Wageningen Economic Research | White paper

Quick scan ‘Locations for highest-potential greenhouse development in the world’

Peter Ravensbergen, Wil Hennen, Gerben Jukema, Hager Fahkry

February 2024

Forecast studies show an increasing demand for greenhouses worldwide, as governments encourage local, safe and sustainable food production. Climate change, scarcity of water and other key resources are adding to the trend towards greenhouses.

This paper shows a world map of the highest suitability for greenhouses, broken down by mid-tech and high-tech greenhouses. This is done by performing a quick scan, which means synthesis and application of existing knowledge and data. Of the countries with the highest potential, more detailed maps are shown.

This paper is commissioned by the Netherlands Enterprise Agency (*Rijksdienst voor Ondernemend Nederland* (RVO)) and funded by the European Community. Dutch Green Delta (DGD) and some of their partners contributed with their expertise and experiential knowledge.

Contents

Summary

The total area of covered crops is very difficult to indicate because there are no clear definitions and hence no uniform data. This study estimates approximately 700,000 hectares of protected horticulture worldwide, of which approximately 53,000 hectares are high-tech greenhouses. This is in line with other literature sources. China provides the greatest uncertainty in data.

Based on the analysis of area suitability, USA is the country with the highest relative score for high-tech, followed by France, Germany, UK and Ukraine. For mid-tech, the USA and France are also the countries with the highest relative score, followed by India, Libya, and Brazil.

Based on the highest market opportunities for greenhouses explored for the production and sales of tomato, the top 5 countries are Germany, the Netherlands, France, the USA, and Spain.

Based on the presence of existing greenhouses, Mexico is the country with the highest surface for high-tech, followed by the Netherlands, Turkey, Belgium and Germany. For mid-tech surfaces the top 5 countries are China, Turkey, Spain, Republic of Korea, and Egypt.

Based on the combination of the 3 analyses above, the top 10 countries with the strongest expected growth in high-tech greenhouses are: the USA, France, Spain, Germany, Poland, the Netherlands, Italy, Japan, Turkey, and China. When we differentiate these countries in 3 categories we identify:

- Emerging countries: the USA, Poland, Italy, Saudi Arabia, and the UK.
- Conversion countries from mid-tech to high-tech greenhouses: Spain, France, China, Japan, India, and South Korea.
- Countries that already have areas of high-tech greenhouses: Germany, the Netherlands, Turkey, Belgium, and Mexico.

All maps, PowerBI datafiles and PowerPoint generated by this project can be downloaded from here.

1. Introduction

Van Horen and Gommersbach (2020) estimated 600,000 hectares of protected horticulture worldwide, of which 50,000 hectares are high-tech greenhouses and a few hundred hectares Indoor/Vertical Farming (without using sunlight). Forecast studies show an increasing demand for greenhouses of several tens of thousands of high-tech greenhouses by 2030 (Ravensbergen and Schoormans, 2022). However, the development of new greenhouse projects is currently virtually at a standstill. This is due to disruptions in the market for energy and other resources, caused by the Covid-19 crisis and by the war in Ukraine.

Dutch greenhouse construction companies that are still doing reasonably well, started focusing on finding new markets abroad years ago, and have also focused on several foreign regions to spread risks. The Dutch supplying industry needs to know what the coming greenhouse locations are in the world with the highest potential for the Dutch greenhouse industry to invest in.

2. Objective, result and scope

The objective is to develop a world map with the highest suitability for greenhouse locations and a lists of top 5 countries for high-tech and mid-tech greenhouses, creating focus for business development of the technical supplying industry for Controlled Environmental Agriculture (CEA). This map is created by synthesis and application of existing knowledge and data.

The result of the project is this interactive whitepaper with a range of maps and charts and PowerPoint presentation with final results.

Not included within the scope of this quick scan are:

- An inventory of vertical farming
- Present (investment) policies of governments
- Private investment programmes
- Legal restrictions e.g. on water usage of lakes
- Restrictions on imports and exports (e.g. tomato from Morocco to EU)
- Availability of local knowledge and expertise.

3. Methodology

The quick scan methodology consists of 3 components:

1. Area potential
   Mapping the areas with the greatest potential for greenhouses based on climate, soil, infrastructure, land use. The Global-Detector GIS tool is used for this purpose.
2. Market potential
   Mapping market opportunities for greenhouses by analysing import, production and consumption of tomato and strawberry in conjunction with land aspects such as ease of doing business, corruption, quality infrastructure. The choice of tomato and strawberry was made in consultation with the experts based on the trade-off between food focus preference and available research capacity. The Market-Explorer tool is used for this purpose.
3. Current potential of greenhouses
   Mapping the current presence of greenhouses in the countries through desk research and a survey of information from the agricultural counsellors of the Netherlands Agricultural Network.

The results of these 3 components are combined to create a top 5 of countries for high-tech greenhouses, looking at the growth of the existing greenhouse area, the conversion from mid-tech to high-tech greenhouses and new emerging countries with no greenhouse history. By connecting the results of the above components, the analysis for greenhouse locations with highest potential becomes robust.

1 Global-Detector

The method of Global-Detector is a knowledge-based spatial analysis and worldwide map construction in interactive workshops with experts or stakeholders in which spatial data – 'on the fly' - are selected, transformed, weighted, and combined (Hennen et al., 2017).

Three expert meetings were held in the period from September to November 2023: one preparation meeting and two interactive workshops. In total, experts of seven horticultural supplying companies, RVO, Dutch Greenhouse Delta, and Wageningen University & Research (WUR) have participated in one or two meetings. The result is a map showing potential for mid- or high-tech investments. From these maps aggregations can be made e.g. on country level. All maps have a resolution of 5'x5' (~10x10km).

