with an investment every 3 years (Figure 7). The Investment Order tool also calculates a "preferred" order by investing every 3 years in the technology with the highest net benefit (Figure 7). The cumulative benefits of the "least investment" order, the "preferred" order and the user orders 1, 2 and 3 are then shown in a graph (Figure 7).

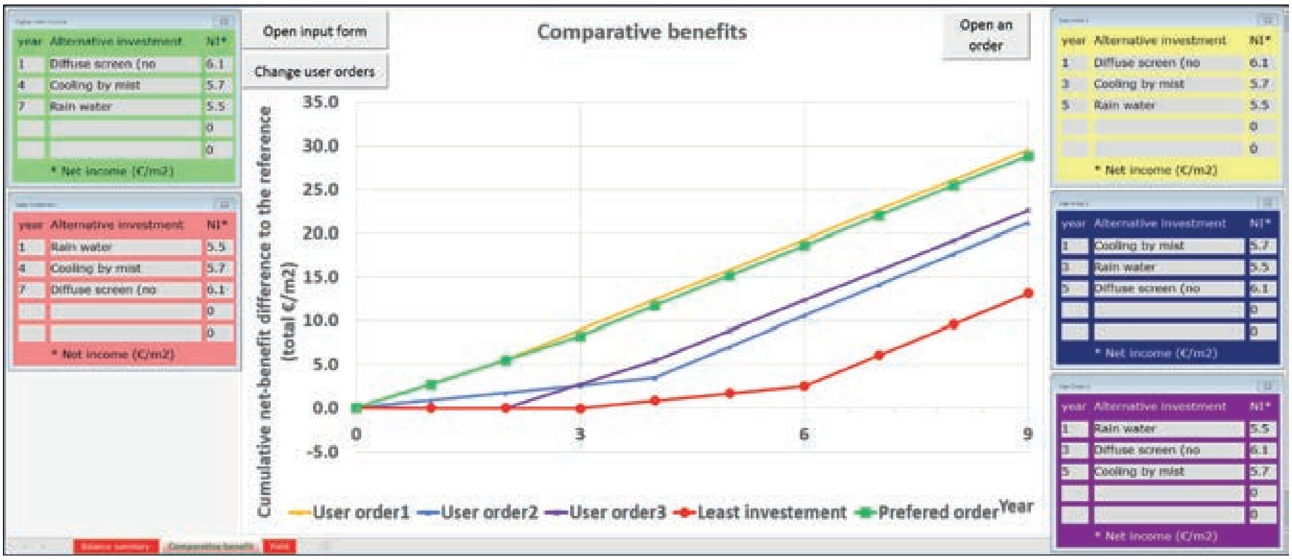

Figure 7 *Graphic representation of the cumulative benefit generated by different investment orders.*

In this case, user order 1 is slightly more profitable than the "preferred" order (which is investing every 3 years in the technology with the highest net benefit) because the investment interval in user order 1 was two instead of three years. The investment in rainwater collection proved to be marginally profitable (about as much costs as profits). However, the investment in a diffuse screen was the most feasible investment.
For advisors and authorities the values used to calculate the net benefit of each technology are available in a summary table (Figure 8). The balance of the data reference, user reference and each technology are shown. Values are calculated relative to the user reference.

Summary of the economic balance: Individual balance of the different alternatives

Cherry tomato - Almeria - Multitunnel - Ref Surface: 1ha		Dataset Reference	User Reference	Reverse osmosis	Rain water	CO2	Diffuse screen (no whitewash)	Thermal screen	Boiler 100W (thermal screen)	Winter variety	Cooling by mist	0	Substrate (quality water)	Recirculation (substrate)	Ammonium
Turnover	€/year/m²	12.1	12.4	12.4	12.4	12.0	14.3	12.2	22.9		13.3		12.0	13.2	
Yield	kg/year/m²	13.0	12.3	12.3	12.3	12.6	16.1	12.4	19.3		13.7		12.9	12.9	
Variable cost	€/year/m²	3.9	4.0	4.1	3.9	7.0	4.2	4.0	24.5		4.1		4.5	4.6	
Depreciation	€/year/m²	2.9	2.9	3.2	3.0	2.9	4.0	4.2	5.0		3.4		3.8	4.6	
Netto - benefit	€/year/m²	5.3	5.6	5.1	5.6	2.0	6.1	4.0	-6.7		5.8		3.7	4.0	
Investement	€/m²	28.6	28.6	2.9	1.5	1.0	5.5	6.5	18.9		5.0		7.4	12.0	
Investement Space	€/year/m2				0.0		0.5				0.2				

Figure 8 *Part of the economic summary of the result of different investments for the given scenario of Cherry tomato in a multi-span in Almería, Spain.*

3.3 Area and crop description

For the application of the investment order methodology two large and highly representative internationally significant greenhouse regions, Jordan Valley and Highlands (Jordan) and Almería (Spain) have been selected. Both greenhouse regions are characterized by the use of relatively simple greenhouse technology, with simple artisan greenhouse structures, a very limited control on the microclimate and, to a certain extent, limited control of the irrigation and nutrition of the crops. A short description of each region follows:

3.3.1 Jordan

Jordan is located in the Middle East in a land locked position with Syria in the north, Iraq to the East, Saudi Arabia to the East and South and Israel to the West. The climate is distinctly different between the 800-meter high Highlands and the Valley of the Jordan that is a 500-1200 meter deep north to south rift. The Highlands have a distinct dessert climate with 400 mm of precipitation, very dry air and rather harsh winters. The Jordan Valley has with mild winters and very hot summers with a precipitation of 200 mm/yr, slightly more humid air and low wind speeds. Jordan is one of the driest countries on earth and water is scarce and of very bad quality with excess levels of sodium, chloride, calcium, magnesium, boron, sulphate and bicarbonate (Fileccia *et al.* 2015). No surface waters are to be used for irrigation and the wastewater of the Amman area is transported back for agricultural purposes. Even so, farmers rely on boreholes to aquifers, rapidly depleting any available stocks. Horticulture relied on export by road to Russia, Eastern Europe and the Gulf area. Since Russia and Eastern Europe can no longer be reached due to the wars in Syria and Iraq, the horticultural industry including covered crops, is in crisis. Main products from plastic houses are tomato, sweet pepper, cucumber, courgette, eggplant and strawberries. The positioning of Jordanian product is poor with no certification and poor cooperation between exporting growers/traders.

The area of plastic houses in Jordan is about 4.000 ha (*JDOS*, 2014). Our estimate is that there are about 95% of very low-tech single tunnel greenhouses. The remaining area is about 5% of widely differing multi-span and polycarbonate glasshouses. The basic single multi-span is uniform. There are two mayor climatological regions within Jordan: The Jordan Valley, which is used for 6-8 month of wintertime production with 3500 ha. The Highlands, which are used for summertime production with 500 ha. The indicative costs are 7.5-10 Euros per m^2; multi-spans between 20 and 50 Euro per m^2.

The area was visited in August 2016.

