European Training Foundation

THE FUTURE OF SKILLS

A case study of the agri-tech sector in Israel

THE EU AGENCY SUPPORTING COUNTRIES TO DEVELOP THROUGH LEARNING

PREFACE

In November 2018 the European Training Foundation (ETF) launched an international reflection to investigate how global trends impact developing and transition economies and to discuss what actions need to be taken to prepare people for a changing world and manage their transitions towards uncertain futures. The ETF conference Skills for the Future: Managing Transition concluded that monitoring and understanding evolving skills demand driven by new technologies and other drivers is indispensable for action. Gathering and assessing reliable intelligence on the evolving skills demand through traditional methods of data collection and analysis and exploration of innovative approaches, in particular using big data, are essential to anticipate and respond to existing and upcoming changes and to adapt education and training.

This study on the future of skills in the agri-tech sector in Israel was launched following the above discussion. The study aims to investigate how various drivers of change – principally technological ones – impact occupations and related skills in the sector and how education and training adapt to these changing needs. The choice of the sector was based on several considerations. First, agriculture is a very important sector for many ETF partner countries in terms of volume of employment. While being a traditional sector, it is also a sector that is changing rapidly, with huge potential to improve the quality of jobs that it creates. Second, agri-tech – defined as the application of technology to improve all elements of the farming and growing process in agriculture, horticulture and aquaculture – has important implications for countries, not only from an economic perspective but also from an environmental and food security perspective. Third, through the years, Israel has developed important experience in agri-tech, especially in the application of technological solutions to agriculture. Worldwide, it is a pioneer in the field and has developed experiences that can be inspirational for other contexts.

The study concentrates on changing skills needs and documents changes in occupations and related skills driven by technological innovation primarily. It does not assess the volume of employment and skills demand, but instead provides qualitative information on occupations and the types of skills required to perform those occupations. The study also provides some information about how companies find (or not) the skills they need and how they reskill their employees to meet the new needs. However, it does not intend to be exhaustive or provide in-depth information for all occupations in the sector, nor does it assess the supply of skills in the sector. The analysis does show the top professional and associate professional occupations most likely to be affected by technological change. A similar analysis can be repeated for business-related roles or for operators and tradespeople. Its aim is to raise awareness about the changing skills demand, identify pointers of change and stimulate a discussion among policy-makers and practitioners in the field so that the findings can be further exploited and used to adapt education and training provision.

The study is part of a series of studies that the ETF is implementing in its partner countries focusing on economic sectors that present niches of innovation and potential for further development. It is based on a new methodological approach which combines traditional research methods (desk research, data analysis and interviews) with the use of big data mining techniques. The use of big data analysis is relatively new and experimental, but its application is increasing in research related to the labour market. Despite its limitations, it provides new insights as well as real-time information on recent trends.

The limitations of each research tool are compensated by using a mixed methodology, where the results from each one are compared and verified from different angles. The result is a consistent set of findings corroborated by different research tools on the emerging trends and technologies in the sector, changing skills needs, new jobs and obsolescent ones, and existing skilling and reskilling practices in companies.

Fondazione Giacomo Brodolini and Erre Quadro have been working with the ETF to conduct this case study. A group of international and national researchers were brought together for this project in addition to the ETF's team of experts. The study was carried out between November 2019 and March 2020. This report was drafted by Riccardo Apreda, Liga Baltina, Terence Hogarth, Pietro Manfredi and Diego Teloni, with the local knowledge and support from Guy Cooper. The draft was extensively commented on by the ETF team – Ummuhan Bardak, Francesca Rosso, Mariavittoria Garlappi and Anastasia Fetsi –, and peer reviewed by Olga Oleynikova and Jason Laker (Editorial Board) as well as the ETF's Arjen Deij, Eva Jansova and Anatolii Garmash.

The study in Israel is a pilot which provided the opportunity to test the ETF methodology: lessons learned from Israel will be applied to the studies to be conducted in other countries. Being the first pilot study of its kind, the report documents all steps of the research and presents the findings in a detailed manner. This is because the ETF wants to raise awareness of all stakeholders in the partner countries, be it researchers, practitioners or policy-makers, about the changing skills needs in the sectors covered by the research. The findings not only raise awareness but also provide food for thought especially in relation to the ability of education and training systems to face the changing skills demand and to prepare workers for the new jobs and occupations. Shorter and more targeted publications (e.g. policy briefs, infographics and a methodological note) will follow at a later stage after all case studies are completed.

Last but not least, the ETF would like to thank all the institutions, individuals and companies (see list in annex) in Israel for sharing information and opinions on the topic, and actively participating in the ETF's workshops organised in Israel in November 2019 as well as the online seminar on the preliminary results held in March 2020. This report would not have been possible without their contributions.

CONTENTS

EXECUTIVE SUMMARY

This report focuses on the agri-tech sector in Israel and presents the results of the sectoral analysis as the first pilot study. Agri-tech is defined as the application of technology to improve all elements of the farming and growing process in agriculture, horticulture and aquaculture. It can be used, for instance, to grow more food from less space or using less water. It may include the use of robots to replace manual labour for planting or picking crops, and the use of big data, machine learning and artificial intelligence to understand more about the soil or growing conditions to solve the challenges that the agriculture sector faces. In fact, by using digital techniques to monitor and optimise agricultural production processes, more modern farming management is increasingly being developed in agriculture, sometimes called precision agriculture.

Compared with other countries in the world, the agriculture sector in Israel reveals relatively high levels of productivity resulting from the application of advanced technological solutions – combined with well-developed management skills – supported by public investment. Recent years, for instance, have seen substantial investments in farm management support, Internet of Things sensors for crop monitoring and pest detection, and water efficiency technologies. Investments in the sector have been able to build on the technologies in which Israel is seen as a global leader. These include in-soil and in-tree sensors, cutting-edge swarming robot drones, plant genetics platforms, and smart irrigation to name just a few. It is the use of these technologies and the interlinkages to other parts of the ecosystem that constitute the agri-tech sector. Given climate change, especially its impact on water supply, the agri-tech sector is critically important not only from an economic perspective but also from an environmental perspective and a food security one too.

Application of the technologies mentioned above is dependent on the skills being available to optimise their use. Identifying the overall level of employment or skills needs in the agri-tech sector proves difficult because the sector is not readily categorised according to classifications of industrial activity. A proxy measure of employment based on summing employment in agriculture and food manufacturing together with a proportionate share of employment in research and development (R&D) indicates that it accounts for as much as 3% of all employment in Israel (in 2019). The same data shows that the share of employment in the sector related to those occupations which one might associate with the increased use of advanced technologies has been increasing. Professional and associate professional occupations are estimated to have accounted for 12% of employment in agri-tech in 2013 but increased to 17% in 2019. This data, at best, provides a rough estimate of employment and skills demand in the sector. To obtain a better insight into skills needs requires data other than official statistics to be collated and analysed. This is where big data analysis is able to fill the gaps in the evidence base, complemented by hands-on experience and testimonies of companies and professionals in the sector.

The background analysis, based on a review of the literature and analysis of official statistics, provides an overview of employment, innovation and skills developments in the agri-tech sector in Israel, for example its magnitude and changes in terms of occupations and qualifications of the workforce over the recent past. But agri-tech is a sector which is not identified in statistical classifications (yet) and, because the pace of technological change is relatively fast, up-to-the-minute data is not always readily available. Therefore, the use of big data analysis and text mining aimed to address these shortcomings as a complementary research tool to other conventional methods of research. The result was the use of a mixed methods approach, combining desk research, data analysis and interviews with data mining techniques and interviews with stakeholders and companies. While the text mining spotted the clusters of early-stage technological developments which are of sufficient magnitude to shape product market strategies and skills needs over the medium term, the interviews with innovative companies and key stakeholders provided a means of corroborating the findings from the data mining and revealed other factors which are likely to facilitate or inhibit future developments.

Drivers of change and emerging technologies

To determine a list of technologies requires an analysis of the drivers of change. This helps focus on the technologies which are most likely to affect production processes and, ultimately, the demand for skills. Big data analysis, combined with insights from desk research, identified the following drivers of change in Israel's agri-tech sector.

- Israel has a favourable innovation ecosystem which facilitates investments in new technologies, creates a wide body of shared knowledge, and provides the means by which innovations in information and communications technology (ICT) can be transferred to agri-tech.
- Private investment and government backing have supported technological developments in agriculture over the recent past, but this is now declining.
- Market factors create an impetus to improve productivity in agriculture and food production. The sector has also seen merger and acquisition activity, with some food companies buying into agriculture and agri-tech.
- International regulations affect the market for crops such as those relating to genetically modified organisms and the use of pesticides on food crops.
- Consumer choices and the increasing preference for healthier and sustainable food creates new business opportunities.
- Although one of the most water-scarce countries in the world, Israel has achieved water security through a number of key innovations in water management. It has also led to the development of new plant varieties which are able to thrive in a relatively arid environment.
- Adjusting to climate change and its propensity to increase seasonal temperature variability and storm frequency has seen more focus on cultivation systems management.
- Waste management and recycling waste from agriculture and other sectors has created new businesses and new jobs.
- The risk of contamination of soil and food from toxic substances seeping into soil has created a demand for alternatives to toxic pesticides.
- Possible spread of new plant diseases, which may even compromise entire crops, has led to investments in finding disease-resistant varieties of plants and more intensive monitoring of potential disease propagation.

The various drivers have implications for the types of technology used in the agri-tech sector. The text mining analysis showed the following list as the most commonly mentioned ones. In particular, the analysis of patents suggests that computer vision and energy harvesting systems are two technologies that have seen a relatively large number of patents filed, indicating that these are likely to be increasingly used in the future. But the list below also indicates multiple technologies that can address agri-tech issues in Israel, not just those related to digitalisation, while more conventional technologies (e.g. tractors and irrigation systems) keep their continued importance in the sector alongside the new ones:

- irrigation systems (e.g. drip irrigation) and devices (e.g. sprinklers, drippers and valves);
- water treatment technologies;

- image analysis, computer vision (e.g. image acquisition and processing, object recognition);
- image capturing devices (e.g. cameras and interferometers);
- data analysis (e.g. big data analytics software);
- energy harvesting systems (i.e. devices that capture environmental energy to power small electronics);
- biomass production (i.e. the use of agricultural products or waste to produce fuels);
- agriculture machinery and equipment (e.g. tractors, rollers, shredders, belts and mowers);
- solar technologies (e.g. solar cells and thermal applications);
- robotics (e.g. harvesting robots and agribots);
- drones (e.g. unmanned aerial vehicles, docking and charge stations);
- control systems;
- sensors and detectors (e.g. in-soil and in-tree sensors);
- spectrometry (i.e. instruments to determine chemical compositions by measuring light emissions);
- dedicated processors (e.g. nanochips);
- signal processing devices;
- pesticides (e.g. fungicides);
- fertilisers;
- biochemistry (e.g. alternative proteins);
- bioinformatics (i.e. the study of biological properties through computer science techniques);
- genetics (e.g. plant genetics platforms and new seeds);
- microbiology (e.g. bioreactors);
- greenhouse technologies (e.g. heat delivery);
- animal trapping devices.

Identifying skills needs

The capacity of the agri-tech sector to get maximum benefit from the new technologies depends on the availability of skills to facilitate their introduction, use and maintenance. To identify the skills attached to the technologies listed above, another round of text mining was undertaken, this time in two online databases that contain detailed information on the skills required to perform existing occupations: (i) the multilingual classification of European Skills, Competences, Qualifications and Occupations (ESCO) database, and (ii) the Occupational Information Network (O*NET) database from the United States. As these databases do not contain emerging (future) jobs or new skills needs, another source – Wikipedia – was used to identify those emerging skills which are outside the International Standard Classification of Education (ISCO) and ESCO classifications and those used in O*NET. This was done to enable access to information beyond the traditional structured data, when considered non-exhaustive.

The results show those jobs where the skills content is most likely to be affected by technological change and then provide more detail about the skills within those jobs which are attached to various technologies. The jobs likely to be most affected by technological change are:

- technical or technology-related occupations, such as engineers and technicians in various technical fields; computer scientists and data scientists; agriculture-related professionals such as agronomists, biochemists and also meteorologists and statisticians; and certain categories of machine operators and tradespeople; and
- business services and related occupations, such as salespeople and export and trade officers; different types of managers, such as project managers and operation managers; and production team leaders.

Technology-related professions are not limited to technical roles; they are employed in other steps of the value chain (e.g. in sales), and there is an increasing demand for them to be involved in improving production efficiency. It is worth noting that business and management roles are important even in a technology-driven sector such as agri-tech and are often filled by people with a technological background.

The analysis shows that the top professional and associate professional occupations most likely to be affected by technological change are electrical engineers, sensor engineers and technicians, optoelectronic engineers and technicians, microelectronics engineers and technicians, photonics engineering technicians, optical engineers and agronomists.

A similar analysis was repeated for business and related services occupations and for operators and tradespeople. Thus, it is not just professional and technician jobs that will be affected, but also those other medium-skilled occupations related to day-to-day farming such as pesticide mixers. The impact of technological change will affect people working at all levels in the sector.

Looking at how the content of those jobs will develop over the short to medium term, it is also possible to identify the particular skills within these occupational groups identified above as the most affected by technology. Based on an analysis of the importance of the technology to the occupation, the importance of each occupation can be ranked. In relation to electrical engineers, for instance, there are numerous potential areas where skills will need to be acquired to master the use of various technologies (typically related to the use of a wide range of sensors in the case of electrical engineers).