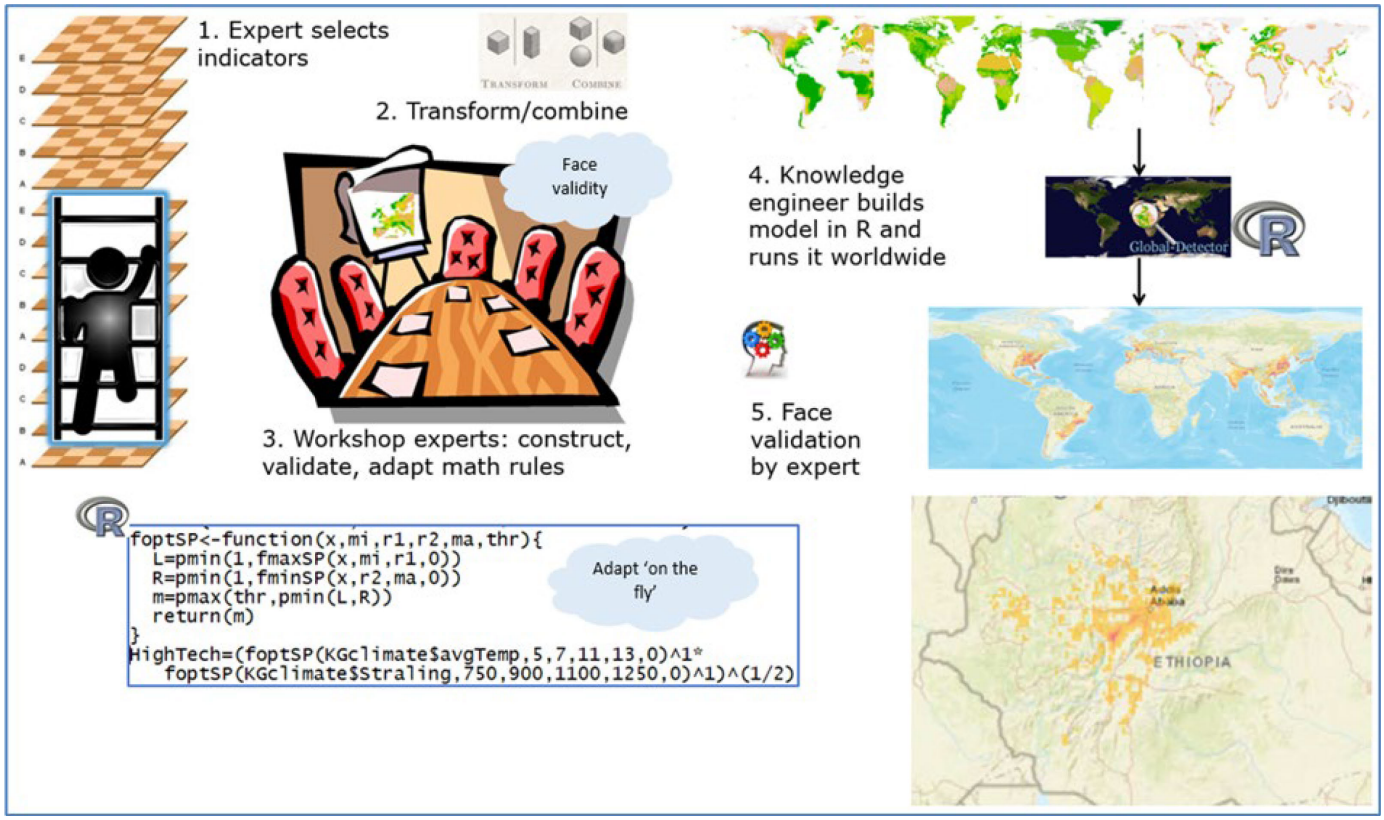

Figure 1 *The method of Global-Detector*

The method of Global-Detector is illustrated in Figure 1. For the relevant issue (in this case CEA investment potential) the knowledge engineer (developer) together with one or a small group of experts select indicators from a database of around 400 indicators available (1.). The selected indicators are transformed and combined in a preliminary model by the developer (2.), and this first version of the model is presented in a workshop with experts (3.). Indicators are shown on a map, also after transformation of indicators (e.g. optimal temperature derived from actual temperature). Experts validate the result (face validation of map) and may suggest making changes in the calculation procedure (e.g. other thresholds for optimal temperature). The developer makes changes to the programming code of the model, which experts can see, and shows the adapted map on screen. When all indicators and aspects are treated and weighted, the developer builds an updated version of the model (4.) which can be validated and processed in a successive workshop (3.) and leads to a definitive version of the model after approval by face validation of maps (5.). Results can be shown and downloaded to a .png file for the entire world, a region (of countries) or a separate country.

For the CEA project, relevant indicators are selected from the many Global-Detector indicators. Also new indicators have been created such as temperature accounting for difference night and day temperature and the risk of earthquakes. To combine indicators to scores for aspects and to final potential score, all indicators have been transformed to the range 0-1 depending on their values. For example, the value of slope for high-tech has been transformed to a value of 0 when the average of a grid cell <3% and a value of 1 when >10%. Values between 3 and 10 have intermediate values between 0 and 1 (e.g. 6.5% becomes 0.5). For some indicators transforming is different between mid and high-tech, the slope range for mid-tech is from 3% to 20%.

The aspects and indicators used are:

- Aspect climate: maximum wet ball temperature (accounting for humidity), not too hot (difference night and day), not too cold, not much snow, solar irradiation, risk cyclones and for USA only risk tornados
- Aspect Water: low precipitation 5 adjacent months, water availability (e.g. precipitation), ground water level
- Aspect Market & Infrastructure: accessibility market (distance, population, spendable income), distance to airports and distance to harbours
- Aspect Miscellaneous: risk earthquakes and electric power supply
- Aspect Restrictions: Protected areas, forests, nature, peat soil, permanent snow, rocks, water, too steep, too high, and high population density.

Within each aspect indicators are weighed to yield the aspect score, and aspects are weighed to yield the final scores. Weights for indicators and aspects may differ between mid and high-tech, for example aspect Climate is more important for mid-tech. Since not all required conditions for investment are taken in account because of non-available data (e.g. availability specialised labour), the result should be used as first step and starting point to investigate the most suitable locations in the world.

2 Market-Explorer

At country level, Market-Explorer combines country suitability for greenhouses by weighting data from different aspects and data sources. Data are mostly from World Bank, FAO, Comtrade.

The aspect 'Country' combines Gross Domestic Product (GDP), income, corruption, Ease of Doing Business (EDB), stability, logistic performance and urbanisation. The aspect 'Consumption' combines consumption amount per country and per capita, development (10 years) and price. For 'Production' the current production amount and development. Same for 'Import', but also the amount of all imported vegetables and fruits. Finally, all aspects are combined to yield a score for perspective of investment for the products tomato and strawberry. Tomato was chosen because it is the largest greenhouse-produced crop in the world and strawberry because it is one of the fast-growing products in greenhouses. Ultimately, only tomato was included in the overall analysis because of the importance of the crop.

In the scheme of Market-Explorer (see Figure 2) the requirements of indicators are mentioned, e.g. the price should be 'high' or, stated otherwise, higher prices result in higher scores for aspect consumption. Weights of indicators and of aspects are visualised by the thickness of the blue arrows in the scheme, e.g. the total consumption in a country has low weight (thin arrow) and price high weight (thick arrow). Combination of indicators requires that values be transformed to the same scale, e.g. from 0 to 1. Indicator values that are lower than 5% of sorted country values have a transformed value of 0 and higher than 95% transformed to 1. Intermediate values get transformed values in the range 0 to 1, e.g. if a country has a median value the transformed value becomes 0.5.