Figure 9-10 *Half tunnel plastic houses (L). Multi-span with screen, pad and fan and substrate (R).*

3.3.2 Spain, Almería

Located in the Southeastern corner of the Spanish Peninsula, Almería is a province with dry Mediterranean climate, with relatively mild winters (frosts rarely occur), warm and dry summers, and very low yearly rainfall that barely averages 350 mm per year. This climate, together with the development of plastic film materials as greenhouse covers and the possibility to extract water from existing aquifers, boosted from the 70´s the development of simple greenhouses to supply the European market with edible vegetables (tomato, pepper, cucumber, eggplant, melon, water melon, etc.) mostly during the winter months, when production in the highly technical northern Europe greenhouses is more limited due to lower light levels and heating costs.

Almería accounts for the largest greenhouse concentration in Europe. According to CAPMA, 2013, the greenhouse area in Almería in season 2012/13 amounted to 28,576 ha. On year 2012/2013, approximately 97.7% of these greenhouses are different versions of an artisan greenhouse structure, the ¨parral¨ type greenhouse (García-García *et al.* 2016). The parral greenhouse (Figure 1) is based on the simple structure used to support vines, and the present design has developed from one with wooden posts and a flat roof to one made of galvanized steel with a multiple pitched roof. These greenhouses rely mostly on limited capacity natural ventilation systems with non-automated opening/closing of vents (96% of the greenhouses which have vents, these are opened/closed either manually or with motors, but not by a climate control), thus only 4% of them vents are automated. Only 1.9% of the greenhouses use heating systems. Growers rely on other cheap and passive techniques to improve the microclimate (whitewash for shading is used by 97.3% of the growers and or double fix internal plastics to improve winter temperatures in some crops like cucumber, according to Garcia-Garcia *et al.* 2016). The large majority of the growers still grow in the soil, most of them using the so called enarenado growing system, which consists on the use of a sand mulch of approximately 20 cm above the original soil or a soil layer brought from elsewhere when original soil quality is low. Only 9.8% used substrate cultivation on season 2012/2013 and the use of re-circulation is testimonial. The indicative costs are basic parral greenhouse 7.5 Euros per m^2; improved parral 15 Euro per m^2; maxed out parral 30 Euro per m^2; multi-spans between 20 and 50 Euro per m^2.

The area was visited in April 2017.

Figure 11-12. *Traditional wooden pole parral (L). Tomato on enarenado (R).*

3.4 Climate data

Climate data were registered with Ludvig Svensson data boxes at nurseries with both, the traditional greenhouse type of the region and a more modern multi-span. In Almería this was the Galdeano nursery and in Jordan the Bakker Brothers nursery. The setup and the results were described in separate reports (*Ludvig Svensson*, 2017a,b; and *Baeza-Romero*, 2018).

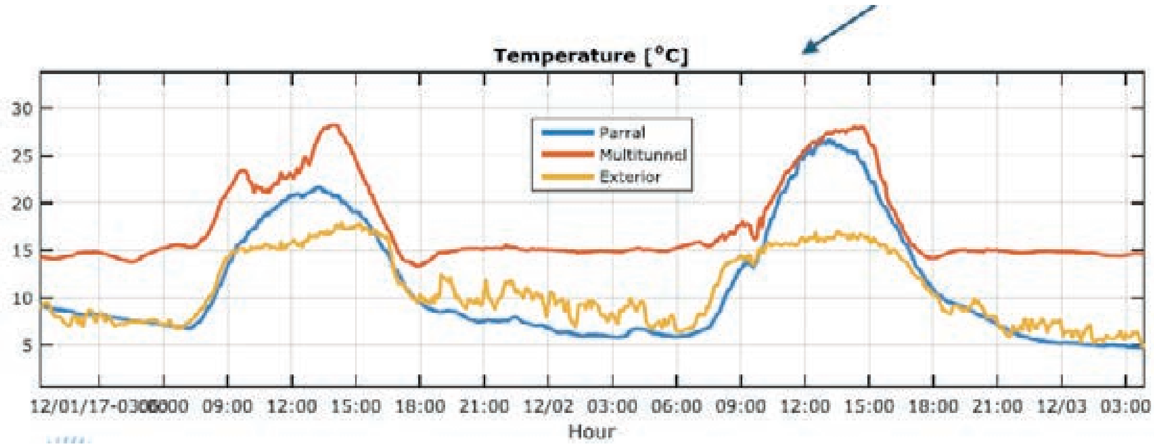

Figure 13 *Example of a temperature registration at the Galdeano nursery in the Almería region between a traditional parral type greenhouse and a multi-span greenhouse.*

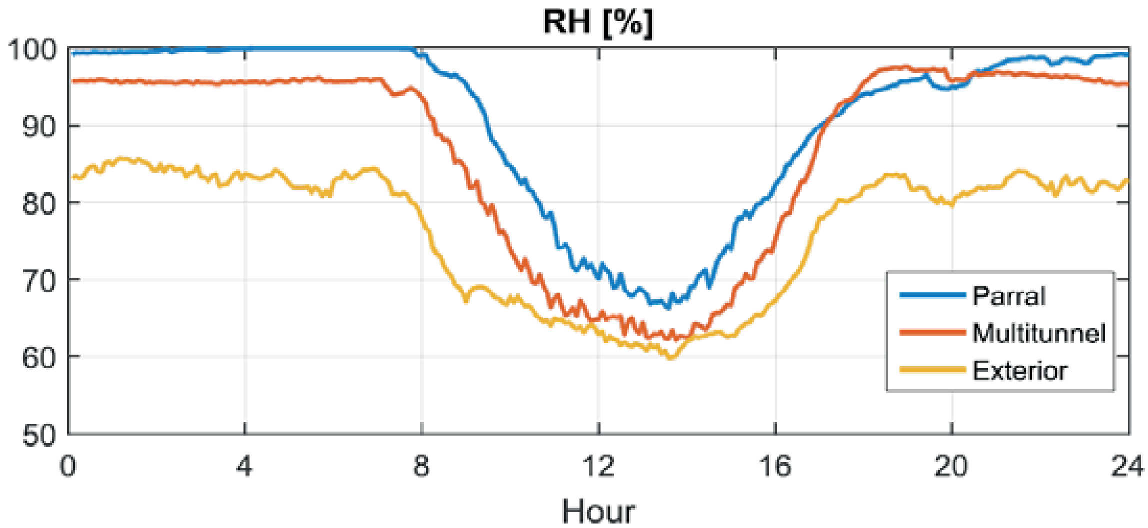

Figure 14 *Example of a relative humidity registration at the Galdeano nursery in the Almería region between a traditional parral type greenhouse and a multi-span greenhouse.*

The climate measurements in Almería confirmed the previously accumulated general climate data and added a few specific peculiarities, especially relevant for the use of screens. Figure 13 and 14 show:

1. The multi-span has a heating system with a night temperature set point of about 15°C.
2. The difference between a greenhouse in which roof vents are always open (parral) and one in which natural ventilation can be controlled (multi-span).
3. The maximum temperatures are higher under the multi-span, possibly because the grower is using a conservative ventilation strategy to increase the 24 hours temperature mean in the multi-span greenhouse.
4. Finally, during two days (probably with very clear nights) the air temperature inside the parral is lower than outside. This is the well-known thermal inversion phenomena. Since the PE plastic film is not fully thermal, a large part of the TIR is transmitted to the very cold sky. Crop is also transpiring and night and consuming energy. All the elements in the greenhouse become colder than outside, and so does the air.
5. Under the parral, we observe that clear saturation conditions occur during the whole of the night time period, very likely driving to condensation on the crop, which is the key to the incidence of pest and diseases. Relative humidity under the parral is also higher during the daytime, as the interior plastic film also largely decreases natural ventilation exchange.