The new skills needed to understand the interface with new technologies will also affect the role of more traditional jobs in agriculture such as agronomists. While the set of skills listed by ESCO for that occupation range from using pesticides to developing irrigation strategies, the information collected from the interviews with key stakeholders and employers revealed that agronomists must now possess a wider range of knowledge, including, for example, precision agriculture techniques (e.g. using monitoring sensors and interpreting data).

It is also apparent that entirely new professions are emerging, typically at the boundary between disciplines or as a result of new technologies which are driving change in the sector. These new jobs include autonomous vehicle robotics drone architect and LED light expert for indoor growing. Some occupations, however, show signs of obsolescence. Low-skilled and manual occupations are among them, but also those highly skilled ones which are narrowly specialised and could be substituted by ICT.

To sum up, the evidence indicates that the new workers will need to possess a wider range of skills than before; in particular, the interviews with companies pointed to the increasing relevance of multidisciplinary competences and the ability to interact with people from different disciplinary or professional backgrounds, as well as the emergence of ‘T-shaped’ profiles, with core competences in one area coupled with additional skills and knowledge in various other subjects.

Responding to change: the views of stakeholders

The review of various policy reports, the collation of official statistics, and the big data analysis take one only so far in looking at the demand for skills. The data mining expanded our knowledge of new and emerging skills, but there is still a need to learn from those connected with the agri-tech sector about their understanding of emerging skills needs and their experience of obtaining those skills to date.

The interviews with the key stakeholders and companies showed the following results:

- All the sector representatives confirmed the results of text mining and recognised that the sector is undergoing a period of advanced technological change as outlined by the big data analysis. The interviews showed no contradiction with the text mining results; rather, they provided complementary information.
- Most companies indicated the importance of skilled workers in the agri-tech sector and their shortage being the main limiting factor to company growth. They also highlighted that the education system produces graduates who have gaps in the knowledge base.
- Recruiting people with the skills needed to adapt to technological change is difficult because of (i) a general high level of demand from the economy as a whole for some of the skills the sector needs; and (ii) the relatively low attractiveness of agriculture compared with other sectors which have a similar demand for skills.
- Strategies to recruit people with the skills the sector needs range from hiring people exiting military service to taking on professionals retiring from large companies, to looking for workers in less central areas in Israel or internationally.
- Many of the firms in the sector are engaging in the training of their workforces (upskilling and reskilling) so that future skills needs will be met. Having more detailed information on the required skills helps them in the adaptation process and may well help to stimulate the supply of highly sought-after skills.
- While the wider ecosystem is supportive in assisting the sector to develop the skills it needs, including the R&D sector and academia, the sector pointed out that universities and technical and vocational education and training are only now starting to adapt to upcoming changes and are often not sufficiently tied to the realities of the work which needs to be undertaken in the sector. The extent of collaboration between companies and education providers remains limited.
- Employers are increasingly looking to technical and vocational institutions rather than the general education system (e.g. universities) to obtain the skills they need.

Improving skills anticipation

The use of a mixed methods approach has provided information on emerging skills needs derived from sources which until recently have been out of reach of skills researchers. Therefore, the report has identified the key technologies that drive skills demand over the short to medium term, and a variety of occupations that will be most affected by technological change. Particular attention has been given to specific technologies shaping the skills needs within specific occupations and the new skills which are currently not included in the existing occupational classifications.

This is not the end of the process. The report raises questions for further research, such as information on the scale of demand, whether that demand is likely to be met, and the impact of unmet skills on the sector and the economy. By identifying the specific skills that will affect a variety of jobs in the future, it is now possible to feed this information into, for instance, skills forecasting and skills foresight exercises, and into the design of employer skills surveys. The latter can help identify the volume of demand for specific occupations/jobs, the actual combinations of skills required within those jobs, and the magnitude of any skills shortages. Given the speed of technological advances in some sectors such as agri-tech, it is necessary to periodically repeat the analysis carried out in this study.

1. INTRODUCTION

As already mentioned in the preface, this report presents the first European Training Foundation (ETF) case study on the future of skills in the agri-tech sector in Israel. It gives the results of our investigation (conducted in Israel during the last quarter of 2019 and first quarter of 2020) on how various drivers of change – principally technological ones – have and will continue to affect jobs and skills needs in the agri-tech sector. It will raise awareness about the changing skills demand and stimulate a discussion among policy-makers, practitioners and researchers in the field so that the findings can be further exploited and used to adapt education and training provision.

The study is not just about identifying skills needs. It is also about developing a mixed methods approach which can be applied in different country settings to provide policy-relevant information about emerging skills demands. While the study documents emerging skills needs in the agri-tech sector, with directions to adapt the supply side in Israel, it also demonstrates how data science text mining techniques can be combined with more conventional methods of skills analysis to provide a comprehensive picture of emerging skills needs and, in doing so, deliver something which is genuinely new.

The report is organised as follows: Chapter 2 sets out the analytical framework of the study and outlines the key steps of the methodological approach used in the Israel study (though a detailed explanation of the general methodological approach is published separately). This is followed, in Chapter 3, by an overview of the agri-tech sector in Israel and its employment potential and occupational structure based on the literature review and secondary analysis of official employment statistics (labour force survey). This provides a good level of contextual background of the sector for readers before going into the details of big data analysis and company interviews.

Chapter 4, based on the text mining exercise, goes on to analyse the main drivers of change affecting the sector and the technological changes which are beginning to take root, and how these are likely to influence future skills needs. Using data derived from the text mining combined with information obtained from the in-depth interviews with key stakeholders and selected innovative companies, Chapter 5 provides information on emerging skills needs and their impact on occupational job profiles. How the companies have responded to observed changes and met their emerging skills needs is outlined in Chapter 6, including their strategies involving education and training providers and research centres. The chapter finishes with a final word on the findings.

The report also includes a list of key stakeholder institutions in Israel that were consulted for the study (see annex), a glossary to set a standard definition of labour-related concepts and better explain some technical terminology, and a detailed bibliography.

2. METHODOLOGICAL APPROACH

The overarching purpose of the study is to understand the drivers of change affecting the agri-tech sector in Israel, ascertain the technological changes that are taking place or are about to take place, and identify the resulting skills needs. The study is about understanding the links between technological change and skills demand so that policy-makers can better respond to emerging skills needs. The initial research questions which provided the framework of the study are shown in Box 2.1.

BOX 2.1 SPECIFIC RESEARCH QUESTIONS

Questions about the state of development in the analysed sector

1. What is the relationship of the selected subsector to the whole sector and the broader economy (e.g. production, employment, export)?
2. What are the main drivers of change currently shaping the sector (e.g. trade, global value chains, new technology, digital tools, the greening of the economy, climate change)?
3. What has driven/generated innovation in this part of the sector and does it have the potential to have an influence on the rest of the sector?

Questions about the empirical evidence on the changes occurring in the sector

4. What are the ongoing changes observed in the sector in terms of production, storage, marketing, business practices, labour and skills utilisation?
5. What are the main occupational profiles used in the sector? Has the content of some occupations evolved as a result of the above changes in the sector, and if so, how?
6. Which new tasks and functions have emerged in the jobs and/or occupations in this sector? Which old ones have disappeared?
7. What are the differences in the job profiles of this innovative sector? What changes are observed in the profiles of new recruitments and job vacancies published?
8. What is the impact of these changes on labour and skills demands in the sector? Do changes require higher levels of the same skills or completely new sets of skills from workers?
9. How do these changes affect ‘skills utilisation’ and working conditions in the sector (e.g. salary, contracts, working hours, formality)?
10. How do businesses meet their new skills needs (new hiring, retraining, etc.)? Are there initiatives/cooperation of companies with education and training providers?

Questions about policy implications

11. Do technology, innovation and other changes push countries towards a higher added value and integration in the global value chain? Are skills contributing to this shift? If so, how?
12. Are there any spill-over effects from the changes in the overall broader sector? What context-specific and general lessons can be derived from these studies?
13. Are changes and innovation in the sector causing education and training to respond and adapt to industry needs?

Note: The last three questions were the most difficult to answer since none of the respondents provided much insight which could be used in the analysis.

The term agri-tech indicates the use of technology to increase the yield, efficiency and profitability of agriculture; it is the application of technology to improve all elements of the farming and growing process in agriculture, horticulture and aquaculture. Agri-tech can be products, services or applications derived from agriculture. It can be used to grow more food from less space or using less water. It can be the use of robots to replace manual labour for planting or picking crops. It can also be the use of big data, machine learning and artificial intelligence (AI) to understand more about the soil or growing conditions to solve the challenges that the agricultural sector faces. By using digital techniques to monitor and optimise agricultural production processes, a new farming management system has been developed in agriculture, sometimes called precision agriculture (see glossary for details)[1]. Given the need for the study to be forward looking, and the fact that the agri-tech sector is difficult to define by using standard classifications of economic activity such as NACE or ISIC, a mixed methods approach is used, combining desk research and data analysis with data mining techniques and interviews with stakeholders and companies (Box 2.2).

BOX 2.2 STEPS FOLLOWED IN THE STUDY'S MIXED METHODS APPROACH

1. Use of well-established methodologies derived from social science, including:
   - a literature review of the agri-tech sector in Israel, and
   - secondary analysis of employment and skills data, in particular in the sector.
2. Big data analysis in relation to the agri-tech sector in Israel:
   - text mining applied to a large volume of documents such as patents or scientific papers connected to agri-tech to identify the technologies and other drivers of change, and
   - comparing and matching the list of relevant technologies extracted from text mining to the related occupations and skills listed by the occupational databases of ESCO and O*NET, by using semantic matching algorithms.
3. In-depth interviews with companies and key stakeholders in the agri-tech sector to verify and refine the results of the two previous steps.

The first step of the study involved reviewing the literature on the innovation, employment and skills pool in Israel in general, followed by a description of the agri-tech sector in particular, including its innovation and employment capacity and the skills needs. Based on the data provided by the Central Bureau of Statistics (CBS) in Israel, it was also possible to make some estimates on the workforce in the agri-tech sector, including its magnitude and changes over time in terms of occupational groups and qualifications and skills demand. This contextual analysis demonstrates that the capacity of the agri-tech sector to introduce the latest technologies does not rest only with skills policies, but also with obtaining investment capital, having links with research institutes, and offering relatively good jobs to attract those with the necessary skills.

The second step was text mining, a technique that allows computers to extract, discover or organise relevant information from large collections of different written resources. Indeed, the textual documentation produced by industries, institutions, research centres and the like produces a vast

[1] Precision agriculture is a farming management concept based on the use of technologies to observe and measure the situation of fields and crops (see glossary for details).

amount of information. However, this is often scattered across many sources and the sheer volume of existing documents makes it impossible for manual searches. Even if manual searches could be done, it is likely that some data would be missed. For this study, a proprietary text mining tool was used to scan the largest possible corpus of data in English. Algorithms using natural language processing, among other techniques, were able to extract and record the number of incidences where a technology (or other relevant entities such as occupations and country names) was mentioned and keep track of all the inter-relationships between key terms.

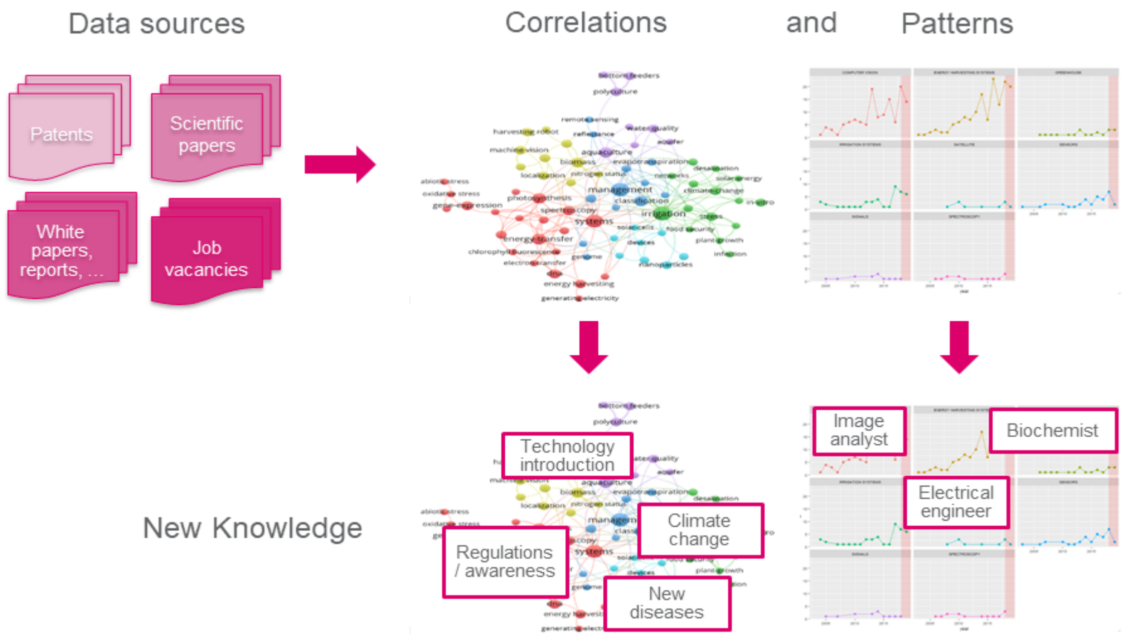
Key sources used for the text mining analysis were patents and scientific papers in English. They are large and accessible corpora of structured data, which is extremely important for the reliability and completeness of results. Patents are widely considered as a good proxy for measuring innovation and anticipating technological changes, while papers and conference proceedings allow the researchers to also study social and economic factors. For patents, data was taken from Espacenet, the official database of the European Patent Office, regarded by many as the most authoritative source of patent information, containing over 120 million documents from around the world and updated daily. For scientific papers, both Scopus (by Elsevier) and Web of Science (by Clarivate) were used, the two largest databases of peer-reviewed papers, where an equivalent study was performed on around 70 million scientific papers. In addition, hundreds of white papers, policy papers, project reports and foresight papers from Israeli and international institutions, as well as web pages dealing with agri-tech topics (examples are in the bibliography), were searched using standard queries and downloaded to be analysed. But there were fewer of the latter documents and they were also unstructured and sometimes of a promotional nature, so were not as relevant as patents and papers.