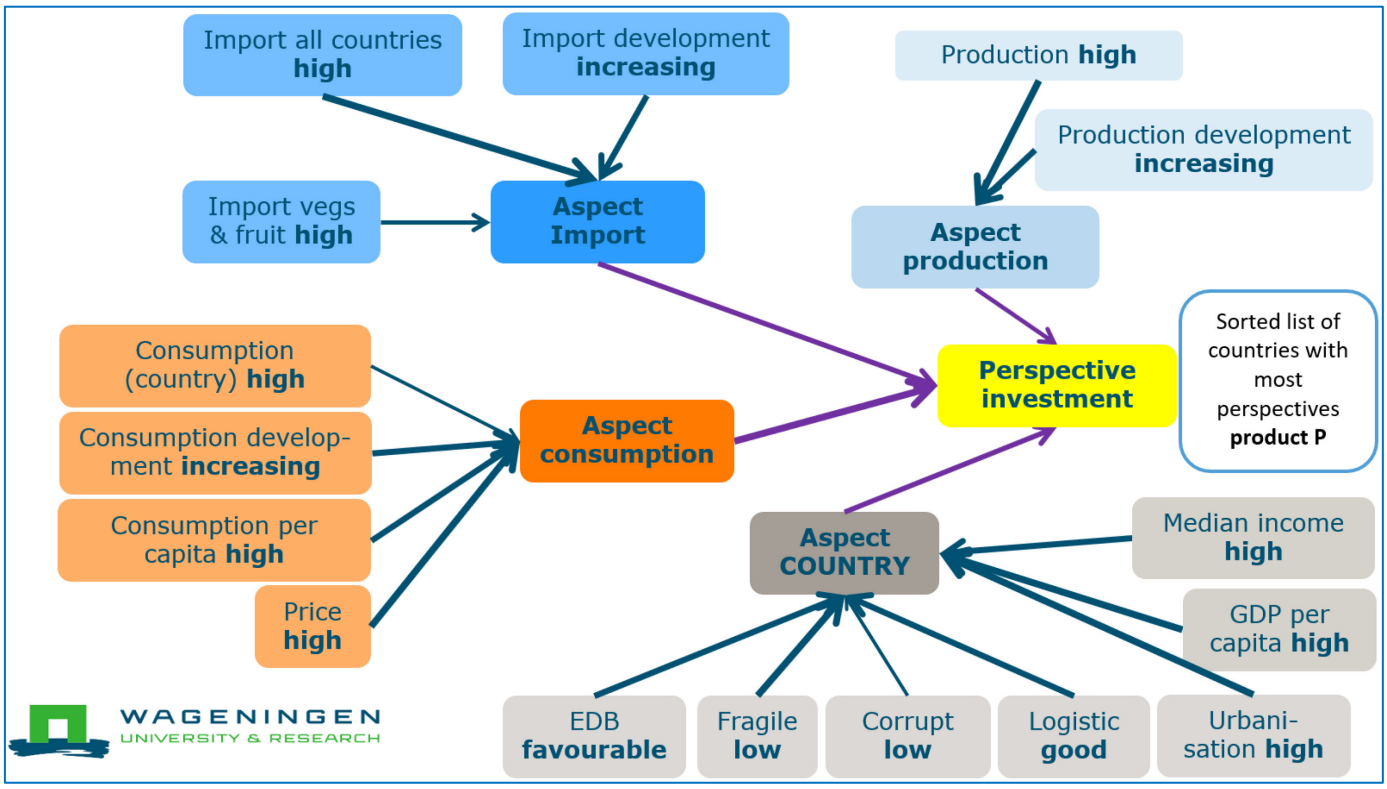

Figure 2 *Market-Explorer scheme*

3 Desk research and surveys

The desk research is aimed at finding current regions where greenhouses are already currently present. The thinking behind this is that with an existing cluster of greenhouses, potential growth can occur faster. An existing cluster of activities can attract faster and different (competing) activities than happens in a place where there are no activities yet. Marshall and Porter, among others, have developed theories on this. Much has also been written about the strength of the agribusiness cluster (Berkhout et al., 2015).

This literature review therefore focused on the following sub-questions;

- How much greenhouse area is present in which countries?
- In which regions within these countries is the area located, and what is its size?
- What different types of greenhouses can be distinguished in these countries?
- Has the area of greenhouses in these countries developed over the years?

Scope

The Global-Detector and Market-Explorer include all countries of the world. For the desk study, the choice of a predefined number of countries was made because it takes too much capacity to examine all countries in this quick scan. These included Europe as an existing and steady growth market, emerging markets such as the United States, Canada and the Middle East but also in the Asian region where countries such as Japan, South Korea, India and China are of interest for greenhouse development.

Approach

This desk study consisted of two parts. First, a literature review was carried out. The following activities were carried out for this purpose;

- The Netherlands Enterprise Agency (*Rijksdienst voor Ondernemend Nederland*, RVO) was asked to supply information.
- The Dutch Greenhouse Delta and its members were asked to provide information.
- Existing archives of Wageningen Economic Research and other staff of Wageningen University & Research were consulted.
- Previous studies on the world area of greenhouses were acquired or collected.
- In addition, an internet search was carried out. This included visits to websites of statistical offices and ministries, industry organisations and research institutes.

The other part involved creating, conducting and analysing a survey to all agricultural counsellors of the Netherlands Agricultural Network (NAN). A mail was sent out calling for them to provide us insights into CEA for their relevant regions. In this survey the following questions were asked:

- What are the areas (size in hectares and geographic locations) of Controlled Environmental Agriculture (CEA) (e.g., glass/plastic)? Do you have any information on the development of these areas (growing, declining)?
- Can you direct us to statistical information or relevant reports on CEA in your region? (Language does not matter)
- Please indicate the regions where CEA is prevalent, possibly using maps or common regional classifications.
- Can you distinguish between high-tech and mid-tech CEA facilities?
- Which aspects do you believe will have the most significant impact on the growth of mid-tech or high-tech greenhouses?

A total of 14 agricultural counsellors responded to the survey.
In an expert meeting, the results and outcomes of the literature review were briefly discussed and reviewed.

Insights obtained by data handling

The information obtained consisted of various data such as written text, website links, contacts, lists of companies, reports, press releases, scanned forms etc. etc. Collecting, reviewing and storing this data in a uniform manner proved to be very time-consuming. While analysing the data, the following insights emerged and that complicated the process;

- There is no database available containing the global area of CEA.
- Many CEA crops/areas are not the main production areas of countries and are therefore mostly not routinely included in the data collection. Therefore, some countries lack CEA data.
- In many cases, data from a consecutive series of years is not available. This is mostly because, for example, agricultural censuses are conducted irregularly.
- There is no clear global definition in the statistics of (type of) greenhouses and which different types of greenhouses exist.
- It is not possible to unequivocally determine which greenhouse type (and equipment) falls into High-, Mid- or Low-tech because data on greenhouse equipment is mostly unavailable. A plastic greenhouse may fall under high-tech due to various equipment. Whereas a glass greenhouse without any equipment falls under mid-tech.
- There is often a difference in area of crops under glass (there may be several rounds or no crops per year), glass area, and area under glass on typified farm types (part of the total). Sometimes it is not clearly indicated what has been measured.
- There is a difference in the unit (in terms of area) used for surface-area.
- Some countries focus more on the value of production/harvest than the area of greenhouses.
- Sometimes there is a language barrier in finding information, because data (e.g. in databases) are only accessible in one's own language. This complicates the research work.
- Software of databases that unlock data are different in each country. This complicates and delays the search for information. Moreover, it does not help with the correct interpretation of any figures.
- Sometimes information is given per sector (e.g. greenhouse vegetables) but no total of the greenhouses (vegetables, fruit, flowers or plants) in a country.
- In some cases, one is dependent on a local expert so that the data made available cannot be verified. In addition, areas are mentioned in sources where the original source is missing.
- In some countries, statistics may be adjusted to give a positive image of the existing situation and therefore do not reflect the actual situation.
- The data collected from different sources differ in many cases. A trade-off must then be made as to which is the most reliable source.

Despite these difficult circumstances, in addition to the quantitative data collected from many countries, many insights were gained through qualitative information, which are presented in this Quick Scan. However, the total amount of information collected and obtained from so many countries is too extensive to analyse and present in this Quick Scan. A follow-up study is recommended.

4. Definitions of High-tech and Mid-tech

As mentioned above, in literature there are no standard definitions for high-tech, mid-tech or low-tech greenhouses. Many different definitions or descriptions of greenhouses are used. Based on all the information, we created the following definition:

A high-tech greenhouse is defined as a multi-arched structure with a transparent roof and walls, with a cover made of plastic or glass, with at least 5 of the following 7 technical installations:

- a climate control unit steering at least temperature and humidity (through flexible ventilation)
- heating or cooling system
- irrigation system (A/B system)
- moving radiation screens
- growing in artificial substrates
- artificial lightning
- usage of integrated pest management.

A mid-tech greenhouse is defined as an arched multi-tunnel covered in plastic with a height ranging from 4 to 4.5 metres, with fewer than 5 of the 7 technical installations mentioned above.

5. Results Global-Detector

For the world, for some regions and countries maps are made for mid-tech and high-tech greenhouse location suitability. The creation of the maps is done by Global-Detector, using programming environment R.