3.5 Investment choices

Extensive use was made on pre-existing literature on the subjects studied (Short and Lee, 2002; García-García *et al.* 2016; Pérez-Parra *et al.* 2004; Baeza-Romero *et al.* 2004; Montero *et al.* 2013; Baptista *et al.* 2012; Garcia-Balanguer, 2017; Tuzel *et al.* 2017).

3.5.1 Technology Spain

3.5.1.1 Almería the symmetrical parral type greenhouse

For Almería, two subsets of simulations have been performed:

1. Considering the artisan symmetric multi-span parral type greenhouses as the base structure.
2. Considering an industrial gothic symmetric multi-span greenhouse as the base structure.

Ad1) The symmetric ¨parral¨ multi-span greenhouse is the most popular variant of the parral type greenhouse nowadays in Almería (63.5% of the total number of greenhouses in Almería are of this symmetric type, García-García *et al.* 2016). Figures 4 and 5 show a drawing and a picture of this type of greenhouse, respectively. Note that we did not focus on the most basic parral type with a planar deck without vents.

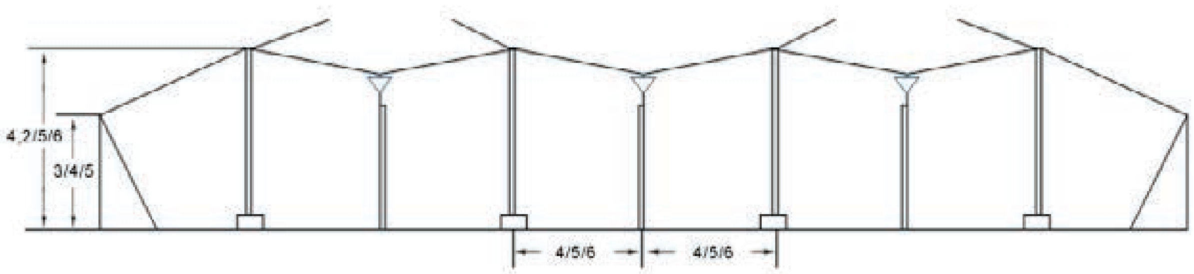

Figure 10 *Sketch of a typical symmetric parral multi-span greenhouse.*

Figure 11 *Photo of a typical symmetric parral multi-span greenhouse.*

The perimeter of the house is defined by rows of I section steel members set in concrete foundations at 2 m intervals and inclined outwards at 60–65° with their upper ends joined by horizontal L section steel members. The sidewalls which are typically 3 m high, are formed by vertical cables or rods attached to the horizontal members and anchored in the soil. The roof is supported by circular posts on concrete foundations at intervals of 8 m in 1 direction and 2 m in the other. The tops of the vertical and inclined posts in each row are connected to tensioned wires, which form part of a 2 m, by 2 m array of wires. Valleys in the roof are created midway between the rows of posts with the 8 m separation where the height of the tensioned wires is reduced by vertical cables connected to ground anchors at 2 m intervals. Along the sides of the greenhouse, there is a transition region 4–8 m wide over which the height of the ridges and valleys is reduced to that of the sidewalls. In the central region, the inclination of the roof surfaces is 10–12° and a typical height of the ridge is 4/5 m.

The film plastic sheets that cover the roof are held between two galvanised steel nets attached to the array of tension wires. The sidewalls are covered in a similar manner to the roof using nets attached to the vertical cables or rods. This method of attaching the cover gives good stability and prevents the film from fluttering when the wind speed is high. A series of holes in the film along each roof valley allows rainwater to pass to an internal galvanized steel gutter and drain to its ends by virtue of the curved profile. Early ‘parral’ greenhouses only used sidewall ventilation; however, it is now common for this to be supplemented by continuous roof ventilators. These are generally placed on one side of the ridge but not always on every span and they do not extend into the transition region of the roof adjacent to the sidewalls. Roof ventilators covered by flaps are the more common type and are now used in 50.8% of ‘parral’ greenhouses.

For the simulations, we have considered a typical symmetric parral greenhouse type with no climate control other than natural ventilation (not automated) and whitewash between 1st of March and 1st of October (Common practice in the area, with variation of days depending on the climatology of the year and the stage of the crop). The basic dimensions of the simulated greenhouse are in Table 6. The reference greenhouse has a whitewash leaving a transmissivity of 40% from March 1st to October 1st, which is common practice in the region for tomato.

Table 6
Basic geometrical and related parameters of the parral type greenhouse structure.

Area	10,000 m^2
Central path width	2.5 m
Gutter height	3.6 m
Roof slope	13º
Span width	8 m
Section length	5 m
% light intercepted by structural elements*	10%
Covering material	Polyethylene film
Leakage**	8e-^{05} m^3/m^2 s (m/s)
Fraction window/ground	15%

* This parameter represents the percentage of incoming solar radiation absorbed by structural elements of the greenhouse.

** This parameter is expressed as an airflow per unit greenhouse wall and per unit wind speed.

3.5.1.2 Almería the symmetric gothic multi-span greenhouse

This type of greenhouse only represents 2.3% of the total greenhouses of Almería, but it represents the number one choice for growers when they decide to make a technology upgrade from an artisan parral type to a more industrial greenhouse type, with higher volume, more tightness, more ventilation area and in general better possibilities of climate control.

This type of greenhouse has a metallic structure, where plastic is tensioned and fixed by means of different clipping systems. Usual span widths are 8 and 9.6 m, although recently, in some countries, the trend is to building even wider spans (12.8 m or even more). Gutter height may vary, but the trend is also to increase it, and now gutter heights of 6 m and more are used. The gothic shape allows for higher light transmission than the semi-circle shape, and easier collection of condensation water. This type of greenhouse has usually roof ventilators of large size (2 m or more) (Figure 6) in a number of at least one per span, but in warm regions, such as Almería , many growers opt for the double roof vent per span, also known as "butterfly" type (Figures 12 and 13).

Figure 12 *Sketch of a typical symmetric gothic shape roof multi-span plastic film greenhouse.*

Figure 13 *Photo of a typical symmetric gothic shape roof multi-span plastic film greenhouse.*

The basic dimensions of the simulated gothic multi-span greenhouse are presented in Table 7.