The data was processed with proprietary algorithms to harmonise inventors', authors', companies' and universities' names, and to consolidate the geo-localisation of parties according to Nomenclature of Territorial Units for Statistics (NUTS) codes. The latter is clearly relevant when interested in country-specific studies. To maintain the focus on Israel, two types of patents were selected: those issued directly by the Israel Patent Office, and the international ones for which at least one of the assignees was located in the country. Papers were selected if Israel was cited among the countries of interest for the study. Erre Quadro's semantic algorithms were able to recognise functional concepts rather than simple keywords, so they were used to scan the full text of each document to identify those with a main focus on agri-tech. Documents from as far back as 1948 were retrieved, but for many analyses, data from only the last 10 or 15 years was used. This is a good time window given the rather long cycles of agriculture, and restricting to even more recent periods would have obscured most temporal trends.

The first phase of this text mining identified two main categories of relevant information: (i) technical and societal drivers of change; and (ii) technologies introduced into the sector and their diffusion over time. In the second phase of text mining, the information identified was compared and matched to the associated occupations and skills listed in the databases of ESCO and O*NET by using semantic matching algorithms (i.e. algorithms able to find semantic connections between different concepts based on contextual information). For example, each occupation in the ESCO database included a description and a list of competences, skills and knowledge considered relevant (either essential or optional) for that occupation. The semantic algorithm looked for matches of each technology with all the concepts associated with that occupation. When a match was found, the occupation was considered associated with the technology. The entire procedure was automated using ESCO's Application Programming Interface (API), which allowed occupational data to be downloaded. If an occupation was impacted by technology at any level, then the text mining found it. If no match was found in ESCO or O*NET due to emerging (future) jobs or new skills needs, other approaches – e.g. connecting the new competences through Wikipedia – were used to try to identify them.

The main advantage of text mining is the ability to search a very large number of documents quickly. In particular, patents and scientific papers are easy to access and structured (compared to social media), so information extraction is facilitated. Although information may be scattered over many different documents, algorithms are able to discover hidden patterns and emerging phenomena which might not be detected by manual search techniques. By correlating concepts and extracting trends, it allows weak signals to be detected and emerging trends to be spotted (see Figure 2.1). This gives a future-oriented perspective and hints at what is not already known from the past. Anticipating the future from the extrapolation of past trends, even with the most sophisticated forecasting models, is likely to fail if the phenomenon of interest is subject to rapid and disruptive change. Text mining at least provides a basis for identifying the variety of disruptive factors which can then be explored with key stakeholders. This is particularly important when thinking about the skills implications of technological change because there is an element of entering the unknown.

FIGURE 2.1 TEXT MINING EXTRACTS: CORRELATIONS AND TRENDS FROM THE DATA, WHICH CAN BE TURNED INTO KNOWLEDGE ABOUT THE FUTURE OF SKILLS AND JOB PROFILES



The third step was complementary qualitative research to obtain information from key stakeholders and companies about their experience of technological changes and other change drivers in the sector and the new skills needs. Focus group discussions were convened in Tel Aviv in November 2019 involving all relevant stakeholders from the agri-tech sector and the education and training system. Around 15 representatives from government institutions, academia and research, as well as public and private associations and organisations, attended the focus group discussions. The purpose was to reflect on the results from the previous steps. After the focus group, face-to-face in-depth interviews were conducted between November 2019 and February 2020. A semi-structured interview technique was used to guide the discussions.

The first target group of interviews was key stakeholders in the agri-tech sector. Some 30 stakeholders were identified during the planning of the field work; the stakeholders represent a broad base, including sector representatives (social partners, professional associations, etc.), policy-makers, government organisations, education and training providers, universities, members of the research community, intermediaries and entrepreneurs. Of the 30 approached, 19 responded to our request of face-to-face interviews to explain how they perceive and manage the process of technological change and how they acquire the skills they need. A full list of these key stakeholders (as institutions, not individual names, 21 in total) is provided in annex. The names of individuals from these institutions are not included for data privacy reasons.

The second target group was the selected innovative companies in the sector, to understand their perception and actions in managing the technological change process in the companies and ways of finding the skills they need. The text mining from patents enabled identification of the top five innovative companies (as measured by the most patent filing in recent years) for each technological cluster or subsector during the analysis. Companies that were the Israeli branch of a multinational with headquarters in another country were removed from the list, as well as the patents filed by universities and government organisations. This led to around 40 Israeli companies being selected. This list was also cross-checked for the 10 most active companies overall (i.e. not distinguishing by subsector when counting patents filed), since companies which are transversally innovative across different subsectors are of interest. A different criterion was adopted for start-ups (selected from the start-up database of Start-up Nation Central). Despite having fewer patents, those start-ups active in subsectors with the fastest-growing innovations were added to the list. The list was finally manually revised to check for duplicates or for mergers and acquisitions, to keep the variety across subsectors and to represent both agriculture companies adopting technologies (agri-centred) and technology providers that apply their expertise in the agriculture sector (tech-centred).

In total, eight companies were interviewed from the sector, covering the widest possible spectrum of agri-tech activities and including enterprises of different sizes and types. In most cases, the interviews were conducted with multiple key personnel within each company/agricultural centre (including CEOs, managers, human resource (HR) managers and marketing staff) and the questions focused on how companies deal with the process of technological change (including barriers to its implementation such as shortages of capital and skills), and the impact on the content of jobs and the related skills needs emerging from these changes. To increase the outreach to agri-tech companies, an online questionnaire was also developed, the content of which was similar to that of the semi-structured interview with closed questions. Although the survey was sent to many companies, only five companies responded. The names of the interviewed companies as well as the individual names are kept confidential for data privacy reasons.

Collecting the views of key stakeholders and interviewing the most innovative companies was an important step since new skills demands can be revealed only by understanding the responses of companies to the signals about emerging technologies. Arguably, by interviewing the most innovative companies, one may not provide a fully balanced picture. However, the study aimed to collect evidence on how the technological changes affect, if implemented, employment and skills. Thus, the research looked at the changes in occupations and necessary skills to perform these occupations, not the volume of skills demand. Accordingly, studying the companies at the forefront of change was key to shedding light on the changes that the other actors will have to follow. In general, no contradiction came out between the results of text mining and interviews. Thus, the report specifies whether the interviews simply confirmed the text mining results or they provided complementary information to the text mining (which is the case in Sections 5.4 and 6).

Combining different research methods brought some advantages, as no single methodology can identify all the emerging skills needs in the agri-tech sector. Different techniques complemented one another, each compensating for the potential shortcomings of the other. The results from different research tools were then compared and verified. For example, companies' product market and skills strategies were difficult to collate by text mining, but this could be done by reading their annual reports and interviewing key personnel. But these were not always ideal sources to find out about the technologies which are transforming or are about to transform products and processes in their sector as companies might simply be unaware of them. Here, text mining identified technologies which are likely to have a major influence on companies' strategies in the future, in addition to other advantages of text mining discussed above.

Nevertheless, there are certain limitations of this study which need to be acknowledged:

- The information provided by companies and other key stakeholders should be regarded as indicative rather than definitive given that only a small number of people were interviewed in the study. Future studies could include more interviews, with a more representative selection of companies and stakeholders, but this tends to be resource-intensive and costly.
- The text mining was limited to searches in English. Hebrew, for example, was not used in the searches. It is likely to be the case, however, that most of the patents and scientific papers were published in English in this period. For future analysis, there is scope to extend the text mining tool to other languages.
- Despite the mixed methods approach used in the study, this report is not able to give an indication of the scale or volume of any change in jobs and employment (e.g. it is not able to say anything about how many extra agronomists will be required), the relative importance of particular skills, or the extent of any skills mismatches. Other methodologies are required to address these issues.
- Due to the very small size of the agri-tech sector in Israel, and the lack of a clear sectoral definition in the ISIC or NACE classifications, the statistical data used for the background information on the sector has clear quality limitations, including the coverage, which needs to be kept in mind while analysing trends and variations.
- Patents are proxies for innovation and tend to be concerned with emerging technologies (e.g. patents are often filed to protect an innovation that is just about to come on stream). But it is possible that some innovations are not patented. Moreover, patents are mainly linked to technological innovation. Non-technological innovations are also important; the review of scientific papers and interviews with companies and stakeholders captured other drivers of change.
- The analysis of skills was limited to those associated with technologies and other trends identified by the text mining. If a certain technology was linked to occupations and skills at high or medium level in ESCO and O*NET databases, this was captured. There were several cases where this link did not exist (e.g. incomplete descriptions of skills). For example, agronomists are not yet linked to precision agriculture in the ESCO database, but the company interviews showed that the agronomists that are sought after have to possess this new knowledge. It could be expected that links might be missing more frequently in the case of medium- and low-skilled occupations.

- If there are completely new (future) occupations and skills needs, they have not been found in the existing ESCO or O*NET databases. In these cases, other non-conventional data sources such as Wikipedia were used to access and identify information beyond the traditional structured ones, when considered non-exhaustive. However, it is clear that the information provided by these types of sources should be handled with care.

Despite these limitations, the data science approach brings some added value. It builds on the conventional forms of skills analyses such as undertaking skills surveys and carrying out skills forecasting. It allows identification of the skills content of jobs in the agri-tech sector and possible changes of skills with new technology. Thus, the focus is on actual jobs and how these will change over the short to medium term, rather than broad aggregations of jobs into occupations. Data is captured on specific skills in specific jobs rather than total demand for certain occupations. The approach is flexible, and the algorithms can be run and rerun in a relatively speedy manner. So if a sudden economic shock or a crisis of some kind emerges – such as Covid-19 – the analysis can be quickly rerun to capture the effects of these (so long as there is data that can be searched).

The report was completed before the outbreak of the Covid-19 pandemic, which brought a high degree of uncertainty regarding the future of employment and skills demand. As the study is concerned with the long-term development of skills demand resulting from technological change, the findings are less sensitive to changes over the shorter term with immediate and direct impact. The pace of change may slow down or accelerate as a result of the pandemic, but the nature of that change is likely to remain the same. The uptake of agri-tech technologies (e.g. robots, drones and sensors for precision agriculture) may be accelerated in the medium term in some countries, due to the Covid-19 experience of high dependency on importing essential goods from overseas (e.g. food and pharmaceuticals). It would not be surprising to see more countries wanting to be self-sufficient in their agricultural production (localised) instead of being dependent on global production chains. Thus, the contribution of agri-tech could be perceived as more important (or even essential) in the plans of some countries for self-sustainable food production.

3. OVERVIEW OF THE AGRI-TECH SECTOR

Key issues covered in this chapter

- The relationship of agri-tech to agriculture and the broader economy.
- The factors which have driven or generated innovation in agri-tech and whether they have the potential to become an influence on the rest of the sector.
- The ongoing changes observed in the sector in terms of production, storage, marketing, business practices, employment and skills utilisation.

3.1 Agri-tech ecosystem

Of the 140 economies covered by the Global Competitiveness Report, Israel occupied 20th position in the Global Competitiveness Index (WEF, 2019). Israel's innovation ecosystem is ranked 10th best in the world and it is one of the countries where entrepreneurial failure is most accepted and innovative companies grow the fastest. It is notable in this regard that Israel has a relatively high number of start-ups: one for every 1 400 people. IVC Research Centre reports currently 9 288 active high-tech companies and more than 300 multinationals with R&D centres in Israel[2]. However, the economy comprises more than just the high-tech sector and it is the more traditional sectors – often dependent on relatively low-skilled labour – which have tended to act as a drag on productivity growth.

Defining the agri-tech sector in Israel is far from straightforward. One interpretation sees agri-tech as an ecosystem that brings together entrepreneurs, innovators, investors, government, universities, etc. In many respects, it is the establishment of ecosystems of a kind depicted in Figure 3.1 which is a fundamental strength of the Israeli economy. This ecosystem is supported by many public, private, research and non-governmental organisations (NGOs) such as Start-up Nation Central[3], Israeli High-Tech Association (under the Manufacturers' Association of Israel), Kibbutz Industries Association[4], Agricultural Research Organisation – Volcani Centre, the Weizmann Institute of Science, and the IsraelAgri online portal. In other words, its economic strength derives from the way in which the private and public sectors plus NGOs combine to stimulate innovation and entrepreneurship. It is this which has earned Israel the nickname 'Start-up Nation' (Senor and Singer, 2009). In Israel, the agri-tech ecosystem is a sizeable one: it is estimated that there are more than 700 agri-tech companies focused on innovation (AgFunder and Start-up Nation Central, 2019).