The final result for location suitability for high-tech greenhouses can be found in Figure 3. More details can be found in separate maps. Maps were produced for 4 regions, namely the world, North-West Europe, Gulf States, Northern Africa each for mid-tech and high-tech greenhouses and for the following 18 countries (grouped in continents):

- Europe: the Netherlands, Belgium, Germany, France, the UK, Spain, Poland, Turkey, and Ukraine
- Asia: Australia, China, India, Japan, South Korea, and Kazakhstan
- North America: Canada, Mexico, and the USA

As an example, Figure 4 shows the scores for the aspects mapped on USA (high-tech); each aspect is a weighted combination of indicators (see chapter 'Methodology'). Aspects are combined to the final potential map (middle). In the USA suitability (high-tech) is predominantly expected in the Eastern half of the country and the Central Valley in California. This region coincides with the current intensive agricultural production.

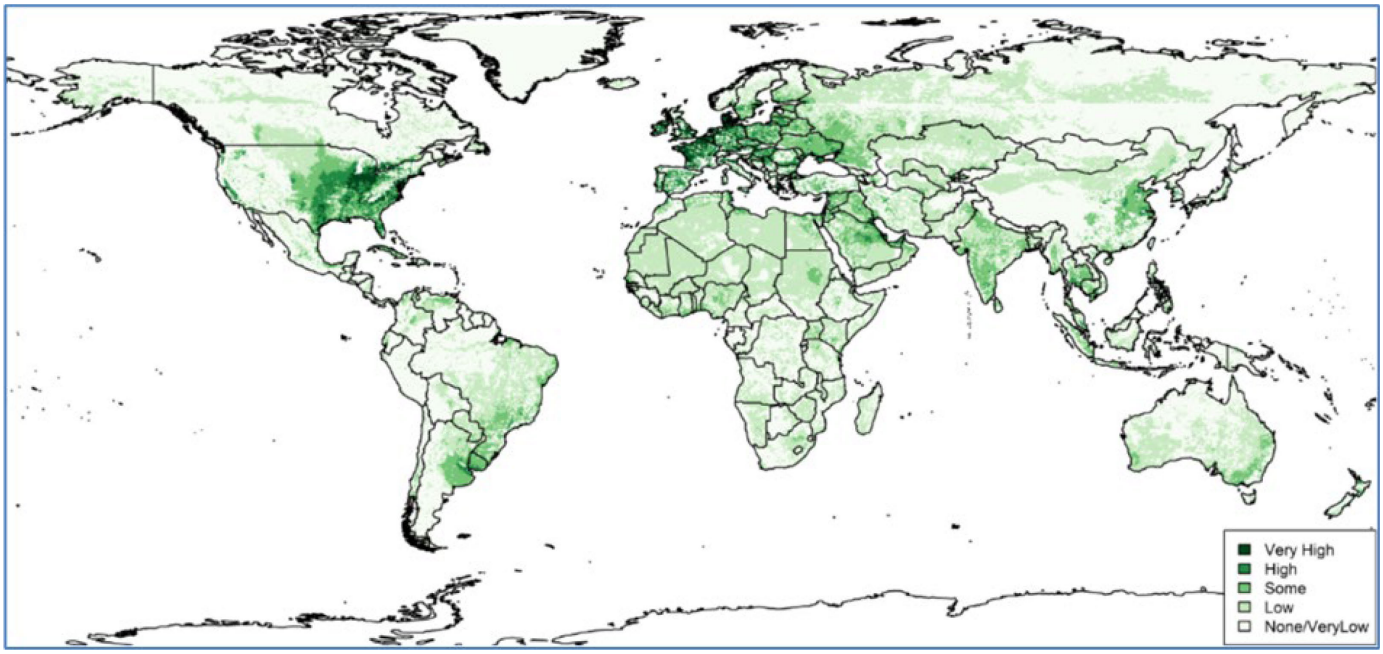

Figure 3 *Final result location suitability for high-tech Greenhouses (Global-Detector)*

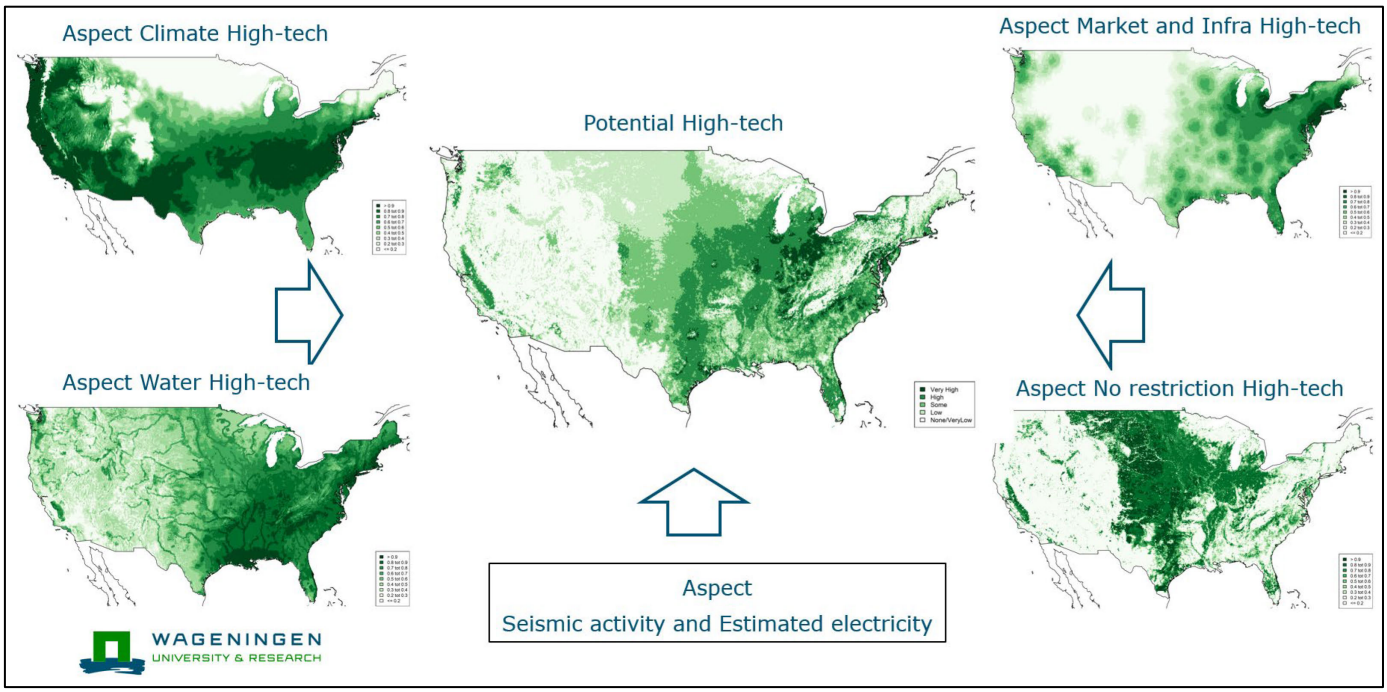

Figure 4 *Scores of aspects and final potential score high-tech for USA (Global-Detector)*

Tables 1 and 2 show the rank of the top 20 countries for both relative (corrected for country size) and absolute (based on estimated suitable area) measures and for mid-tech (left table) and high-tech (right table). The third column is a combination of relative and absolute. The countries in red colour appear in both top 20 lists of each table, e.g. Ukraine, Argentina, and India. Not shown are all other countries below the top 20, many of them have poor suitability. Despite the high potential in far southern Ontario, Canada is not in the top 20 because its absolute and especially relative (due to the size of the country) country-level scores are low.