Table 7
Basic geometrical and related parameters of the gothic multi-span type greenhouse structure.

Area	10,000 m^2
Central path width	3 m
Gutter height	5 m
Roof slope	22º
Span width	8 m
Section length	5 m
% light intercepted by structural elements*	10%
Covering material	Polyethylene film
Leakage**	1.6e-^{04} m^3/m^2 s (m/s)
Fraction window/ground	15%

* This parameter represents the percentage of incoming solar radiation absorbed by structural elements of the greenhouse.

** This parameter is expressed as an airflow per unit greenhouse wall and per unit wind speed.

The reference gothic greenhouse has a whitewash leaving a transmissivity of 50% from April 1st to October 1st, which is common practice in the region for tomato in this type of greenhouse.

3.5.1.3 Almería, options

Ventilation

The simulated ventilation set points, common to all scenarios are shown in Table 8.

Table 8
Ventilation temperature and humidity set points used in the simulations

	Starting date	Sunrise/Sunset
Ventilation temperature (ºC) set points	01-08	22 19
Ventilation temperature (ºC) set points	01-10	24 22
Ventilation temperature (ºC) set points	01-12	25 23
Ventilation temperature (ºC) set points	01-02	24 22
Ventilation temperature (ºC) set points	01-03	22 20
Ventilation R.H. (%) set points	All cycle	90 85

Artificial light

Reference greenhouse but with the artificial High Vapour Sodium Lamps as described in Table 9.

Table 9

Most important parameters of the simulated artificial lights.

	Starting date	
Artificial lights	01-10	On
Artificial lights	01-04	0ff
Lamps intensity		92 W/m^2
Hours that lights are off per day		6 h
Time lamps are switched off		20 h
PAR fraction of the lamps		43%

Light screening (Shading screen)

A mobile shading screen (50% aluminized and 50% open) was simulated according to Table 10.

Table 10

Summary of model assumptions for the simulations of an internal mobile shading screen.

Screen type		COLS50
Screen system		Shading screen
Max. Tout Screen*		16
Screen closes below**		1
Screen closes above***	15-07	(500 90)
Screen closes above***	01-09	(1000 90)
Screen closes above***	01-04	(500 60); (650 75); (800 90)

* Shading screen is not used as an energy screen when outside temperature is above this value.

** Shading screen is completely closed for energy saving when outside temperature is below this value.

*** On each date, shading screen is closed with a percentage given by the second number when solar radiation exceeds the first number. With more than one interval, values are interpolated in between intervals.

Energy saving screen

Reference greenhouse with mobile energy saving screen (SLS10Ultraplus) according to Table 11.

Table 11

Model assumptions for the simulation of a mobile energy saving/thermal screen.

Screen system	Energy screen
Screen type	1243 Luxous
Max. Tout Screen	16
Screen Closes Below	(-30 300); (-10 200); (5 50); (12 5)
Chink On Temp. Excess*	(2 3); (5 10)
Chink On Hum. Excess*	(1 10); (2 13)

* When temperature excess exceed 1st parameter, screen is open with a gap (%) equal to the second parameter.

Boiler (Heating system)
A low metal pipe heating system has been simulated, with a maximum heating power of (100 W/m^{-2}) and the following assumptions for the heating set points (Table 12).

Table 12
Summary of more relevant set points used in the simulations of a heating system.

	Starting date	Sunrise/Sunset
Heating set point temperature (ºC):	01-08	18 15
Heating set point temperature (ºC):	01-10	18 16
Heating set point temperature (ºC):	01-05	18 15

Improved ventilation
Same as the reference, but with a 30% (ventilation area /ground area) ratio.

Cooling by mist
Reference, but with a fog system with a maximum water supply of 300 gr/m^2 h, activated when greenhouse air temperature exceeds 27ºC or R.H. decreases below 75%.

CO_2 enrichment
Reference greenhouse with pure CO_2 enrichment with a maximum dosing capacity of 120 kg/ha h and a set point of 800 ppm.

3.5.2 Technology Jordan.

For Jordan, two subsets of simulations have been performed, this time for two different climate regions in the country:
• Jordan highlands, for which climate data sets obtained from Amman Airport, have been used.
• Jordan Valley, for which climate data sets obtained for the location of Deir Alla have been used.

3.5.2.1 Jordan, the simple high tunnels
For Jordan, the reference greenhouse considered has been the most popular in the country, that is, the simple high tunnels. These structures are simple arcs with enough height for workers to walk freely inside, covered with a plastic film (usually PE film). Ventilation is limited to the front gable, usually covered with an anti-insect screen, and some permanent small openings in the plastic film on the sidewalls (Figure 8 a, b). During the warmest season, mud is applied to the roof to provide some shading for the crop. These openings may or may not be protected with an anti-insect screen.

Figure 14 *Details of some typical high tunnels used for cultivation in Jordan.*

Figure 15 *Mud screen on typical high tunnels used for cultivation in Jordan.*

For the simulations done for both studied regions (Jordan Valley and Highlands), the reference greenhouse was a tunnel with no climate control other than small natural ventilation provided by the front wall and small permanent holes on the sidewalls (not automated) and whitewash (60% shading) by adding dust to the cover between 1st of April and 1st of November (Common practice in the area, with variation of days depending on the climatology of the year and the stage of the crop). The basic dimensions of the simulated tunnel greenhouse are the following (Table 13).

Table 13
Basic geometrical characteristics of high tunnels in Jordan, used in the simulations.

Area:	405 m^2
Central path width:	0 m
Gutter height:	2.5 m
Roof slope:	15º
Span width:	8 m
Section length:	3 m
% light intercepted by structural elements*:	12 %
Covering material:	Polyethylene film
Leakage**:	5e-^{04} m^3/m^2 s (m/s)
Fraction window/ground:	5%

The reference greenhouse has a whitewash leaving a transmissivity of 40% from March 1st to October 1st, which is common practice in the region for tomato.

3.5.2.2 Jordan, the fixed roof vents multi-span and the gothic automated butterfly multi-span
For Jordan, two alternatives to improve the performance of the reference high tunnel have been analysed:

a. Multi-span with fixed roof vents. This type of greenhouse is also quite popular in many warm regions of the world, also in the tropics and the subtropics (Figure 9). In this greenhouse, the roof vents (1 per span) are always open.

Figure 16 *Example of the multi-span greenhouse with fixed roof vents simulated.*

b. Gothic type multi-span with double roof vents per span and automated ventilation. Similar to the one simulated for Almería, but with a slight wider span.

Table 14 summarizes the most important geometrical characteristics of these two types of greenhouses used in the simulations.

Table 14
Basic geometrical characteristics of the two simulated multi-span type greenhouses in Jordan.