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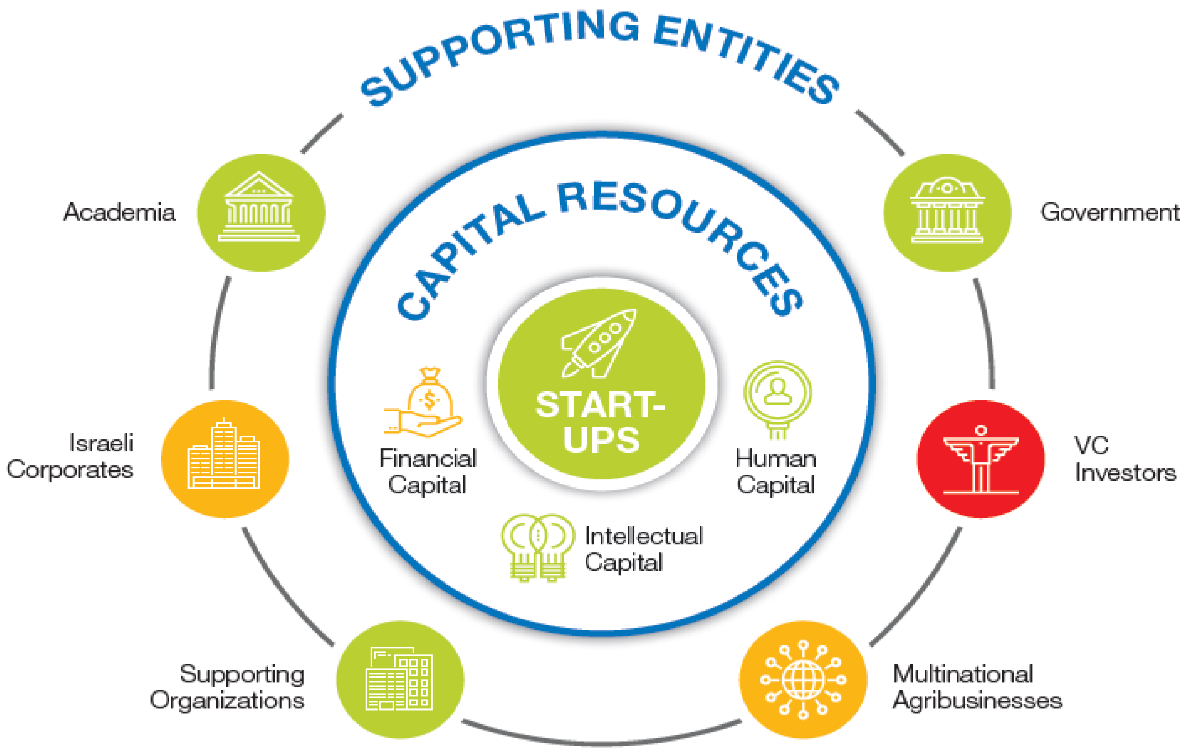
[2] See IVC Research Centre website, www.ivc-online.com/

[3] Start-up Nation Central is an Israel-based non-profit, serving as a gateway to Israeli innovation. The organisation leverages its in-depth knowledge of Israel's innovation sector to connect business leaders, governments and NGOs from across the globe to the most relevant people and technologies that can address their most pressing challenges. It covers six fields of innovation: agri-tech, fintech, cybersecurity, digital health, watertech, and industry 4.0 (including AI). In 2018, more than 6 600 companies were engaged in Start-up Nation Central's services. See www.startupnationcentral.org

[4] Founded in 1962, Kibbutz Industries Association is an umbrella of more than 300 industrial plants on kibbutzim, moshavim (see glossary) and regional enterprises.

FIGURE 3.1 THE AGRI-TECH ECOSYSTEM IN ISRAEL



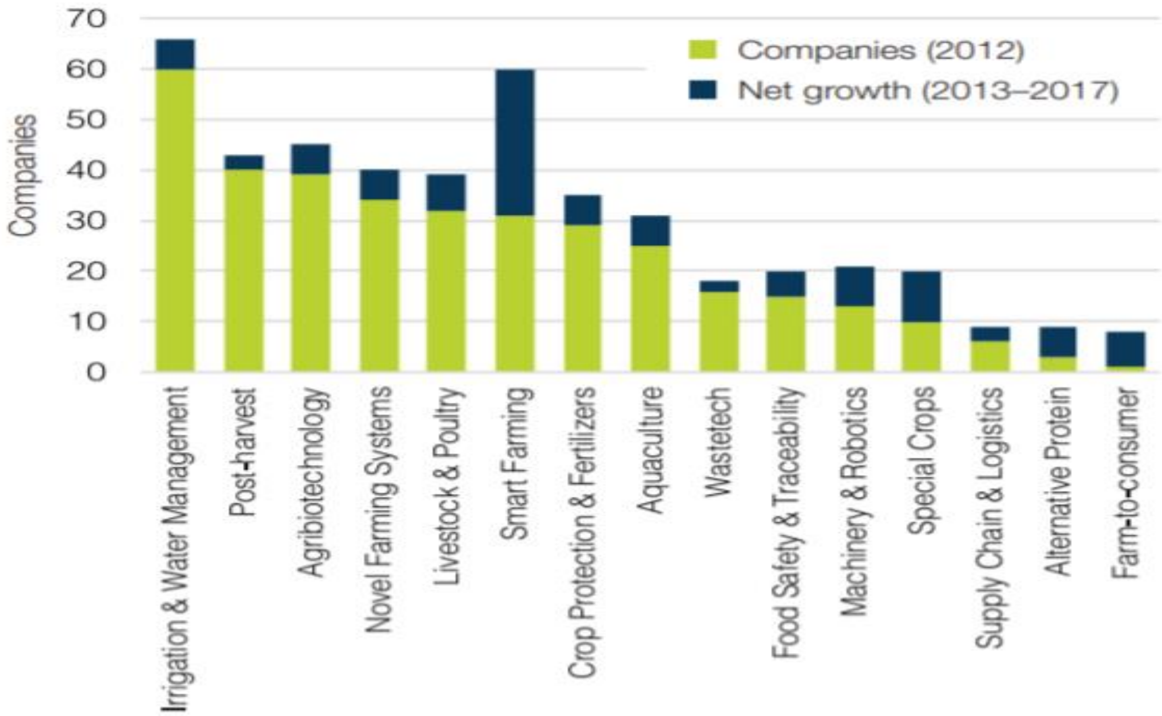
Note: VC – venture capital
Source: Rausnitz et al. (2019)

Before going into further details of the agri-tech sector, it is important to state the basic facts of Israel's agriculture system. The natural features of the Israeli landscape make it difficult to grow crops: over half of Israel's saline soil is arid or semi-arid (only 20% is arable) and Israel's natural water supplies are below the United Nations' definition of water poverty. Despite this, Israel manages to produce 95% of its own food requirements. According to the Israeli Ministry of Agriculture, the leading agricultural subsectors with the highest production value are fruit and vegetable crops, and poultry and beef (including milk and eggs). The share of total agricultural output accounted for by these sectors in 2015 was: fruit 24%; vegetables, potatoes and marrows 20%; poultry 19%; beef 15%; and smaller others. The value of agricultural production totalled ILS 30 billion in 2016, while its total export amounted to ILS 4.6 billion (15% of total agricultural products, but less than 2% of the total national exports). Israel's exports are mainly vegetable products, such as dates, peppers, avocados, carrots, flowers and herbs, mostly to markets in Europe, Russia, the US and the Far East.

Thus, agriculture in Israel relies not so much on a natural comparative advantage in farming, but on an induced one built on technological progress and innovation (OECD, 2017). For example, 60% of the water used for agriculture in Israel is water that is not suitable for domestic consumption (MARD, n.d.). Growth in the agriculture sector has been dependent on investments and research in agricultural technology, relying on close cooperation between farmers and technological research, as well as substantial public funding. Over recent decades, Israel has become a world leader in agricultural technology development. Technological achievements include computer-controlled drip irrigation, computerised early-warning systems for leaks, thermal imaging for crop water stress detection, biological pest control, and new varieties of fruits and vegetables. Water shortages are alleviated through extensive water reuse (86%) and desalination plants. All these technological solutions have become important sources of exports.

The range of Israel's agricultural innovation capabilities is broad and varied, including in-soil and in-tree sensors, cutting-edge swarming robot drones, plant genetics platforms, cultured meat, alternative proteins, smart irrigation, and big data analytics software. In developing its capabilities, the sector has been able to capitalise on the country's acknowledged strengths in data-enabled technologies and the Internet of Things. The focus has been on precision agriculture which increases agricultural production by improving growing processes and the quality of crops. This reflects, at least in part, changes in the behaviour of consumers who want to know more about the whole value chain attached to the products they eat and drink. As a result, agri-tech has been growing in Israel. Figure 3.2 demonstrates that over recent years, there has been substantial growth in the creation of new agri-tech companies (e.g. see the net growth in smart farming companies).

FIGURE 3.2 AGRI-TECH SECTOR GROWTH IN ISRAEL, 2013–17



Source: Liljedahl (2017)

The rapid development of agri-tech has been driven by a combination of the availability of government support (for example, 17% of the public budget for R&D is allocated to agriculture); well-established R&D infrastructure with which farmers cooperate (cf. the ecosystem approach); and the need to respond to the shortage of natural resources (e.g. water). This has fostered an innovative system of 'growing more with less'. In achieving this goal, the sector has been able to benefit from both public and private investments in R&D and the technological innovations taking place in the agri-tech sector (OECD, 2017).

Developments continue apace in the agriculture sector. Over recent years, several policies have been put in place, such as the introduction of a new water pricing system and the reduction of regulatory burden in the agri-food chain to lower food prices, reduce trade costs and encourage trade flows. The sustainability of the system has been improved by measures that encourage the treatment of agricultural waste to reduce its impacts on the environment and human health and to increase its use as a source of renewable energy production. Additional resources have been allocated to programmes that decrease the negative impact of intensive agriculture on natural resources. All of this has had an impact on productivity. According to the Organisation for Economic Cooperation and Development (OECD, 2017) report on agriculture, Israel's annual growth rate for total factor productivity in agriculture has been well above the world average. It is the result of applying advanced technology, high managerial skills of Israeli farmers and well-streamed public investments.

3.2 Employment and skills in the agri-tech sector

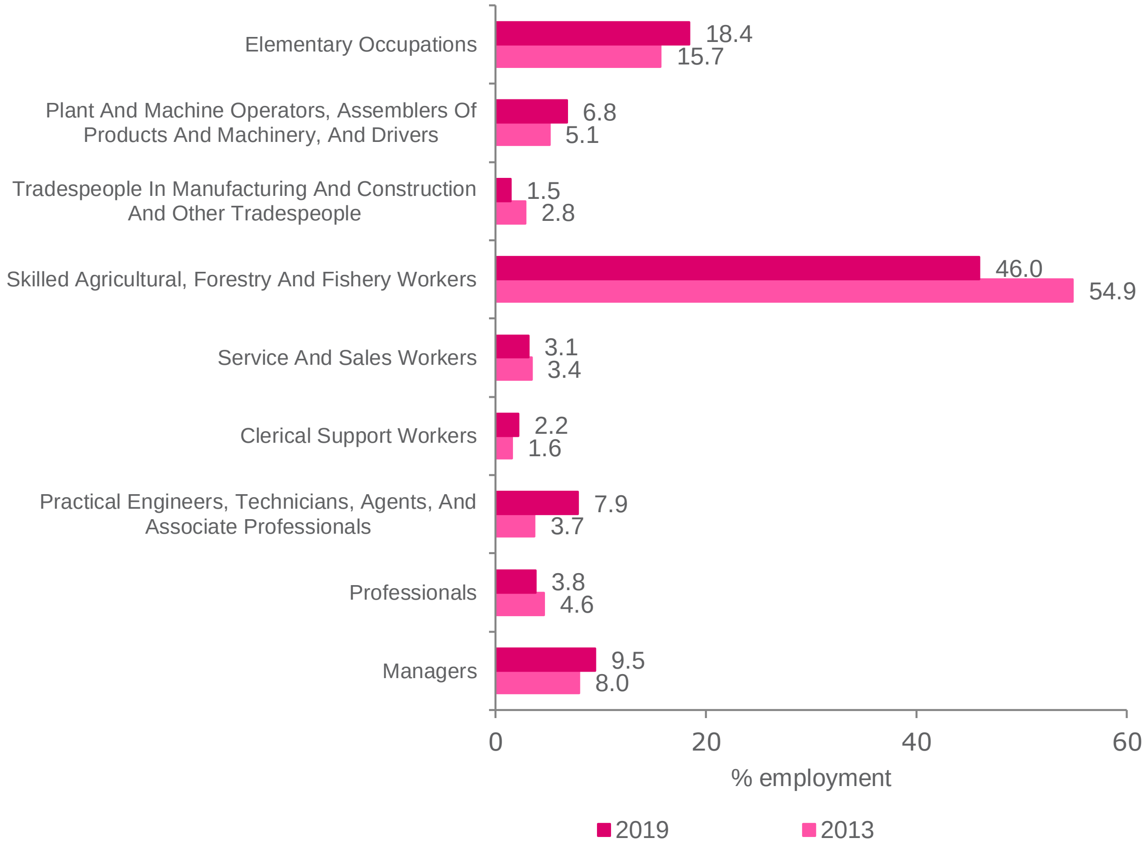
Employment in the agriculture sector has been in decline over the long term (see Figure 3.3). In comparison with EU employment in the sector, it is relatively small, accounting for around 1% of employment in 2018 compared with 4% in the EU. It is estimated that 72 000 people are directly employed in agriculture in Israel, including around 21 000 foreign workers. In addition, an estimated 170 000 people are employed in the production of agricultural inputs and the distribution of agricultural outputs (World Bank, 2020).