Mid-Tech

France is the country with the highest relative score for mid-tech, while the USA has highest absolute score (and rang) for mid-tech, predominantly due to the large size of the country. If we look at the combined score (third column), the USA, France and India are the top 3. We see also the South European countries such as Spain and Italy. Interesting in the top 20 is Saudi Arabia as well many African countries such as Libya, Sudan, Egypt, Mali, Niger, Chad, and Nigeria.

High-tech

Interesting is that France is also the country with the highest relative score for high-tech, while the USA also has highest absolute score (and rang) for high-tech, predominantly due to the large size of the country.

In the combined score we see many European countries in the top 20. Also here Saudi Arabia in the top 20 is remarkable. India and China are also in the top 20, partly due to the size of these countries. Denmark and some states in the Gulf have higher comparable relative potential for high-tech than mid-tech. In Uruguay, for example, mid-tech is more suitable.

Table 1 and Table 2 *Mid-tech classification and high-tech classification of countries as outcome of the Global-Detector: relative, absolute and combined*

Mid-tech Classification

Country (relative)	Country (absolute)	
France	USA	**USA**
Germany	Brazil	**France**
UK	Australia	**India**
Uruguay	India	**Libya**
Ireland	Sudan	**Brazil**
Spain	China	**Germany**
Netherlands	Libya	**Spain**
Italy	Saudi Arabia	**Argentina**
Belgium	Argentina	**Sudan**
USA	Algeria	**Saudi Arabia**
Denmark	France	**UK**
Ukraine	Mali	**Ukraine**
Hungary	Chad	**Uruguay**
Libya	Egypt	**Italy**
Poland	Niger	**Egypt**
Syria	Nigeria	**Mali**
India	Indonesia	**Niger**
Czech Rep.	Iran	**Chad**
Argentina	Spain	**Australia**
Brazil	Ukraine	**Nigeria**

High-tech Classification

Country	Country	
France	USA	**USA**
Germany	Brazil	**France**
Denmark	China	**Germany**
USA	India	**UK**
UK	Saudi Arabia	**Ukraine**
Netherlands	Australia	**Saudi Arabia**
Belgium	France	**Spain**
Ireland	Russia	**India**
Poland	Sudan	**Poland**
Italy	Argentina	**Italy**
Ukraine	Ukraine	**China**
Hungary	Germany	**Uruguay**
Spain	Libya	**Argentina**
Uruguay	Spain	**Denmark**
Lithuania	Egypt	**Thailand**
Czech Rep.	Mali	**Romania**
Kuwait	UK	**Brazil**
UAE	Nigeria	**Ireland**
Romania	Iran	**Hongaria**
Saudi Arabia	Poland	**Netherlands**

6. Results Market-Explorer

For all countries in the world the calculations have been performed by Market-Explorer. This is done for both tomatoes and strawberries, and for each product the final results are scored. Those products were selected based on companies' preferences.

The final scores of all countries are categorised in 7 groups with the same number of countries in each group. The maps below (see Figure 5 and Figure 6) from PowerBI show the results for tomatoes expressed in colour and size, ranging from small red circles (very low score) to large green circles (very high score).

Scores for indicators, aspects and final are stored in tables from which the PowerBI maps can be created. Complete PowerBI datafiles can be downloaded here.

The top 20 countries with the highest score are:

- *Tomato*
  - **Germany**, **the Netherlands**, **France**, **the USA**, **Spain**, **Italy**, **Japan**, the UAE, **the UK**, **Belgium**, Israel, Poland, Russia, Portugal, Bulgaria, Oman, **Switzerland**, **Sweden**, **Canada**, **Finland**
- *Strawberry*
  - **the UK**, **the Netherlands**, **Belgium**, **the USA**, **Canada**, **Spain**, **Germany**, **France**, **Japan**, Belarus, Norway, **Switzerland**, Mexico, Denmark, **Sweden**, **Finland**, **Italy**, Ireland, Australia, Czech Republic

Countries in both top 20 lists are in bold.

We see that many European countries have the highest market opportunities for greenhouses based on the market analysis of tomato and strawberry. In addition, the USA, Japan, and Canada have high market opportunities. For tomato, the UAE and Oman are eye-catching and for strawberry Mexico and Australia.

Since it is not easy to find an explanation why a country has a certain calculated outcome, texts for each country are constructed by Market-Explorer (in Dutch language) that can be downloaded here. Figure 7 is such a text for Mexico (tomatoes), showing aspects, indicators or final that are (very) favourable in green and (very) unfavourable in red colour. If the score has an intermediate value (0.4 to 0.6) the qualification is skipped.

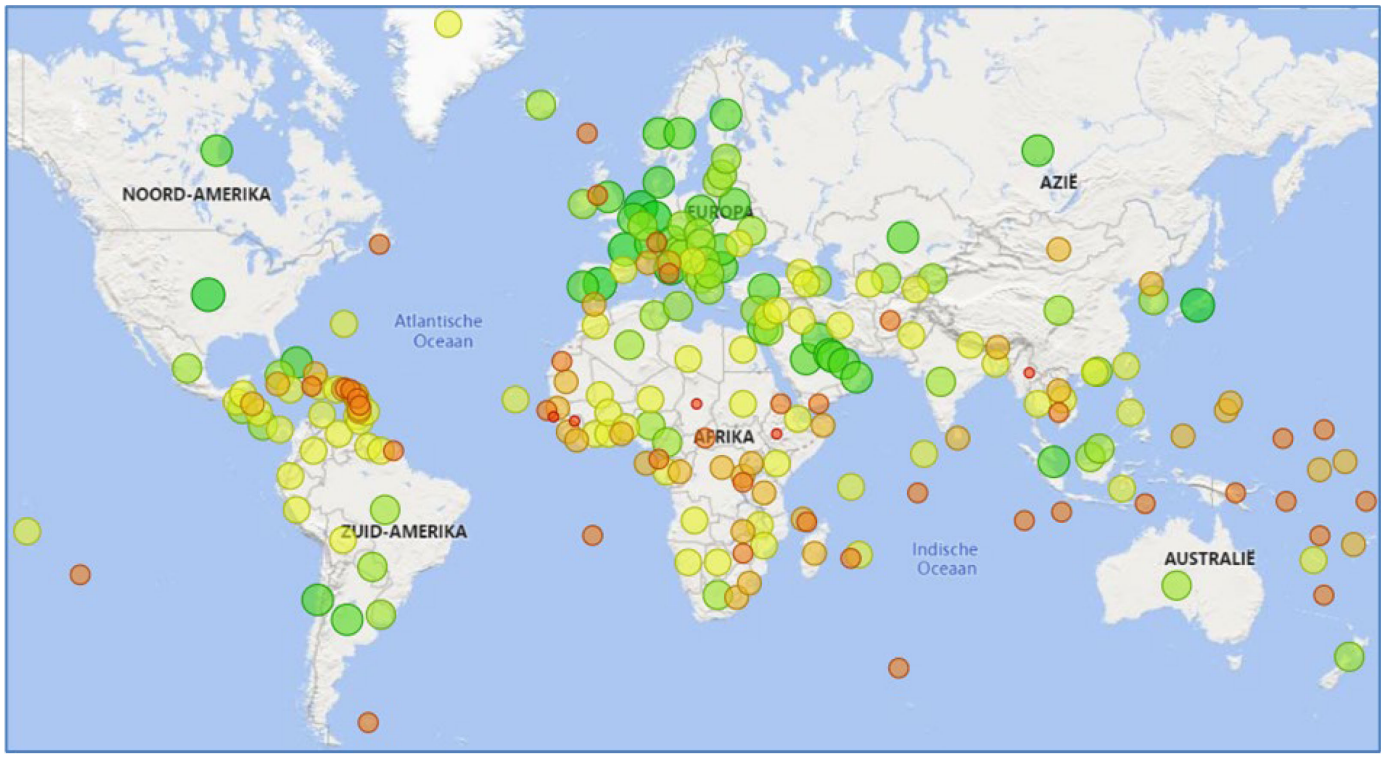

Figure 5 *Results Market-Explorer for tomatoes for the world (see text for explanation)*