Greenhouse area:	5000	m²
Path width:	3	m
hGutter:	3	m
Span width	9.6	m
Roof slope:	22	deg
Deck material:	PE film	
Leakage:	1.60E-04	$m^3/m^2/s=m/s$
Window length*:	2	m
Window height-fixed roof vent type:	1.2	m
Window height-double roof vent type:	1.6	m
fr_Window fixed vent type:	5	%
fr_Window double controlled vent type:	15	%

We have also assumed application of 40% reflecting paint (crop is smaller and intercepts more light, so more shading is required to maintain temperatures inside the greenhouse), starting in April until first of July, when shading is reduced to 30% and removed on September 15th. In the simulation, we have considered roof vents are implemented with an anti-thrips net, which reduces ventilation area by 40% (Perez-Parra *et al.* 2004).

3.5.2.3 Jordan, options

Ventilation

The simulated ventilation set points for the gothic multi-span greenhouse simulations, the only one with possibilities of vent control are given in Table 15 (*Baeza-Romero*, 2016).

Table 15
Basic ventilation set points used for the gothic multi-span greenhouse (both regions).

	Starting date	Sunrise/Sunset
Vent set points	01-08	22 19
Vent set points	01-10	24 22
Vent set points	01-12	25 23
Vent set points	01-02	24 22
Vent set points	01-03	22 20

For the Jordan Valley and the Highlands, these are the technological packages scenarios that have been simulated.

Multi-span with controlled vents and a shading screen
Gothic multi-span greenhouse with double controllable vents and with a mobile shading screen (50% aluminized and 50% open) with following assumptions (Table 16).

Table 16

Summary of information used for the simulation of the shading screen for Jordan.

Screen system:	Start date	Shade screen	
Screen type:		COLS50	
Max. Tout Screen:		15	Screen is not used when temperature is above 15oC
Screen closes below:		1	
Screen closes above:	15-07	(500 90)	If the outside radiation exceeds the first value, the screen will close with the second value
Screen closes above:	01-09	(1000 90)	
Screen closes above:	01-04	(500 60);(650 75);(800 90)	
Chink on temp. excess:		2	If temp excess exceeds 1st parameter, screen is opened with a chink of 2nd parameter
Chink on hum. Excess:		2	If humid excess exceeds 1st parameter, screen is opened with a chink of 2nd parameter

Multi-span with controlled vents and an energy saving/thermal screen

Reference greenhouse with mobile energy saving screen (XLS18 REVOLUX/Tempa8570 FR) with following assumptions (Table 17).

Table 17

Summary of information used for the simulation of the energy saving screen.

Screensystem[2]:	Energy screen	
Screentype2:	Tempa 8570fr	
MaxToutScreen2:	15	Screen is not used when temperature is above 15oC
ScrCloseBelow2:	(-20 1);(100 1)	
ChinkOnTempExc2:	2	If temp excess exceeds 1st parameter, screen is opened with a chink of 2nd parameter
ChinkOnHumExc2:	2	If humid excess exceeds 1st parameter, screen is opened with a chink of 2nd parameter

Multi-span with controllable double vents+ shading screen + energy saving screen + Boiler (Low power heating system). Both short and extended cycle

A low metal pipe heating system has been simulated, with a maximum heating power of (40 W/m^{-2}) and the following assumptions for the heating set points (Table 18).

Table 18

Heating system set points.

	Starting date	Sunrise/Sunset
Set point temperature (ºC):	01-08	18 15
Set point temperature (ºC):	01-10	18 16
Set point temperature (ºC):	01-05	18 15

Multi-span controlled ventilation + Cooling by high-pressure fog

Reference, but with a fog system with a maximum water supply of 400 gr/m^2 h and the following activation points (Table 19).

Table 19

Set points and system capacity used for the fog system in the simulations.

Fogging Dose:		400	Maximum spraying capacity in grams / (m^2 hour)
MinTempFogging:	01-04	26	Minimum air temperature above which the spray is allowed it is drier than75% RV
MinTempFogging:	01-10	28	Minimum air temperature above which the spray is allowed it is drier than75% RV
MinVocht:		75	

CO_2 enrichment

Reference greenhouse with pure CO_2 enrichment with a maximum dosing capacity of 120 kg/ha h and a set point of 800 ppm.

3.5.3 Technological assumptions apart from KASPRO

3.5.3.1 Influence of EC on yield / Reverse Osmosis

The detailed description of the choices made is to be found in a separate monograph (van der Salm *et al.* 2016). This particular study deals with the influence of salinity on yield. In a first step general quantitative information on salinity and yield is given. In a second step, the information is used to predict yield loss for Jordanian circumstances. In a third step, the financial consequences of this yield loss are shown. In a fourth step, we calculate the costs of solving the problem by using a reverse osmosis installation.

Main results:

- For tomatoes and bell peppers the yield loss is 3-4 kg m^{-2} at EC 5 dS m^{-1}.
- The salinity yield decrease is linear above a certain “safe” threshold value.
- Some crops or cultivars are more sensitive to salt stress than others are.
- The monetary loss at EC 5 dS m^{-1}, amounts to 24k€/ha/yr for bell pepper and 15k€/ha/yr for tomato.
- The total annual costs of Reverse Osmosis is € 5700 for a farm of 0.5 ha and €47000,- for a 10 ha farm.
- At an EC of 4 dS m^{-1}, investment in a RO is profitable for tomato farms with an area of over 0.8 ha.
- At an EC of 3 dS m^{-1}, investment in a RO is profitable for bell pepper farms with an area of over 0.8 ha.

The Investment Order tool allows the grower to report the EC of his raw irrigation water. The tool then uses this value to estimate the yield effects for the standard situation and those investments including a reverse osmosis treatment.

3.5.3.2 Rain water Collection

The detailed description of the choices made is to be found in a separate monograph (*Van Os*, 2016). In the Investment Order tool rain water collection is a separate investment option. The costs of collecting the water are weighed against the extra yield to be expected by using improved water. The yield increase is calculated using the salinity yield decrease relationship of the salinity / reverse osmosis module described in paragraph 3.4.3.1.

3.5.3.3 Low ammonium / urea inputs

Urea derived or straight supplied ammonium is known to have a direct effect on root zone pH, which has a direct impact on yield. Therefore, the user can provide a description of his current fertilizer (Figure 17) or the values of the fertilizer he intends to use. Urea is counted as two units of ammonium. Based on the ratio of ammonium to nitrate in the (compound) fertiliser, the nitrate level supplied and the amount of fertigation supplied, the influx of ammonium is calculated. From the daily amount of ammonium supplied, the amount of acid produced is estimated. The buffer capacity of the substrate expressed in gram calcium carbonate equivalents per square meter allows calculating how many days the substrate can neutralize the acid produced and thus can hold the pH at an acceptable level. If the cultivation length surpasses the period of buffering the yield drops very fast to zero as the roots will be damaged. This possible yield drop results in a pop up warning against the use of this fertiliser.