FIGURE 3.3 EMPLOYMENT IN AGRICULTURE, 1995–2018

Source: Aggregation/calculation of the research team using OECD's statistics 1995–2018

An indication of skills demand in the agriculture sector can be obtained from looking at its occupational structure (see Figure 3.4). It reveals the sector's dependency on people in skilled manual jobs (i.e. skilled agricultural forestry and fishery workers), but it also reveals a pattern of change with an increasing dependence on relatively high-level jobs (i.e. the growth in managers and practical engineers and technicians) and low-skilled ones (elementary occupations). This is consistent with theories that see the main impact of technological change as increasing the demand for people working in high- and low-skilled jobs because these are the ones which are less amenable to substitution by automation. At the same time, the digitalisation of agriculture might require farmers to have new cross-cutting skills, such as access to and processing of complex information, basic and advanced ICT skills to make full use of digital tools and applications, and a wide set of soft skills such as problem-solving and creative thinking.

FIGURE 3.4 OCCUPATIONAL DISTRIBUTION OF EMPLOYMENT IN THE AGRICULTURE SECTOR, 2013 AND 2019



Source: Israel CBS, labour force survey statistics

Agriculture, however, is not synonymous with the agri-tech sector. It is part of it, but the agri-tech sector encompasses much more besides. Agri-tech comprises the technological capability to change how food and other agricultural products are grown, harvested, packaged, stored, transported, processed and sold – making the farm-to-table process more efficient, sustainable and safe. Ideally, one can define the sector with respect to an industrial classification such as NACE. This tends towards defining the sector as a combination of various subsectors (see Box 3.1).

BOX 3.1 SPECIFICATION OF AGRI-TECH SECTOR ACCORDING TO NACE REV.2

A – Agriculture, forestry and fishing (division 01 to 03, but with the exception here of 01.4 – animal production, 01.7 – hunting, and 03.1 – fishing)

CA – Manufacture of food products, beverages and tobacco products (division 10 to 12, with the exception of 10.1 and 10.2 about meat and fish)

CE – Manufacture of chemicals (division 20): manufacture of fertilisers and nitrogen compounds (20.15); manufacture of pesticides and other agrochemical products (20.2)

CI – Manufacture of computer, electronic and optical products (division 26)

CK – Manufacture of machinery and equipment not classified elsewhere (division 28): manufacture of agricultural and forestry machinery (28.3)

G – Wholesale and retail trade: wholesale of agricultural raw materials and live animals (46.2); wholesale of food, beverages and tobacco (46.3); wholesale of agricultural machinery, equipment and supplies (46.6); retail sale of food, beverages and tobacco (47.2)

JC – IT and other information services (division 62 and 63): computer programming, consultancy and related activities (62); information service activities (63)

MB – Scientific research and development (division 72): research and experimental development on natural sciences and engineering (72.1).

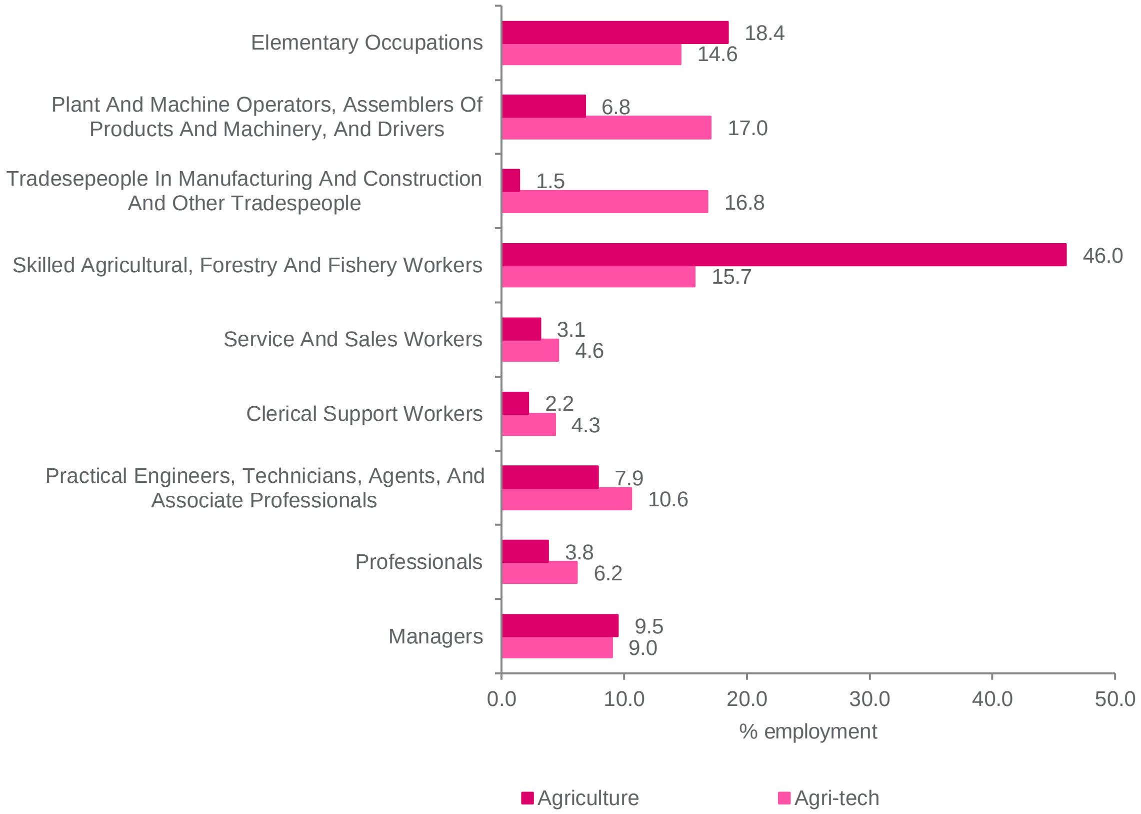
Source: derived from Eurostat (2008)

In practice, the data to provide a reliable estimate of employment by occupation or qualification level is not readily available. To provide estimates for agri-tech, the shares of employment in all the NACE sectors included in Box 3.1 are used; for example, employment in agriculture has been added to that of manufacturing (food and drinks, chemicals, agricultural equipment) and wholesale and trade, and an estimate has been provided for employment in professional, scientific and technical activities that are likely to be linked to agri-tech, since agri-tech also contains people involved in R&D[5]. Using this definition, it is estimated that the agri-tech sector accounts for around 3% of total employment in Israel. It needs to be recognised that this is a rough estimate, but it serves to demonstrate that the sector is much larger than agriculture alone.

Figure 3.5 compares the occupational distribution of employment in agriculture and agri-tech which includes the shares of NACE sectors included in Box 3.1. In general, it reveals that agri-tech is more dependent on professionals, associate professionals and production workers (craft and assembly line workers). On the other hand, the agriculture sector is dependent on skilled agricultural, forestry and fishery workers, followed by elementary occupations.

[5] This was based on the labour force survey statistics from 2019, shared by the Israeli Central Bureau of Statistics. The percentage has been estimated by multiplying the number of people employed in this sector by the overall proportion of employment accounted for by agriculture and food and drink manufacture (around 3%). In this way, an indicative estimate of skills demand in the agri-tech sector has been derived.

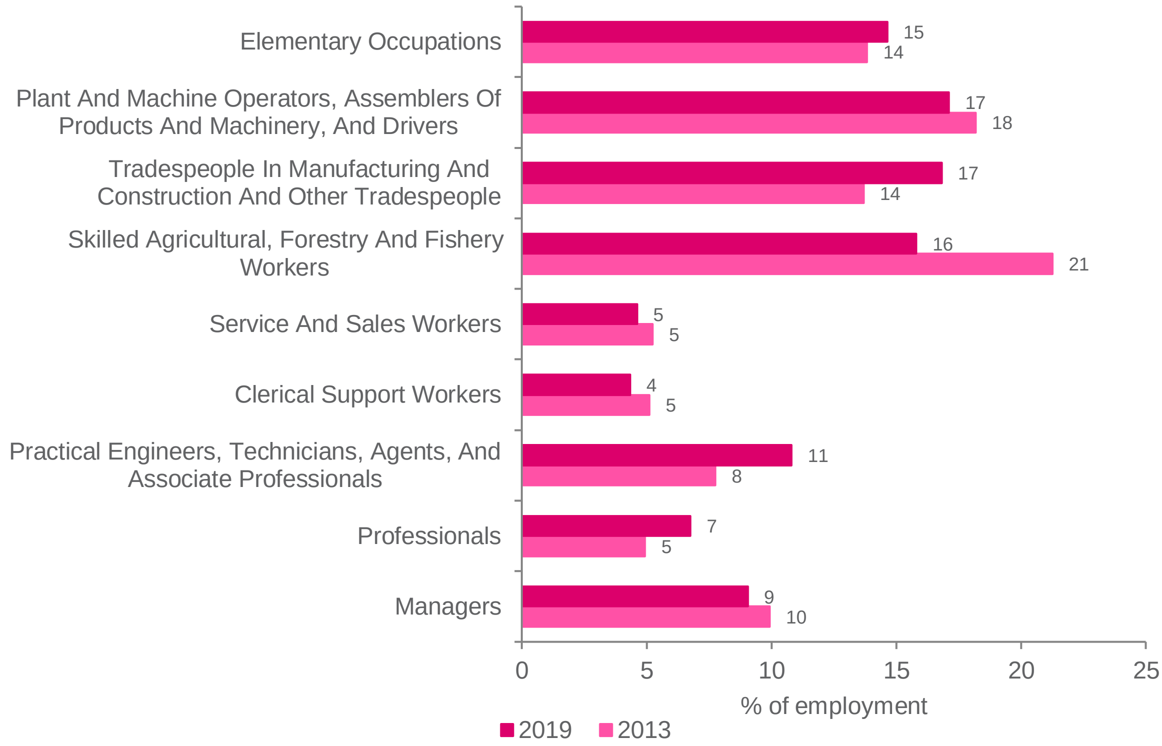
FIGURE 3.5 COMPARISON OF THE OCCUPATIONAL DISTRIBUTION OF EMPLOYMENT IN AGRICULTURE AND AGRI-TECH SECTORS, 2019



Source: Israel CBS, own calculations

Figure 3.6 shows how the occupational structure of the agri-tech sector has changed from 2013 to 2019. The most striking change is the significant increase of employment by the following occupational groups: professionals (from 5% to 7%), practical engineers and technicians (from 8% to 11%) and tradespeople (from 14% to 17%), reflecting perhaps the increasing dependence of the sector on new technologies. Another significant change pattern is the significant decrease of employment in the following occupational groups: skilled agricultural workers (from 21% to 16%) and plant and machine operators (from 18% to 17%).

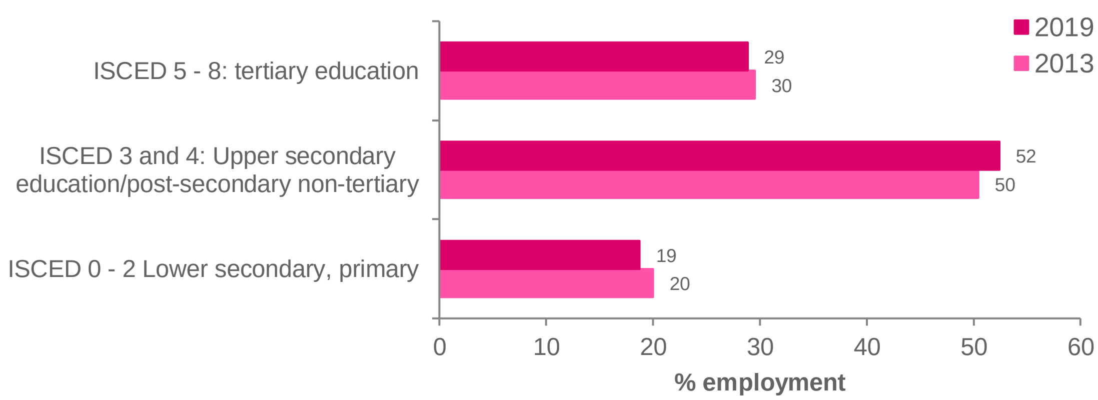
FIGURE 3.6 OCCUPATIONAL STRUCTURE OF EMPLOYMENT IN THE AGRI-TECH SECTOR, 2013 AND 2019



Source: Israel CBS, own calculations

Another way of looking at changing patterns of skills demand is to look at how the qualification structure of employment has changed from 2013 to 2019. Figure 3.7 shows the highest level of educational attainment of those working in the agri-tech sector and how this has changed over time. It reveals a pattern consistent with occupational change, with an increasing dependence on those who are relatively more highly skilled – i.e. those with higher and medium qualification levels.

FIGURE 3.7 QUALIFICATION STRUCTURE OF EMPLOYMENT IN THE AGRI-TECH SECTOR, 2013 AND 2019



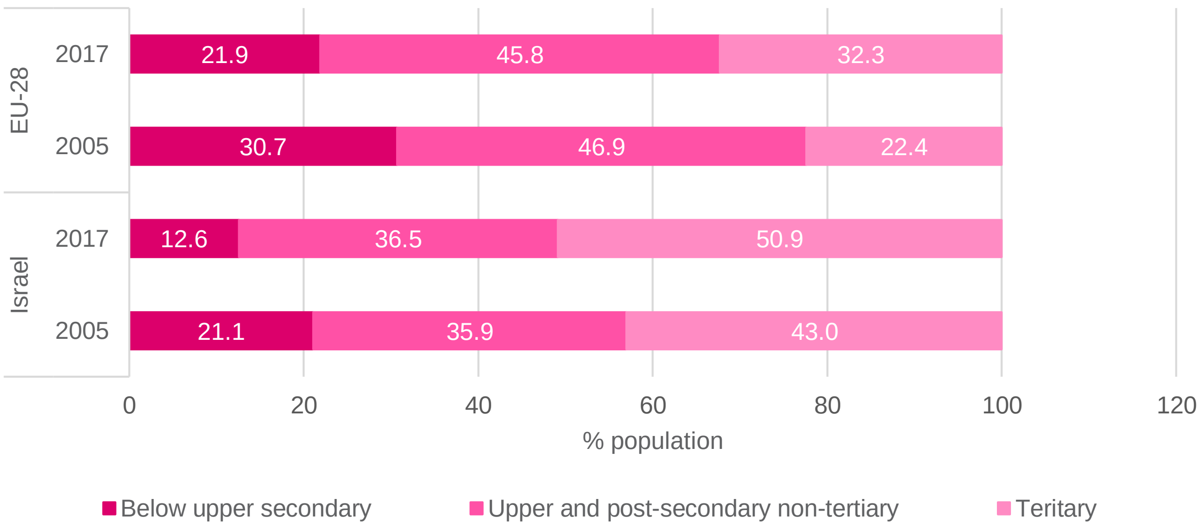
Note: ISCED – International Standard Classification of Education
Source: Israel CBS, own calculations

3.3 Supply-side considerations

The previous section indicated the way in which demand for skills has been changing in the agri-tech sector. A further consideration is whether the supply side is able to deliver the skills the sector needs. This question cannot be addressed here, but it is possible to provide some key information about the education and training system in Israel which can serve to inform issues raised in the following sections.