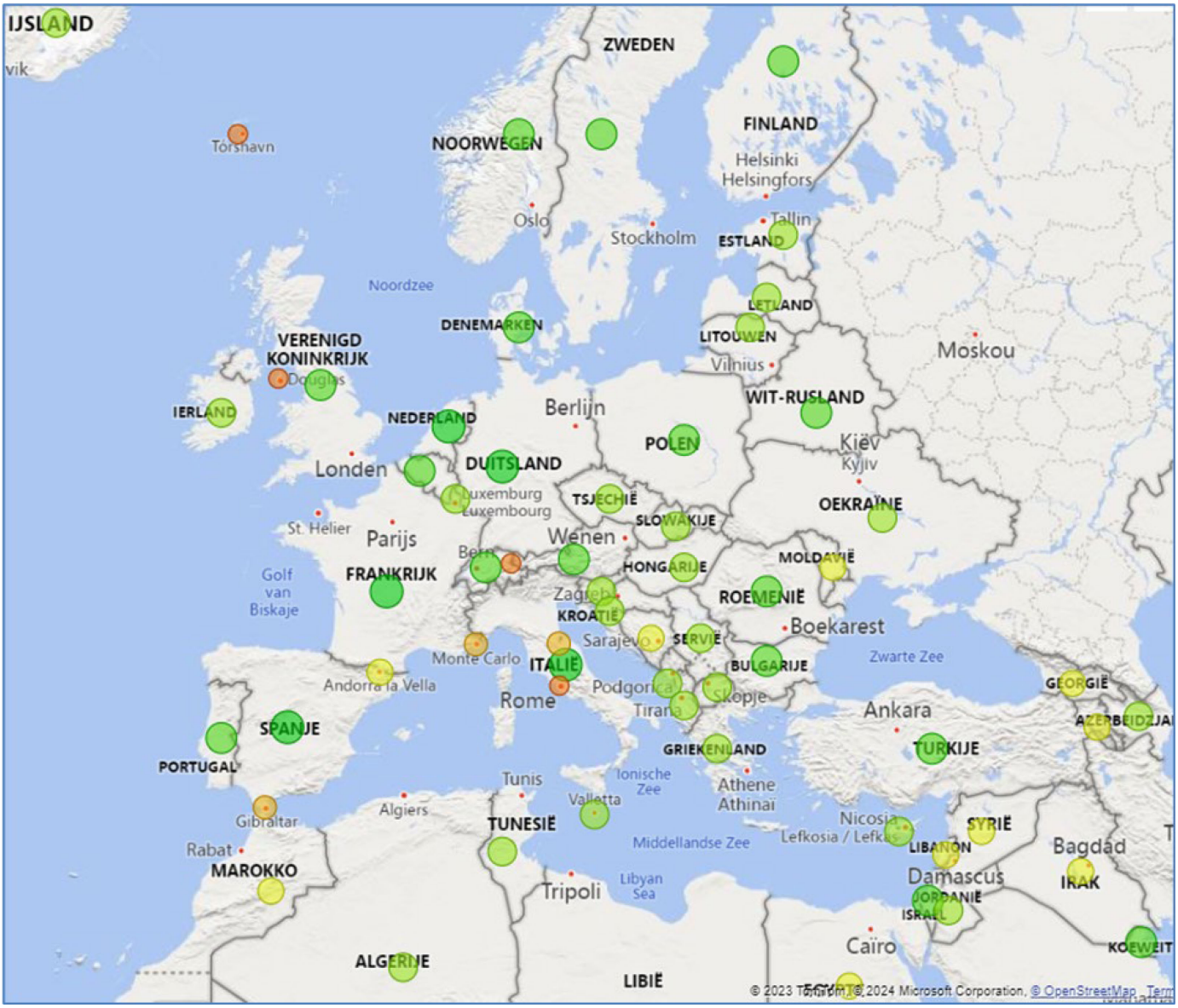

Figure 6 *Results Market-Explorer for tomatoes in Europe (see text for explanation)*

Potentieel voor **Mexico** is **redelijk gunstig**. Het aspect COUNTRY is hiervoor redelijk gunstig, waarbij de indicatoren Ease Doning Business redelijk gunstig, Stabiliteit redelijk gunstig, Logistiek gunstig, Urbanisatie gunstig, Inkomen redelijk gunstig. Het aspect CONSUMPTIE is hiervoor redelijk gunstig, waarbij de indicatoren Consumption **zeer gunstig**, Consumptie PP gunstig, Prijs redelijk ongunstig. Het aspect PRODUKTIE is hiervoor **zeer gunstig**, waarbij de indicatoren Productie **zeer gunstig**, Productie ontwikkeling gunstig. Het aspect IMPORT is hiervoor redelijk ongunstig, waarbij de indicatoren Import produkt ongunstig, Import ontwikkeling ongunstig, Import Fruit&Vegs gunstig.

Figure 7 *Market-Explorer qualification of scores for indicators, aspect and final for Mexico (tomatoes)*

7. Results current potential

Table 3 presents the data from the desk study of the 20 countries with the highest amount of hectares of greenhouses, divided into high-tech and mid-tech greenhouses. The acreages are continually improved, as soon as new information becomes available. These figures will be used for further calculations.

Very striking is the huge area of covered crops in China, because this is so large. It is even more than the sum of all areas of all other countries. In the data found, it is unclear which greenhouse types are involved. Experts also speak of a much lower acreage of 1,000 hectares of high-tech greenhouses in China (Agroberichten Buitenland, 2023).

Next, Turkey and Spain have many greenhouses that are mainly mid-tech. Actually, the same applies to Mexico, where the proportion of high-tech in plastic multi-span greenhouses seems to be significant.

Japan and South Korea also score high and consist mainly of mid-tech greenhouses.
The Netherlands, Belgium, and Germany score relatively high with an acreage of high-tech greenhouses.

The main focus of the desk study and survey was on the countries that had been determined to be in interesting regions and for which sufficient information was available.

Ultimately, given the preconditions, around 20 countries were focused on. Clearly, collecting data from all countries in the world takes a lot of time and is actually a continuous process. When recording the data, the most recent year of data for a given country was used as the starting point. For each country, the total area of greenhouses was determined and indicated (or estimated) the area of high-tech and other greenhouse species. In addition, a regional breakdown of the area of greenhouses in those countries was made for about 18 countries. To combine the information obtained with the data from the Global Detector, a list of regions was used that was also usable in these maps.

The list of countries with combined maps of current regions with CEA and greenhouse suitability potential (Global detector) is as follows, and maps can be downloaded here:

- Europe: the Netherlands, Belgium, Germany, France, Spain, the UK, Italy, Poland, Turkey
- Asia: Australia, China, India, Japan, South Korea, Saudi Arabia
- North America: the USA, Canada, Mexico

Figure 8 and Figure 9 (see below) of the USA and Mexico are examples of the combined maps of current regions with CEA and suitability potential for greenhouses (Global detector).