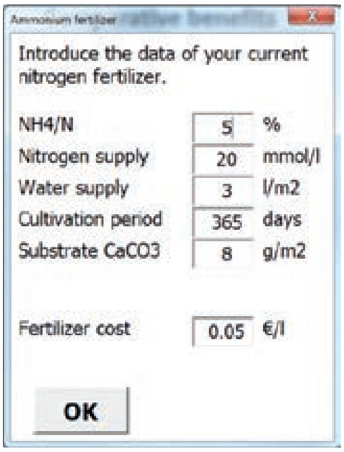

Figure 17 *Input field for the evaluation of ammonium fertiliser effect on yield.*

3.5.3.4 Resistant varieties

IFAPA kindly supplied us with dataset of production in Almería. When KASPRO was used to evaluate yield data from Almería it turned out the winter production was slightly higher and the summer production slightly lower than the model predicted. This was interpreted as the effect of the improved tolerance for low temperatures of the varieties used in Almería for winter production in unheated parral greenhouses. Based on this effect we introduced the choice for a winter variety of tomato for the Almerían unheated greenhouses. It is expected that many other varieties exist that can show a specific advantage such as higher salinity tolerance.

3.5.3.5 The choice between soil and substrate

The choice for substrate over soil based growing results in a higher yield of at maximum 15% because of a more frequent and more precise dosing of water and fertilisers according to the need of the plant. In the Investment Order tool the user is asked to put in the number of irrigation cycles supplied to the crop per day. Between 0 and 15 cycles a day the yield is allowed to increase 1% for every extra irrigation cycle given.

The advantage of using recirculation is only counted as a reduction in costs for water and fertiliser use of one Euro per meter square. Recirculation allows the water use to reduce with 50% and the fertiliser use with 60%. Even so, the cost reductions are not much higher than the costs associated with a more precise nutrient dosing system, disinfection and the sampling required.

A more common reason to use substrate growing and recirculation is to control diseases in soil and irrigation water. Yields can increase 5-50% once the soil is diseased with e.g. any of nematodes, Fusarium and Phythophthora. This advantage is not incorporated in the tool as the differences in disease problems between nurseries can be substantial.

3.6 Area trips

These trips are reported separately in considerably more detail but parts are reported here as they indicate how the concept of the tool and the tool itself were received in the regions. This bears on both, the technical performance and the position the tool finds in the socio-economical context. This also illustrates how the tool helps not only in decision making, but also in elucidating risk perception. The latter may become very important when offering alternative investments, as resistance to change may be motivated by risk avoidance while initially voiced as a rational argument.

3.6.1 Jordan 08-09 August 2016

The first trip to Jordan took place on 08-09 August 2016 (*Blok*, 2016). The trip included all partners except Grodan. It confirmed the regional selection criteria were met but it also made clear the area is well behind in technological development, knowledge infrastructure and export position. The potential for selling Dutch products was classified as much lower than that of Almería. Consequently, efforts in Jordan were put on a lower level than those for Almería. Nevertheless, contacts with local SQM, Bakker Brothers and Rijk Zwaan employees were made. An improved passive cooling greenhouse was realised early 2019 with the HAED-JO project, with equipment delivered by Priva, Grodan and Royal Brinkman. For this project we used data from a report in which the yield and water use results of the improved greenhouse were compared to the traditional half tunnels (*Brunsting*, 2019). The report is very important for the Investment Order Report for two reasons: a) it shows how KASPRO delivers reliable yield estimates for the new technology with a slight tendency to underestimate the effects of improvements and b) it shows how important the delivery of soft skill support is.

3.6.2 Jordan May 2017

The second trip to Jordan was by Ludvig Svensson and Bakker brothers to establish measuring equipment. The equipment is described in a brief report (*Svensson*, 2017a) as are the outcomes of the data (Baeza-Romero *et al.* 2019; Blok *et al.* 2019). Further data was delivered by a parallel project in which Priva and Grodan participated (Brunsting, 2019).

3.6.3 Jordan February 2019

This trip by Grodan, Priva, Ludvig Svensson and Royal Brinkman was focused on visiting local grower involved in or interested in buying new technology with a Dutch embassy contribution. The trip confirmed the high risks for financing in the area as well as the excessive need for knowledge support compared to the Almería region. Especially the carelessness with regard to virus infection struck the delegation unfavourably. In Jordan the economic situation in 2017-2018 as influenced by war in neighbouring countries, was so bad the Investment Order tool showed no investments were feasible at the then current market prices. Even so, some front-runners decided to invest in improved greenhouses. Investments by these export-oriented nurseries were in passively cooled greenhouses i.e. cooling by the evaporating plants rather than by using the water-consuming pad and fan technology. This requires plastic houses with very large ventilation openings and ample height to stimulate natural ventilation by air movement. For the growers involved in the HAED-JO program, this already required large technological steps including: a) harvesting on trolleys b) using high wire spool systems; c) using substrate and drip irrigation. A change not yet incorporated in the Investment Order tool was the change in the propagation system from a small plant in a plug to larger plants in larger plugs or in a plug-block combination. In Jordan investing in recirculation of nutrient solution in the same cultivation was not yet feasible even though Jordan is one of the four most water stressed countries in the world. The alternative was to reuse the drain water in an adjacent lower value crop, usually a soil born crop.

3.6.4 Almería 10-11 April 2017

The first trip to Almería took place from 10-11 April 2017 (Blok *et al.* 2017). Representatives from SQM, Grodan, Priva, Bakker Brothers, Ludvig Svensson and Wageningen University & Research Greenhouse Horticulture visited the horticultural area around Almería, Andalucía, Spain. The group visited horticulture related companies and nurseries to get an impression on the technical level of the primary producers and their willingness to invest in technical improvements in the nurseries. The visit was organised by Esteban Baeza Romero with the help of Spanish and Dutch companies. Six growers, a research station and a propagator were visited. Most companies visited were approached via the two largest cooperatives in the area. Most nurseries visited had several greenhouse types. The greenhouse types showed the full range of technical levels within the area, ranging from the most simple parral type (<10 Euro/m^2) to the most sophisticated parral type greenhouse with substrate system, heightened steel frame, rainwater collection system, 2 way ventilation and screens (20 Euro/m^2). Visits also included some modern multi-span plastic houses and Venlo type glasshouses (>>25 Euro/m^2). The concluding discussion gave rise to a more specified project goal and follow up actions as well as a clearer delineation between the Jordanian and Spanish parts of the project and the role of each partner within each of the two pilot regions.

3.6.5 Almería 17-19 Sept 2018

The second trip to Almería took place from 17-18 September 2018 (Blok *et al.* 2018). The investment Order consortium visited Almería in the South of Spain for a second time during the run time of the investment Project. The goal was to demonstrate the 1.0 version of the Investment Order tool. The tool is an Excel program, combining local yield and income increase against the costs of various alternative investments. The tool helps to identify the most interesting investment order. The tool was demonstrated a bank (Cajamar), a regional government research institute (IFAPA) and three growers in the area. This report gives a detailed listing of the arguments exchanged, actions to be taken and the conclusions and follow up required. The overall outcome is that there is a rather acute need for the decision support the Investment Order tool offers. The tool needs to be improved into a 2.0 version using the comments offered. A follow up visit in November 2018 is desirable as there is the chance to meet with at least two groups of growers actively seeking investments/yield increase.