Among OECD countries, Israel has one of the highest shares of gross domestic product (GDP) spent on primary, secondary and post-secondary non-tertiary education. Figure 3.8 reveals that the population of Israel is relatively highly educated. The OECD reports that tertiary-educated adults have good labour market prospects in Israel (OECD, 2019). Concerns, however, have been raised about the spending per student on tertiary education, which stands significantly below the OECD average. At lower levels, there are skills gaps related to various key basic skills, with Programme for the International Assessment of Adult Competencies (PIAAC) reporting that a substantial share of the population lacks proficiency in mathematics, literacy and digital skills (OECD, 2016b).

FIGURE 3.8 EDUCATIONAL ATTAINMENT OF 16 TO 64-YEAR-OLDS, 2005 AND 2017



Source: OECD, Eurostat

There is a well-developed technical and vocational education and training (TVET) system, which is delivered in vocational schools for young people, academic colleges, and adult training centres and on-the-job training. The ETF 2020 Torino Process underlines the impressive progress in technology-related pathways in the TVET system in recent years. As such, the TVET system at secondary and tertiary levels has become more of a valid provider of skills needed by the economy, in parallel and in cooperation with universities. However, room for further improvements exists, for instance by enhancing practical training in companies; as suggested by the OECD, new on-the-job training programmes in workplaces could be created as part of technological education in high schools, also expanding cooperation with employers (OECD, 2018b).

Nevertheless, as noted above, a high percentage of students enter tertiary education. This is important in the context of supplying Israel's high-tech sector with the skills it needs. Over recent decades, the number of people entering higher education has substantially increased, as has the number of institutions providing higher education. At the same time, many of the skills the agri-tech sector requires are relatively high-level ones, which are in demand in other sectors (and in other countries). The potential for skills shortages to arise is exacerbated by the retirement of many skilled workers who emigrated to Israel in the 1960s. While there is some scope for labour supply to be increased among Arab Israelis and Haredi men and women, the evidence points to the fact that the labour market is tightening (Fuchs and Epstein, 2019). And if the sector were to grow, there are more general supply-side constraints linked to the size of the labour force and the limited reserve stocks of labour that can be drawn on, especially so given the qualification level it requires of its workers.

Main findings of the chapter

- The agri-tech sector in Israel covers different subsectors from agriculture, food/drink manufacture, scientific R&D and wholesale and retail trade.
- The sector employs a substantial number of people and has growth potential. It is visible from the analysis of occupational structure that it is experiencing increasing demand towards higher-level skills to drive forward the innovation on which the sector depends.
- Some of the skills on which it depends are likely to be in demand in other sectors such as science, technology, engineering and mathematics (STEM) related to biotechnologies. These sectors are typically ones which most countries experience shortages in, given that the supply side typically struggles to keep up with the pace of change in demand (i.e. the demand for new skills to work with new technologies).
- At the same time, sight must not be lost of the substantial number of people working in jobs where skills levels are relatively modest. It is likely that these people will also experience changes in the skills content of their jobs resulting from technological change.

4. KEY DRIVERS OF CHANGE IN THE SECTOR

Key issues covered in this chapter

- Analysis of the main drivers of change currently shaping the sector, such as trade, global value chains, new technology, digital tools, the greening of the economy and climate change.

The preceding chapter outlined the broad contours of skills demand in the agri-tech sector. In moving towards a more detailed analysis of skills needs – i.e. what are the actual skills people use in their jobs and how are they likely to change? – there is a need to understand the factors that are shaping change and the technologies associated with that change. But it is not just about analysing technological change. There is also a need to consider a variety of non-technological factors which will shape the future as well. In this chapter, consideration is given to the range of technological and non-technological factors shaping change in agri-tech.

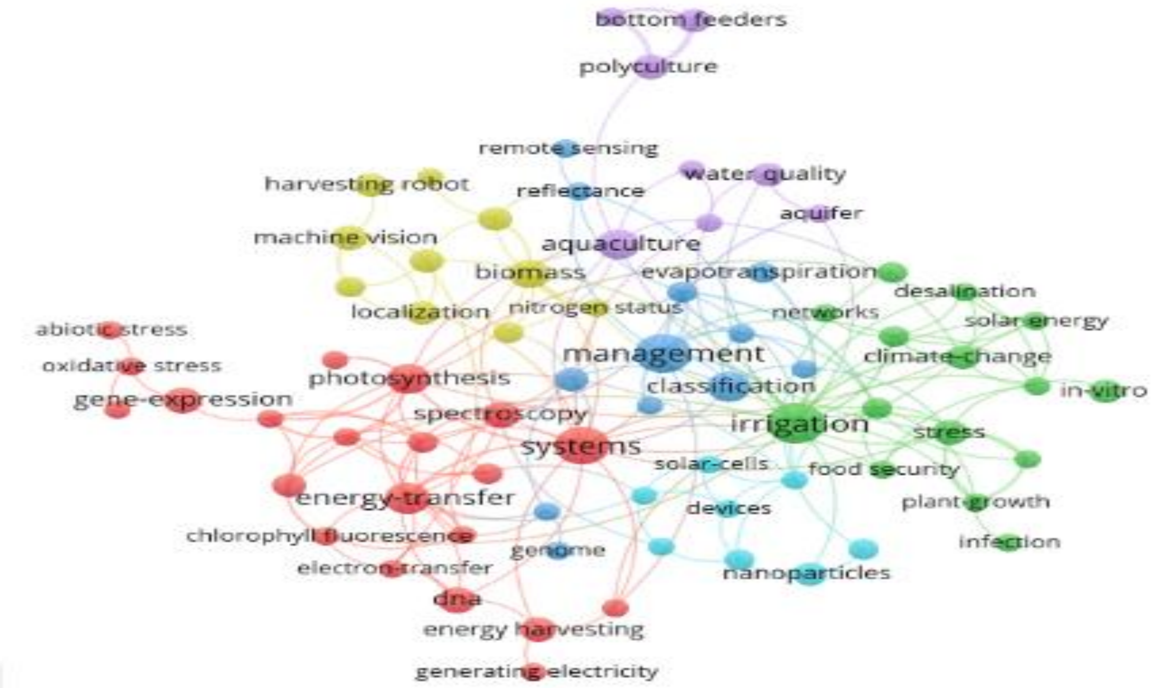
4.1 Identifying drivers of demand

Rapid technological development is a major factor influencing the demand for skills. Technology does not account for everything. There are many other factors such as social, economic and environmental ones which shape future skills needs.

In order to study all the possible drivers of change, the entire Scopus and Web of Science databases were searched to find scientific papers and conference proceedings related to the agri-tech sector in Israel. In addition, websites were scraped for direct information and access to various studies. The documents gathered were scanned with text mining tools to extract the most relevant keywords which were then clustered by using network analysis.

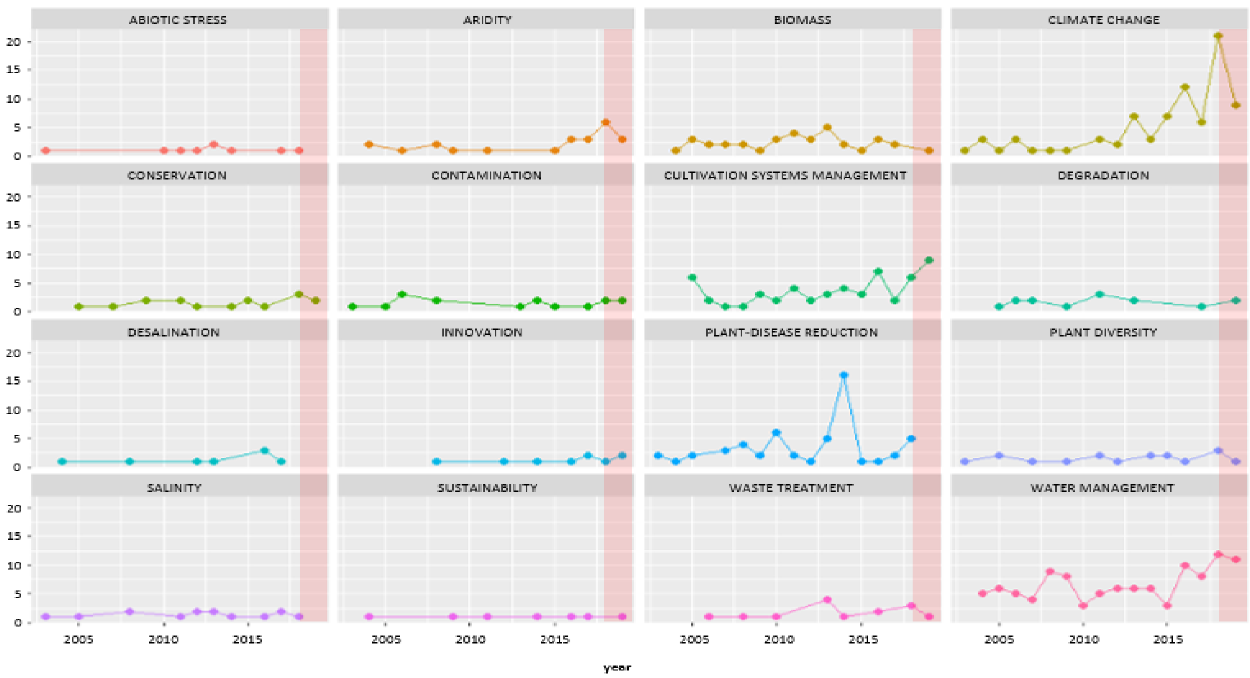
Figure 4.1 provides a snapshot of such a clustering process: for example, the green group of connected terms clearly points to the semantic area of climate change. Browsing the network of correlations between the topics provides an understanding of the relationships between them. For instance, attention to climate aspects could turn into attention towards renewable energy, which then leads to the development of technologies such as solar cells (light blue cluster). The inspection of all clusters (Figure 4.1 shows only a subset) provides the basis for identifying potential candidates for drivers of change.

FIGURE 4.1 NETWORK DIAGRAM OF KEYWORDS RELATED TO THE AGRI-TECH SECTOR IN ISRAEL FROM THE ANALYSIS OF SCIENTIFIC PAPERS



A driver of change is considered to be a factor that strongly influences the evolution of future scenarios. By combining the clustering with an analysis of change over time (i.e. the number of scientific papers each year), it is possible to identify whether one is observing phenomena which are increasing (see Figure 4.2 for examples).

FIGURE 4.2 DISTRIBUTION OVER THE YEARS OF KEY CONCEPTS IDENTIFIED FROM THE ANALYSIS OF SCIENTIFIC PAPERS ON AGRI-TECH



From the text mining described above, a series of drivers of change were identified. Table 4.1 provides the full list with associated subtopics.

TABLE 4.1 ASSOCIATION BETWEEN DRIVERS OF CHANGE AND SPECIFIC SUBTOPICS

Driver of change	Type	Specific topics (with potential implications for skills demand)
Regulations affecting the market for agricultural products	Human – external (mainly global rather than national)	Cannabis cultivation
Government backing of specific areas/ investments in R&D	Human – internal (policy-related)	Crop resistance Genetic engineering International sales
Consumer awareness of/ regulations for specific problems	Human – internal (policy-related)	Toxicity assessment Health risk assessment Denitrification Decontamination Pesticides formulation
Technological innovation	Human – external (mainly global rather than national)	Genetic engineering Robotics for harvesting Machine vision Solar technologies Energy harvesting
Climate change	Environmental – external	Management strategies Crop irrigation management Soil management Environmental management and assessment Thermal impact Air pollution impact Emissions mitigation strategies Renewable energies (relevant to agriculture: solar, biomass, etc.) Weather forecasting Plant stress Pest control Aridification
Aridity/water scarcity	Environmental – internal	Irrigation systems Water conservation Watershed management Water use efficiency Water stress detection Water purification Water quality management Aridification Arid agriculture expertise Crop resistance Genetic engineering Wastewater reuse
Contamination/pollution	Environmental – internal	Toxicity assessment Health risk assessment Decontamination of soil Denitrification Water toxicity Pesticides formulation
Plant diseases	Environmental – external	Fertiliser deficiencies Biology of diseases Weather changes Pesticides and pest control
Need for waste management	Environmental – internal	Wastewater reuse Waste heat recovery Bio-waste management Waste disposal Management and logistics

The results obtained were validated and supplemented by the interviews with both stakeholders and companies during the field missions. This led to the identification of one additional driver of change not captured by the text mining: the Israeli innovation ecosystem, and to an improved appreciation of one cluster initially considered of less significance: market factors. Before elaborating further on the technological drivers of change, the principal non-technological ones are described.