Table 3 *Current amount of hectares of Controlled Environmental Agriculture (CEA)*

Total CEA (ha)		Total high-tech (ha)		Total mid-tech (ha)	
China	1.894.215	China	??	China	??
Turkey	81.088	Mexico	15.214	Turkey	75.125
Spain	73.115	The Netherlands	10.540	Spain	71.126
Republic of Korea	56.467	Turkey	5.963	Republic of Korea	56.100
Mexico	51.853	Belgium	2.726	Egypt	50.000
Egypt	51.350	Germany	2.262	Japan	40.569
Japan	42.164	Spain	1.989	Mexico	36.639
Morocco	23.770	Japan	1.595	Morocco	??
Algeria	21.025	Poland	1.573	Algeria	21.025
India	14.366	Uzbekistan	1.500	India	14.009
The Netherlands	10.640	Canada	1.426	Ukraine	9.989
Ukraine	10.325	Egypt	1.350	Greece	8.264
France	9.834	Australia	1.153	USA	7.212
United States	9.201	USA	1.008	France	??
Greece	8.404	Azerbaijan	500	Tunisia	7.490
Tunisia	7.740	Republic of Korea	367	Ecuador	??
Ecuador	6.783	India	357	Argentina	??
Argentina	6.517	Ukraine	335	Colombia	??
Germany	5.883	Romania	316	Poland	4.001
Poland	5.574	Tunisia	250	Germany	3.621

??* We do not know exactly what this number is, but it is estimated to be in this order of magnitude

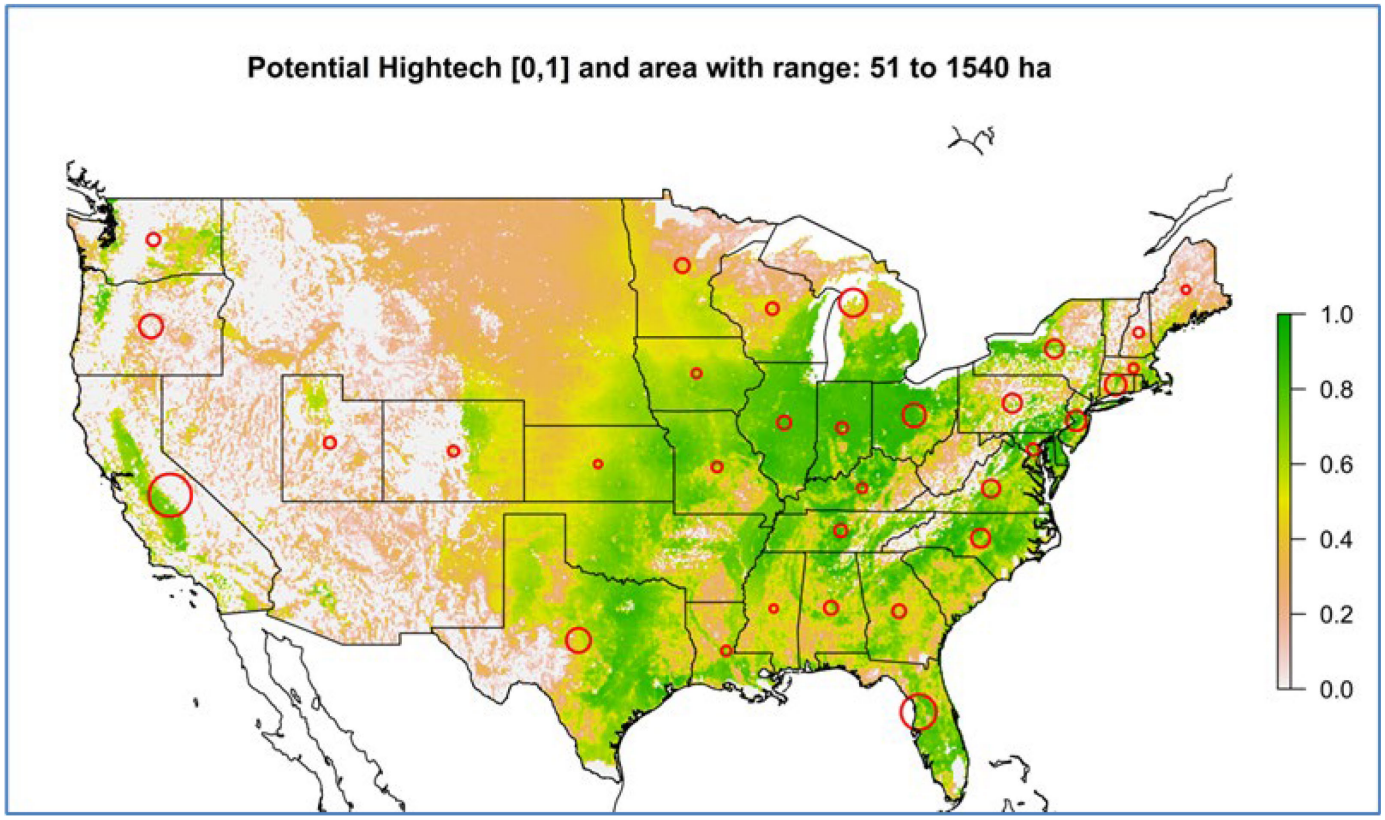

Figure 8 *Potential for high-tech (Global-Detector) and current areas in states of USA*