An important side effect of demonstrating the tool was growers discuss detailed nursery information not easily offered in other settings. Growers with special varieties, with export contracts and with organic products enjoy special prices, which allows them investments that are more diverse. Most growers have a rough appreciation of the investments that could be feasible, but the perception of risks easily prevents them from acting on the best choices. As an example, organic growers perceive the risks of high humidity as cause of fungal diseases as so important they sometimes avoid thermal screens even though the resulting lower plant head temperatures in clear nights are a much worse cause of fungal disease by invoking condensation. Another outcome was that the appreciation of light as a driver of yield is often underestimated. This is reflected by the preference of white wash with a heavy shading factor, even though screening has become more feasible. Some growers apply whitewash 4-5 times per season accepting the lower cost and higher yield presented by a light screen. The irrigation equipment is generally effective, but recirculation of drainage water is almost absent in the region. With 30000 ha involved, this situation deserves a structural approach in cooperation with authorities.

Some other outcomes in general terms: a) The reverse osmosis proved straightforward information on the raw water EC maximum above which reverse osmosis is feasible. b) The switch to substrate was equally straightforward, with the exception for soils that allow five or more irrigation cycles per day. c) The climate-adapted varieties of the region proved indeed feasible in a winter cultivation in unheated greenhouses compared to the varieties developed for heated greenhouses. d) The recirculation of drainage water increased the costs more than or equal to the increase in yield. e) The investments in ventilation capacity, shading screens and / or thermal screens proved always interesting although the exact combination depends on microclimate information. Finally heating and carbon dioxide were not yet within reach of most Parral and the basic multi-span. In all cases, the outcome is dependent on many variables like cultivation period and length, microclimate and price agreements, etc., which illustrates the need for a tool like the Investment Order tool.

3.6.6 Almería 08-09 April 2019

The third trip to Almería took place from 08-09 April 2019 (Blok *et al.* 2019). The investment Order consortium paid another visit to Almería in the South of Spain within the run time of the investment Project. The goal was to demonstrate the 2.0 version of the Investment Order tool to a group of researchers and cooperatives at the IFAPA experimental station and to a group of researchers and bankers at the CAJAMAR experimental station. The Investment Order tool v2.0 is an Excel program, using greenhouse parameters and local climate to find the resulting yield. Local prices are used to then get the economic yield and combine it with costs for various alternative investments to arrive at an estimate of profitability. The tool consequently helps to compare alternatives and identifies the most interesting investment order. For IFAPA the outcome is that the consortium can try to make an appointment for demonstration with 1-4 cooperatives using IFAPA contacts. The possibilities for IFAPA to co-develop with their own funds seem limited. For CAJAMAR a proposal will be prepared to develop the tool in a 3.0 version which could be a) web based b) a protected MATLAB program c) allow the CAJAMAR to simply use their own data sets for investments and depreciation. CAJAMAR suggested the financing of this tool should partly include some of the companies involved and suggested including some non-consortium (Spanish) companies.

3.7 Restrictions and conditions

The investment order tool is a technical help with some limits on its validity/use:
1. The starting level should be described in terms of standard technical environment, yield level and prices for the cultivated products as well as full climatic data. The tool and starting level are thus highly specific for location and technology level.
2. The tool is about technical decisions and therefore cannot foresee certain cultural sentiments which affect the decision making process. Nevertheless, the tool is not useless for dealing with cultural matters as creating effective cultural change often includes the use of factual truth as part of a communication strategy.
3. The tool is using complex models to deliver linear one-cause one-effect relationships. If there is interaction – like with light / temperature / carbon dioxide – the tool will be less precise than the full models. It is however believed the decisions by the tool allow for faster and accurate comparisons of a great many investments by less specialised operators.

3.8 Future and Adaptive Greenhouse Concept

Altogether, the use of KASPRO has grown over years into a methodology of study developed by Wageningen University & Research Greenhouse Horticulture, which is referred to as “the adaptive greenhouse” and can be better understood by Figure 18 (Bakker, 2009; Van Os *et al.* 2009; Blok *et al.* 2013; Elings *et al.* 2013; Hemming *et al.* 2017; Speetjens *et al.* 2017; Van Os *et al.* 2017).

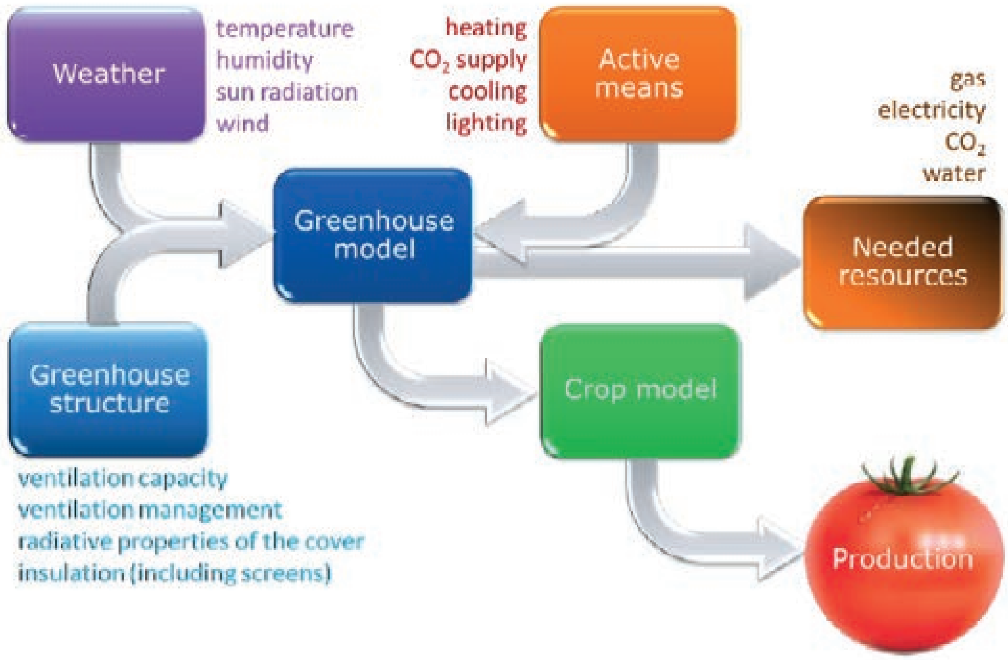

Figure 18 *The adaptive greenhouse approach in schedule.*

4 Conclusions

The general conclusions, answering to the goal set in chapter one, are:

1. Regarding the technical level of the primary producers in Jordan and Almería:
   - **Producers in Jordan** are actively interested in multi-span and substrate growing. Two growers have, with co-financing from the Dutch embassy and many willing supply companies, realised two times 7000 m^2 of such improved greenhouse concepts. Jordanian growers needed a lot of detailed on site communication on the advantages of the solution offered over the existing half tunnels and some multi-spans already offered.
     - Communication was focussed on <u>why</u> the concept offered included certain costs and excludes certain other costs. This discussion was often in response to competing offers from companies not using the Investment Order tool.
       - An example is why we advise such a high greenhouse (to better create natural ventilation flow).
       - A related discussion was why we leave out pad and fan or fogging (the costs surpass the extra yield at their yield level).
   - The investment in Jordan is only of interest with a generous subsidy as long as the blocked export through Iraq/Syria is keeping vegetable prices extremely low.