Israel's favourable innovation ecosystem and culture

As both the desk research and the interviews pointed out, the sector benefits from the presence of a thriving ecosystem. One main factor is the accessibility to investment opportunities from both national and international actors. The cultural aspects are also important, in particular the entrepreneurial attitude (widespread and encouraged in academia as well, with researchers allowed to be involved in companies) and the connectedness of the innovation community, which favours the exchange of ideas and collaboration, as well as the transfer of knowledge across different industries. Indirect benefits derive from the availability of technology providers (combined with the transferability of ICT skills) and the mobility of managers and professionals who are able to readily move between sectors.

Market factors

The agricultural sector, traditionally characterised as one with low profitability, is undergoing a significant transition in terms of its market position. According to the interviews with stakeholders and companies, recent years have witnessed a surge in mergers and acquisitions and a resulting concentration of market power. Moreover, the big players are often not established agriculture companies but come from adjacent businesses such as food manufacturers looking to secure their supply of inputs, and technology providers looking to diversify the markets in which they operate. As remarked on by various stakeholders, another important economic factor is the increase in labour costs which makes Israeli products less competitive in the global market. This has pushed companies towards increasing efficiency by adopting management and production strategies borrowed from industrial processes including the use of automation.

Investments (private and public) and government backing

Israel is an attractive destination for international investors who have played a big role in supporting the agri-tech sector. From interviews, it emerged that agriculture tends to have long investment cycles (i.e. the period over which returns will be realised) which has tended not to be attractive to private investors who typically prefer to invest in ICT (and, to a lesser extent, genetics or food tech) where returns are accrued faster. A similar issue is encountered with public investments: some stakeholders stated that agri-tech has been high on the national agenda for the last 20 years, but now the government's priorities have shifted to high-tech sectors, such as electronics, ICT, medicine and security.

International and national regulations affecting the market for crops

Changes in norms and trade regulations can create new opportunities for business but also challenges which can undermine a company's business model. One striking example which emerged from the text mining concerns the legal cultivation of cannabis. Since the 2016 reform, over 200 firms have applied for a licence to grow cannabis; in addition to 8 existing farms, 70 start-ups have been created to serve a market worth an estimated ILS 4 billion. The government is investing in research related to cannabis's medical application, but interviewees stated that there was at present a degree of uncertainty about the regulations which hampers the development of cannabis seed banks.

Similarly, the ban on genetically modified organisms in many countries affects entire market segments. As an example of a new business which has stemmed from the search for alternatives when a regulation bans use of a product, one company which was interviewed reported that the phasing out of the methyl bromide pesticide was one of the factors which prompted it to develop new grafting techniques.

Consumer awareness and national regulations

Consumer choices are a relevant driver of change. The increasing preference in the western world for healthier and tastier foods, coupled with traceability and sustainability (which emerged as a finding from the data analysis), clearly affects the way agriculture produces crops and vegetables. Interestingly, this type of change is directly related to innovation and technology used to bring about greener production and improved animal welfare. The increased attention given to environmental and health issues creates new opportunities for business and, thereby, new jobs. For example, the stricter regulations introduced regarding pesticide residues in food not only affected pesticide producers and farmers but prompted, as reported in the interviews, the development of devices to monitor such residues which can potentially serve the global market.

Climate change

This factor is a composite driver with many facets, ranging from energy production to the modification of ecosystems, from delayed growing seasons to the spread of pathogens (see Table 4.1 for specific topics emerging from the data mining). Given its wide-ranging impact on agriculture, it is a particularly relevant driver to focus on. It has implications for skills needed in relation to issues such as renewable energy, soil management, weather forecasting and pest control. The text mining analysis showed an impact on agriculture with a nationwide effort to mitigate its more adverse impacts.

Shortage of resources (e.g. water)

Having to cope with a shortage of national resources, most notably water, has been a factor driving innovation over many years. Recently the problem has been further exacerbated, as revealed by the text mining analysis, by salinisation and contamination. To overcome these problems, Israel has come up with several key innovations such as the construction of a national water conveyance system to connect all water infrastructure, the reuse of treated wastewater for irrigation, and large-scale desalination. The success of the strategies put in place to deal with resource shortages is influenced by levels of government support and/or the availability of private investment capital.

Contamination and pollution of soil and food

The text mining revealed a rather large cluster around the issue of contamination and pollution. Even though toxic waste disposal in Israel has significantly improved over the past few years, it is still not at a satisfactory level. Poisonous materials which seep into the soil are a threat to the aquifers and a potential health hazard to surrounding communities. Furthermore, highly toxic pesticides continue to be used in Israel with a negative impact on soil and the products themselves (thus with potential market implications).

Waste management (and possible reuse)

Agriculture is both affected by other sectors' waste and is a net producer of waste itself. Upcycling of agricultural waste as an input into other value chains can be a source of new business and jobs.

Spread of new plant diseases

The spread of new, unforeseen, diseases or the re-emergence or mutations of old ones may compromise entire crops and therefore requires immediate targeted action. The text mining revealed that other factors such as climate change that affects pathogen development can worsen the impact.

4.2 The role of innovation

The discussion below is about technology as a driver of change. It is important to remark that the focus is not about technology per se but about its potential to influence, through its adoption, the demand for employment and skills. From a methodological point of view, the interest is in the functional use of technology rather than its performance or actual content. Every technology exists to fulfil a purpose for the user, solve a real-life problem or provide an advantage. In the theory of engineering design, the purpose is referred to as the *function* of the technology.

The current literature on the future of work and skills focuses more on the potential of new technologies, but existing empirical evidence is very limited on the actual impact of technology use in companies. By looking at the functional use of the technology – i.e. on the actual problem it solves or the actual beneficial uses it enables – it is possible to study its real impact in the real world. Moreover, even if a specific technology is not eventually adopted, if the need expressed by its functional use is real, in the long term, another substitute technology will appear. In this sense, the functional approach allows for an understanding of the obsolescence and/or resilience of certain jobs or occupations, and forecasting or even designing the shifts occurring between jobs and the trajectory of skills from one job to another.

The first analysis is a general one and concerns the competitive potential provided by technological development. One indicator of the innovative capacity of a country is given by its capability to invent, expressed by the patents filed by companies and research centres. Of course, not only quantity but also the quality is important, yet even the number of patents provides a useful measure of innovation.

Figure 4.3a shows the patents filed over the years in the agri-tech sector in Israel, whereas Figure 4.3b compares the latter with the total number of filed patents in Israel. Figure 4.4 compares the number of agri-tech patents filed in Israel versus the total number of patents worldwide related to the agri-tech sector. As can be seen from Figure 4.3a, innovation in agri-tech is growing in absolute terms in the country and is indeed a driving force for the sector, yet not at the same pace compared to the rest of Israel innovation (4.3b) ; even though the number of agri-tech-related patents shows significant growth over the years, the gap with the total number of Israeli patents (which is an indicator of overall investment in R&D) has increased over the years too.

FIGURE 4.3A ISRAELI AGRI-TECH PATENTS OVER THE YEARS

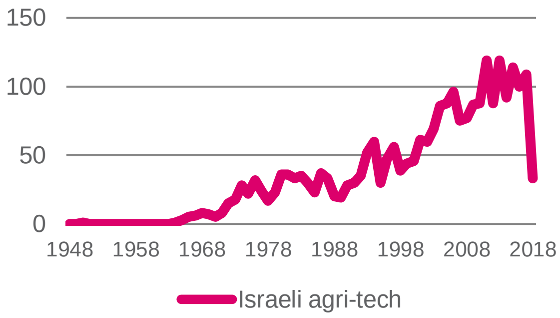
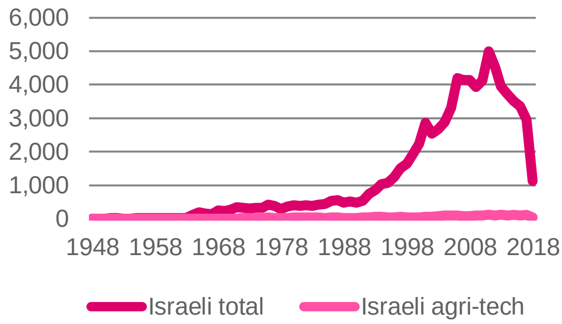


FIGURE 4.3B COMPARISON WITH TOTAL OF ISRAELI PATENTS



This is consistent with the general picture: although Israel's agricultural sector is highly developed, its importance in the overall economy is relatively small. Israel's agriculture accounted for about 6% of GDP in 1979 and shrunk to about 3.3% in 2014 (Watchmen of Israel, n.d.). In 2019, it represents around 2.5% of Israel's GDP. In the 1970s, agricultural patents accounted for around 8% of the total, and the rate of growth was higher than average, indicating that agriculture was a driving force of innovation. In the 2010s, agri-tech patents accounted for 2.6% of the total Israeli patents because the main driver of innovation became ICT. This is confirmation that investments are shifting to other faster-developing sectors.

While the focus for innovation has shifted to other economic sectors, the possible positive externalities of agri-tech-related innovations need to be considered when framed in the context of international trade. The products and services related to such innovations can be exported worldwide and potentially open new markets for Israeli companies (for example, Israel is already one of the biggest exporters of genetically modified seeds). This potentially leads to the creation of jobs – and the demand for skills – related to roles such as export/import managers, sales personnel and international customer services. To study such a hypothesis, it is important to consider the worldwide competitive situation (as illustrated in Figure 4.4).

FIGURE 4.4A WORLDWIDE AGRI-TECH PATENTS OVER TIME

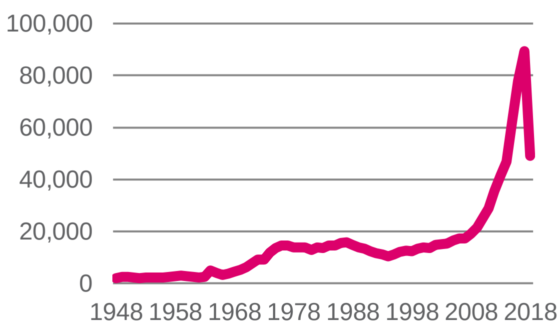
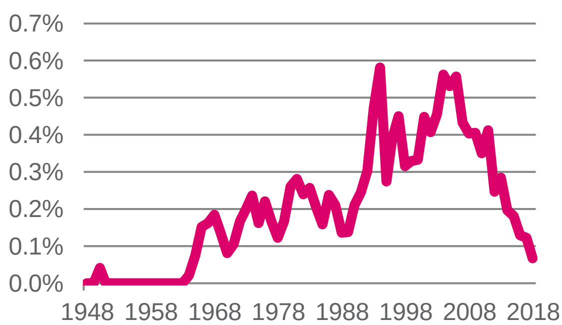


FIGURE 4.4B PROPORTION OF GLOBAL AGRI-TECH PATENTS STEMMING FROM ISRAEL



Even though the number of Israeli agri-tech patents, if compared to the total number worldwide, is a relatively small value, it is still possible to see how this fraction steadily increased over the years until around 10 years ago. In other words, Israel has been increasingly contributing to global agri-tech innovations, keeping it at the frontier in R&D. Over the last 10 years, however, there has been a steep decrease in relative importance. Innovation has experienced exponential growth worldwide, driven by the precision agriculture revolution; even though Israeli patent filing has grown in this period, it has done so at a slower pace than that observed worldwide. In the medium term, this may lead to a loss of competitiveness, with implications for jobs and employment. If this manifests itself, then the potential positive spill-overs from increased international trade may well be offset.

4.3 Evolution of the technology landscape

Identifying new technologies

Various data sources have been analysed through text mining techniques, providing insights into the ongoing changes in the technology landscape of the Israeli agri-tech sector. First of all, the vast majority of innovations are occurring in the subsectors listed in Table 4.2, where it is reasonable to expect, in the near future, a change in the demand for both new jobs and new skills. The list is ranked according to the intensity of the innovative activity in descending order.