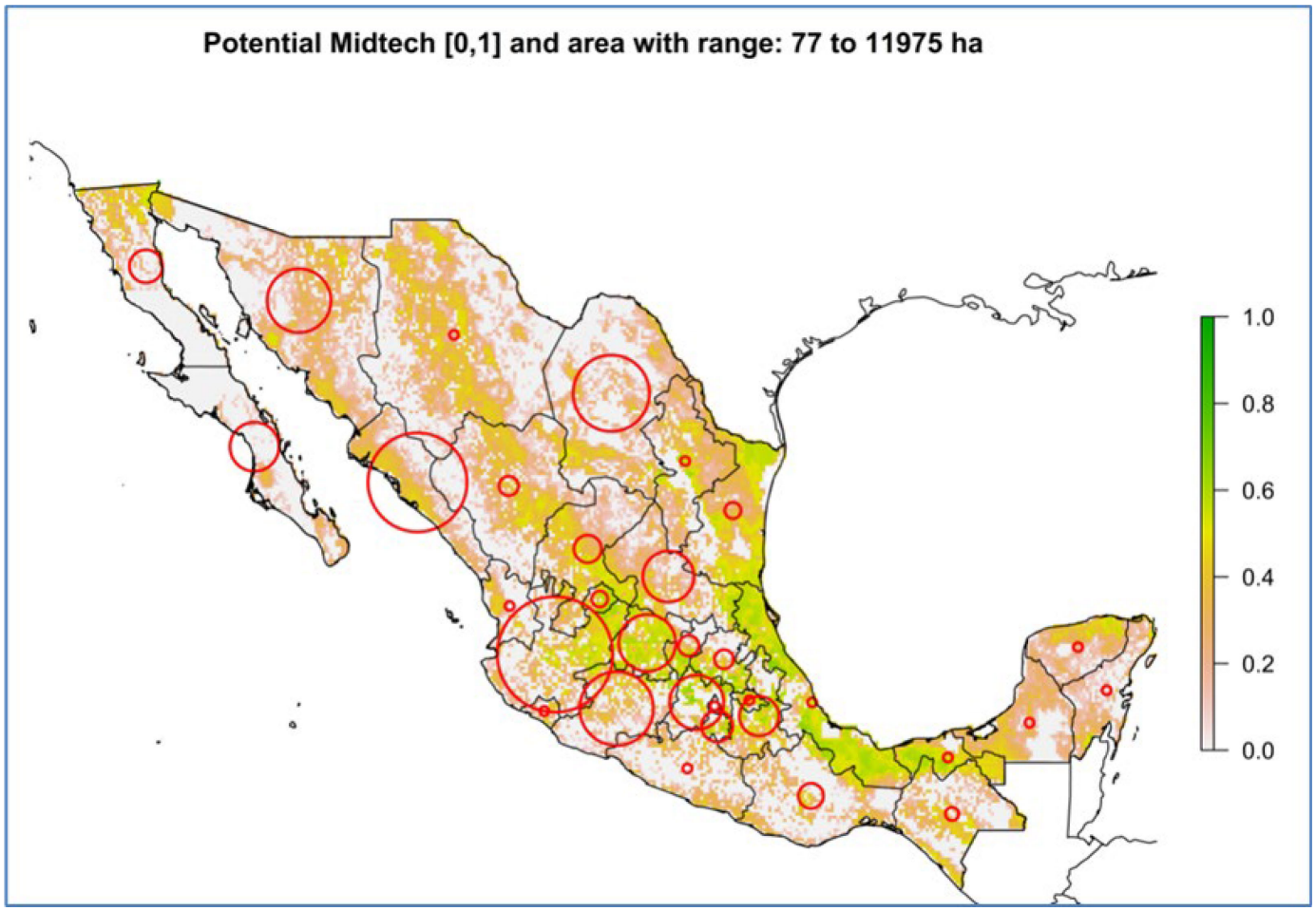

Figure 9 *Potential for mid-tech (Global-Detector) and current areas in states of Mexico*

In Figure 8 the areas for states in the USA which have currently more than 50 hectares are expressed by red circles. The size ranges from small (51 hectares) to large (1,540 hectares). The range is shown in the header of the map as well as the technology (high-tech). The scores for high-tech potential by Global-Detector are represented by colours ranging from white (0) to dark green (1).

In Mexico the potential for mid-tech is generally higher than for high-tech. The map in Figure 9 below shows the mid-tech potential from Global-Detector combined with the current production in the states ranging from 77 to 11,975 hectares. On the map a pixel (5'x5' grid cell) is about 10,000 hectares so even states with a very large current production area have only a very small fraction of land used for greenhouse production.

8. Total combined analysis

The three different approaches eventually merged through rankings. The Global detector looked at which countries had the most places in absolute and relative terms where CEA was best suitable. This was done for both high- and mid-tech greenhouses. A calculated factor determined the ranking of the countries. For the Market-Explorer, it was chosen to use the calculations done for tomatoes. This is an important crop worldwide and therefore data are also available for most countries. Again, a factor was calculated first and then countries were ranked. The countries for which data were found from the literature review were also ranked by total area of greenhouses. These scores were then averaged. The distinction between high- and mid-tech was made by the differences that emerged from the Global Detector calculations.

Table 4 *Results from the analysis of the three approaches (MT = mid-tech, HT = high-tech)*

Total End score	Total End score MT	Total end score HT
Spain	Spain	USA
USA	France	France
France	USA	Spain
Germany	Germany	Germany
Italy	Italy	Poland
Turkey	Turkey	Netherlands
Netherlands	Poland	Italy
Poland	Netherlands	Japan
Japan	Argentina	Turkey
China	Ukraine	China

We can see that 8 out of 10 countries score both high on mid-tech and high-tech, although the order is different. We also see many European countries both at mid-tech and high-tech.

For mid-tech, Spain, France and USA score highest. For high-tech, it is the same countries but in a different order, namely USA, France and Spain.

Notable in high-tech are the countries Japan and China in the top 10. Remarkable is that Canada is not listed in the end score.

9. Final Result

Based on the results of the different approaches and with expert knowledge we differentiate the countries in 3 categories (see Table 5):

- Countries with highest potential for high-tech greenhouses that have already high-tech CEA (expanding markets):
  Here we see Germany, the Netherlands, China, Turkey, and Belgium.
- Countries with highest potential for conversion of mid-tech to high-tech greenhouses (conversion markets):
  Here we see Spain, France, China, Japan, and South Korea.
- Countries with highest potential that have hardly any high-tech greenhouses (emerging markets):
  Here we see the USA, Poland, Italy, Saudi Arabia, and the UK. Ukraine is still listed, but because of the war, Ukraine may be removed from this list, because the datasets used are data from before the beginning of the war in 2022.

Table 5 *Top 5 countries with highest potential for high-tech CEA, differentiated in 3 categories*

Countries with high-tech CEA	Conversion mid-tech to high-tech countries	Emerging high-tech countries
Germany (MT)	**Spain** (MT)	**USA** (MT)
Netherlands	**France** (MT)	**Poland**
Turkey (MT)	China*	Italy (MT)
China*	Japan	Ukraine
Belgium	India	Saudi Arabia
Mexico	South Korea	UK

Bold: highest score for high-tech potential

(MT): highest score for mid-tech potential

*China has an extraordinarily large area of high-tech as well as mid-tech

10. Conclusions

The total area of covered crops is very difficult to indicate because there are no clear definitions and hence no uniform data. We estimate that there are approximately 700,000 hectares of covered cultivation in the world (excluding China). We estimate that about approximately 53,000 hectares of this are high-tech (excluding China). This is in line with other literature sources. China provides the greatest uncertainty in data.

The area under covered cultivation is expected to grow. We did not perform growth analyses in this quick scan, but developments on enhanced food security and climate adaptation, seem to confirm this trend.

Based on the analysis of area suitability, market perspective and presence of existing greenhouses, the countries with the strongest expected growth in high-tech greenhouses are: the USA, France, Spain, Germany, Poland, the Netherlands, Italy, Japan, Turkey, and China. When we differentiate these countries in 3 categories we identify:

- Emerging countries: USA, Poland, Italy, Saudi Arabia and, the UK.
- Conversion countries from mid-tech to high-tech greenhouse: Spain, France, China, Japan, India, South Korea.
- Countries that have already high-tech greenhouse: Germany, the Netherlands, Turkey, Belgium, and Mexico.

11. Reading list

Agroberichten Buitenland, 2023. Challenges of operating high-tech greenhouses in China (part 2) 28-06-2023

Petra Berkhout, Marcel van Asseldonk, Jan Benninga, Lan Gé, Robert Hoste, Bert Smit, 2015. De kracht van het agrocluster. Het belang van de primaire landbouw voor het totale agrocomplex. Wageningen, LEI Wageningen UR (University & Research Centre), LEI Report 2015-032. 56 blz.; 7 fig.; 13 tab.; 51 ref.

Hennen, W., Daane, A. Duijvendijk, K. van, 2017. Global-Detector; GIS- and Knowledge-based tool for a global detection of the potential for production, supply and demand. In L. Ragia, J. G. Rocha and R. Laurini (Eds.), Proceedings of the 3rd International Conference on Geographical Information Systems Theory, Applications and Management; Porto, Portugal, 27-28 April 2017

Horen, L. van, Gommersbach, R., 2020. Een goed klimaat voor Tuinbouwtechniek. Rabobank. https://research.rabobank.com/far/en/documents/847630_2872522_rabobank_een-goed-klimaat-voor-tuinbouwtechniek_vanhoren_dec2020.pdf

Ravensbergen, P. Schoormans, M., 2022. Horticulture Tomorrow: Hoe kan de concurrentiepositie en innovatiekracht van het internationale Controlled Environment Agriculture-cluster en haar in Nederland gevestigde leden behouden worden? Wageningen University & Research. Dutch version: https://edepot.wur.nl/578315, English version: https://edepot.wur.nl/578314

Photo front page credits: Shutterstock

Contact & informatie

2024-030

Peter Ravensbergen
T +31 (0)6 2246 1324
E Peter.ravensbergen@wur.nl
www.wur.eu/economic-research