   - **Producers in Spain** are not particularly interested in multi-span and substrate growing as they regard improved parral and enarenado as viable alternatives. They need a lot of detailed on site communication on the advantages of the solution offered compared to fragmented outcomes of local research.
     - Such communication is focussed on why our concept improves yield over local solutions and how it deals with the many very micro site-specific risks.
       - An example of discussion on extra yield is why we advise so much ventilation (to use the plant to cool the greenhouse).
       - An example of discussion on micro site is why we do not raise night time temperature (some sites might indeed require a different screen).

     The investment in Spain is within the reach of individual growers if they are convinced of the return on investment.
   - A major reason for Almerían growers not to invest is a high-risk aversion.
     - In several cases this leads to a conservative attitude, refusing an agreed upon better solution out of fear of undesirable side effects. Examples are:
       - The use of screens over whitewash is low driven by the fear of too high night time humidity.
       - The whitewash is applied too thick and too long for fear of burning the plants.

   When comparing Jordan and Almería there are many similarities; light levels, water quality, yield level. However, Spanish growers are better organised and the local research is having impact and some status. The climate in Jordan is much more uniform than the wide varieties in microclimate in the Almerían area. Many Almerían growers need to be helped to address risks of side effects of new solutions.

2. Regarding the creation of an Investment Order tool for Jordan and Almería allowing some 20 investment alternatives quantified in terms of economic advantage and costs involved:
   - The tool allows for uniform comparison of very different investments just as designed.
   - The tool allows a structured discussion with growers, often resulting in more detailed information on prices and considerations given by growers than otherwise possible.
   - A better understanding between growers, researchers and (bank) extension officers.
   - Reading the tables delivered by the tool requires quite some on the spot economic skill.

3. Regarding the willingness within the area to use the tool to speed and direct investments.
    - Growers and advisors perceive the tool as reliable and indicative.
    - Risk perception suggested investments need to be addressed apart from the tool as risk aversion still –and apparently unnecessary- slows investments.
    - Growers and advisers have a real desire to use their own data on prices for investments too. This functional addition at the one hand increases trust in the tool but at the other hand could lead to too optimistic scenarios. At present, this extra flexibility is offered to Cajamar. If Cajamar decides to order this addition, the project Investment Order tool will have a direct sequel.

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Annex 1 List of preselected investments

- Influence of EC on yield.
    a. Input: Salinity yield decrease (SYD), costs of water and RO, price of crop, margins.
    b. Output: costs of Yield decrease versus EC and yield loss per EC versus treatment costs (investment plus running costs).
- Influence of rain water collection.
    a. Input: SYD, costs of water collection, price of crop, margins, rain data, evapotranspiration data.
    b. Output: costs of Yield increase versus reduced water costs versus water collection costs (investment plus running costs).
- Advantage of low urea/ammonium fertilisers over high urea/ammonium fertilisers.
    a. Input: Marketable yield depression by pH and ammonium problems, costs of nutrients, price of crop.
    b. Output: Marketable yield decrease versus pH-ammonium and investment in low urea/ammonium fertiliser. Marketable is meant to keep track of quality effects like BER occurrence.
- Advantage of using resistant or tolerant varieties over the non-resistant standard varieties.
    a. Input: Yield decrease of using new varieties versus the risk and damage levels for specific diseases versus the costs of yield decrease and crop protection.
    b. Output: Break-even point of resistant /tolerant varieties versus disease risk index and versus number of plants effectively lost.
- Influence of light on yield.
    a. Input: Relation light vs yield vs starting yield level. Transmissions of plastics and glass, Thickness, age, UV-stabilisation and diffusivity (dust accumulation).
    b. Output; choice of cover regardless of wind influence and life time.
- Influence of shading on yield.
    a. Input: Light sum transmission, climate data; radiation distribution over time. Hours of shading; critical levels for opening and closing.
    b. Output comparison fixed screening, movable screen, removable fixed screening. Yield advantage of movable over fixed screen.
- Influence of screens on temperature.
    a. Input: Light sum transmission, radiation loss to the night sky, climate data; radiation distribution over time. Hours of shading; critical levels for opening and closing.
    b. Output comparison fixed screening, movable screen, removable fixed screening. Yield advantage of moveable over fixed screen.
- Influence of temperature on yield.
    a. Input: Relationship with fruit pollination / setting. Climate data.
    a. Output: later to be specified
- Leaf area / light interception. To be specified later.
- Influence of ventilation on temperature / RH. To be specified later.
- Heating. To be specified later.
- Cooling by pad and fan / high pressure mist. To be specified later.
- Diseases. To be specified later.
- Biological control. No yield depression by spraying. To be specified later.
- Plant size, path width and spacing in relation to light interception. To be specified later.
- Carbon dioxide in relation to ventilation and in relation to substrate used.
- The choice between soil and substrate (and free draining versus closed system).
- Crop management (e.g. high wire or the like with influence on the generative / vegetative balance).
- Mechanisation of labour (e.g. use of harvest trolleys).
- More to be specified later.

Some suggested issues for a Spanish list are:

a. Several levels of ventilation to be compared.
b. Role of planting density on light, humidity high and low levels (Jordan too).
c. Role of planting densities on production.
d. Role of energy screen on night time T.
e. Role of low tech nutrient units in the area and their relative importance / incidence.
f. Effect on yield and quality (brix, quality classification) of variability in exact composition of nutrient solutions, division over the fertilizers over the different containers and crop- and stage-specific variations.

Suggested technical detail and prices to look for:

- Dates of applying whitewash as well as dosage / thickness.
- Specification of the different plastics used.
- Specifications of the thin foils for the ‘doble techo’ system.
- Specifications of the different insect nets used.
- Increasing work efficiency by saving in hours labour or prevention of potentially costly mistakes by uneducated labourers, and increasing quality of produce to the customer’s demand is also important in decision making.

NB This technical detail is to be delivered by the companies involved rather than WUR, who will not need this level of detail to run the tool, but may benefit from the data when after the project it becomes possible to handle more detail.

To explore the potential of nature to improve the quality of life

Wageningen University & Research,
BU Greenhouse Horticulture
P.O. Box 20
2665 ZG Bleiswijk
Violierenweg 1
2665 MV Bleiswijk
The Netherlands
T +31 (0)317 48 56 06
www.wur.nl/glastuinbouw

Report WPR-891

The mission of Wageningen University and Research is “To explore the potential of nature to improve the quality of life”. Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 5,000 employees and 10,000 students, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.