TABLE 4.2 FAMILIES (CLUSTERS) OF ISRAELI AGRI-TECH PATENTS (RANKED FROM THE HIGHEST TO THE LOWEST)

Number of patents	Cluster
686	New varieties of plants
642	Horticulture, viticulture and floriculture
417	Irrigation systems
366	Pesticides
318	Microbiology
185	Biochemistry
182	Harvesting, transport and storage devices
108	Dissemination and substance distribution devices
104	Animal entrapment or removal devices
88	Sensors and measuring devices
78	Fertilisers
77	Soil processing devices
72	Monitoring devices
56	Measurement devices and biochemical tests
39	Data analysis
35	Water treatment

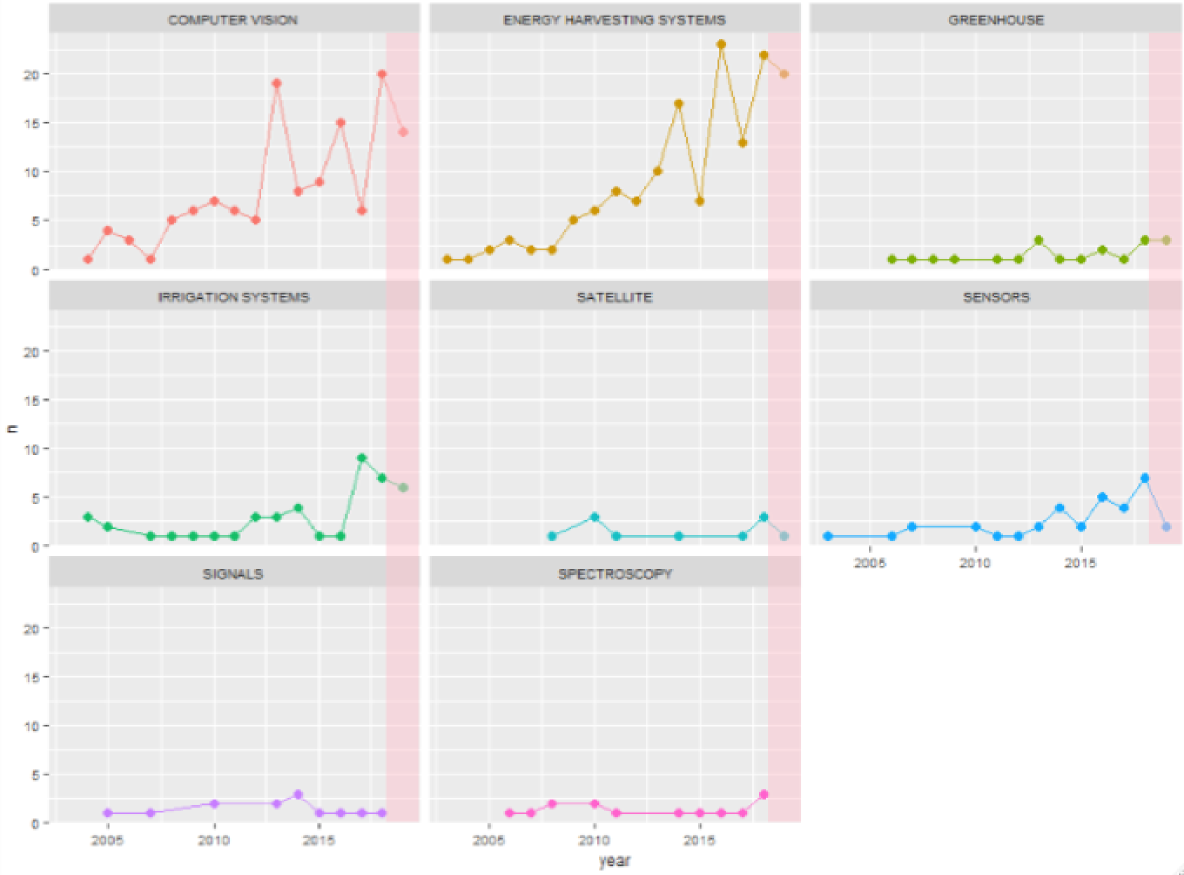
It is clear that more than 60% of agri-tech patents belong to four clusters: new varieties of plants; horticulture, viticulture and floriculture; irrigation systems; and pesticides. This is consistent with the analysis of the drivers of change in Section 4.1, as well as with the idea of the functional use of technology. For example, the cluster about irrigation systems reflects the need to manage issues such as frequent droughts, desertification of agricultural land and depleting resources. Water scarcity is considered the primary limiting factor in Israel’s agriculture (Megersa and Abdulahi, 2015), which requires innovative solutions to be found.

As for the actual technologies that have been or are being introduced, the following list contains all the most recent and most active ones within each of the above clusters, as determined from the text mining analysis (note: the same technology can actually appear in more clusters, which will increase its significance):

- irrigation systems (e.g. drip irrigation) and devices (e.g. sprinklers, drippers and valves);
- water treatment technologies;
- image analysis, computer vision (e.g. image acquisition and processing, and object recognition);
- image capturing devices (e.g. cameras and interferometers);
- data analysis (e.g. big data analytics software);
- energy harvesting systems (i.e. devices that capture environmental energy to power small electronics – see glossary);
- biomass production (i.e. the use of agricultural products or waste to produce fuels);
- solar technologies (e.g. solar cells and thermal applications);
- robotics (e.g. harvesting robots and agribots);
- drones (e.g. unmanned aerial vehicles, docking and charge stations);
- agriculture machinery and equipment (e.g. tractors, rollers, shredders, belts and mowers);
- control systems;
- sensors and detectors (e.g. in-soil and in-tree sensors);
- spectrometry (i.e. instruments to determine chemical compositions by measuring light emissions – see glossary);
- dedicated processors (e.g. nanochips);
- signal processing devices;
- pesticides (e.g. fungicides);
- fertilisers;
- biochemistry (e.g. alternative proteins);
- bioinformatics (i.e. the study of biological properties through computer science techniques – see glossary);
- genetics (e.g. plant genetics platforms and new seeds);
- microbiology (e.g. bioreactors);
- greenhouse technologies (e.g. heat delivery);
- animal trapping devices.

Changes in the citing of various technologies gives an indication of key trends (see Figure 4.5).

FIGURE 4.5 TEMPORAL TRENDS FOR THE CITATION OF SPECIFIC TECHNOLOGIES



A few comments are necessary to explain the above list of relevant technologies and the associated temporal trends. First, while the presence of certain technologies, such as irrigation systems, could have been easily predicted given what is already known about the country, other occurrences are less obvious and would have been more difficult to determine without text mining and clustering techniques, for example in the case of energy harvesting systems (related to the renewable energy cluster) or spectroscopy, a predominant word in patents related to the cluster of sensors and measuring devices (spectrometers are being adopted by farmers, for example, to manage forage dry-matter fluctuations as they happen and consequently maximise production and income). It has to be noted that although irrigation systems have a total number of 417 filed patents and therefore are considered a relevant cluster, its overall temporal trend does not show any significant growth over time with the exception of a specific technology: drip irrigation. The use of drip irrigation technologies in Israel has contributed to a 1 600% increase in the value of products grown over the last 65 years.

Second, some technologies seem to be relevant because of their numerical occurrence in the data, as in the case of the already mentioned irrigation systems or that of pesticides. Other technologies, such as data analysis and water treatment technologies, present weaker signals but are included as relevant since they reveal a fast-growing trend. More than half of the water used in irrigation comes from the recycling of 86% of Israeli wastewater, which is considered the second most important component of the Israeli strategy to overcome water scarcity and sustain agriculture in arid regions. Also of interest are vehicle guidance and image processing systems (also appearing in computer vision). Machine learning and deep learning algorithms are having a major impact on these technologies with various imaging techniques being developed to solve problems in multiple fields of agriculture (Pandurng and Lomte, 2015). For instance, image analysis is currently being used to detect nutrient deficiencies in plants, assist pest detection, and inspect fruit quality.

Finally, a high recurrence of certain technologies can have a two-sided explanation. For example, part of the innovation related to pesticides is aimed at developing new molecules active against insects, but at the same time, there is increasing innovative activity that is trying to solve the problem of pesticides disproportionately used in Israeli agriculture. A report by the group Forensic Architecture from July 2019 found that aerial herbicides have destroyed entire swathes of formerly arable land reaching to the Gaza territory (IMEMC, 2019). According to another report, the use of pesticides and insecticides in Israeli agriculture is among the highest in the world. Remnants of chemicals in fruits and vegetables may create potential risks for human health (Makover-Belikov, 2019). The increased concern about this problem is consequently leading to greater technological innovation – observed in the patent data – to monitor pesticide residues. For instance, a recent 2019 article reveals the invention of a device which is capable of detecting pesticide residues in food in real time (Klein Leichman, 2019).

Transversal technologies

Table 4.3 shows the occurrence within the data of the relevant technologies (some of them have been merged in one cluster) in the various subsectors. As can be seen from the table, a few technologies, in particular computer vision, control systems and sensors, are not just growing quickly but their application is also transversal, affecting almost all the above-mentioned subsectors.

Given that the knowledge of a certain technology is key for its use, there is a clear correlation between transversal technologies and transversal competences (see glossary). The notion of transversality has various implications for employment and skills. Transversality relates to:

- having knowledge of related technologies (i.e. being able to work across a range of interrelated technologies); and
- having knowledge of using technologies in different settings (i.e. working with technology in different sectors or subsectors).

The implication of transverse technologies in relation to skills is explored in the next chapter.

TABLE 4.3 HOW TOPICS/TECHNOLOGIES ARE LINKED TO SUBSECTORS (AS INDICATED BY PATENT CLUSTERS)

	New varieties of plants	Horticulture, viticulture	Irrigation systems	Pesticides	Microbiology	Biochemistry	Harvesting, transport, storage	Substance distribution	Animal entrapment or removal	Sensors and measuring devices	Fertilisers	Soil processing devices	Monitoring devices	Measurement and tests	Data analysis	Water treatment
Robotics		■					■			■		■	■		■	
Vehicles (drones)							■		■	■		■	■		■	■
Irrigation devices		■	■													
Valves		■	■										■			
Control systems			■				■	■	■	■	■		■		■	■
Charge stations							■						■			
Microchips				■						■			■		■	
Trapping devices									■							
Signals							■		■	■		■	■		■	
Spectrometer										■			■			
Processor		■							■	■			■		■	
Image analysis	■						■	■	■	■			■		■	■
Genetics, cells, etc.	■			■	■	■					■			■		
Fertilisers, pesticides, etc.		■		■				■	■		■					
Sensors	■	■	■				■	■	■	■		■	■		■	■
Agricultural machinery		■					■					■				
Plants and flowers	■				■		■									
Greenhouses		■														

Potentially disruptive technologies

In the interviews with key stakeholders and companies, mention was made of those technologies which, in the interviewees' opinion, are likely to come on stream in the foreseeable future which would transform elements of the agri-tech sector, in other words 'game-changers'. These identified technologies are listed below.

- AI/machine learning applied to predictions or simulations of real cases will allow better, faster and more efficient production of results. AI adoption will benefit many areas, from precision agriculture to genetics to bioinformatics. Experts will always be needed to generate and interpret data, yet the introduction of such technologies will either lead to a decrease in the number of people required or will allow them to tackle a wider range of issues.
- CRISPR is a genome-editing technique that allows greater precision with respect to other approaches (see glossary). Technical advantages aside, it has less controversial implications and thus may overcome the public's current negative perception.
- Vertical/indoor growing will allow control of all parameters related to plant cultivation, even the most expensive ones, such as climate ('now we adapt to climate, tomorrow we control it'), and it will be possible to apply factory-like methods to agriculture. Moreover, it will greatly reduce the issues of plant protection (hence contamination) and water consumption.

- Improved resolution of satellite imaging (coupled with AI) will allow measuring of relevant parameters (such as plant or soil condition) without the need for hardware/sensors on the field.
- Robots and mechatronics will reduce the need for manual labour and increase productivity. Harvesting robots have the potential to reduce the need for agricultural labourers.
- Molecular delivery systems (systems for transporting a beneficial compound into a biological system in an efficient and localised way) will reduce the use of active molecules.
- New materials introduction has the potential to reshape almost any aspect of agriculture; examples include nanotechnology, biosensors (i.e. sensors made of organic material), microelectromechanical systems (MEMs, i.e. microscopic devices that could be introduced in biological structures) and electro-optics.

Technologies are also already in place which are likely to further transform the sector in the future.

- Currently, 9% of farms in the world are irrigated with precision techniques, such as drip irrigation (see glossary), due to the absence of pressurised water or electricity. Reaching the remaining 91% will lead to a real breakthrough even without inventing new techniques. Given the increasing water shortages in the world as a result of global warming, the wider application of drip irrigation could have a profound impact from both technological and societal perspectives.
- E-commerce is also being introduced to the agriculture value chain in Israel (as in the rest of the world) and has the potential to change the way business is conducted, providing, for example, direct access to the global market to local farmers.

Main findings of the chapter

- There are a wide range of technologies coming on stream which are likely to transform the agri-tech sector. Many technologies, not just digital ones, have shown a positive trend of adoption, with possible implications for related jobs profiles and skills.
- According to interviewees, certain technologies, from AI to indoor growing, have the potential to completely disrupt and reshape the production and business models of the sector. Moreover, the existing technologies which are already in place may further transform the sector if more farms adopt them.
- Transversal or cross-sectoral technologies (i.e. those required by various sectors or subsectors) are becoming increasingly apparent in the sector, as many technologies are interrelated, indicating the need for skills covering various technologies.
- Technology adoption is not the only driver of change. Other factors include Israel’s favourable innovation ecosystem and culture, the capacity to attract private and public investment and international regulation. Among environmental factors are climate change, resource scarcity, contamination and pollution, the problem of waste, and the possible spread of new diseases.
- Technical innovation is growing and will reshape the competences of workers leading to a shift of value from labour to knowledge and management. The way in which new technologies are introduced and the extent to which they sit side by side with older technologies potentially creates a complex set of skills demands.
- Positive externalities of innovation such as increased exports of products, services and technologies have the potential to create new jobs. However, the rate of innovation in agri-tech in the country is slowing down compared with the rest of the world.

5. ONGOING CHANGES IN JOBS AND SKILLS DEMAND

Key issues covered in this chapter

- Analysis of the main occupational profiles used in the sector and of the evolution of the skills content of some occupations as a result of the changes occurring in the sector.
- Analysis of new tasks and functions which have emerged in the jobs and/or occupations in this sector, as well as of the old ones that have disappeared (or are likely to disappear).
- The impact of the drivers of change on labour and skills demands in the sector, and whether such changes require higher levels of the same skills or completely new sets of skills.

While the previous chapter looked at the drivers of change in the agri-tech sector and the associated technological changes, this chapter focuses on the implications of these changes. From both the data mining and the interviews, it is evident that employees will be increasingly sought for two groups of occupations due to the changes being introduced into agri-tech: (i) technical or technology-related occupations (see Section 5.1); and (ii) business services and related occupations (see Section 5.2). Section 5.3 discusses new skills needs for existing jobs and new emerging jobs or occupations for both categories of occupations above. In addition, attention is given to jobs or occupations which may become obsolete. The last section (5.4) turns to the important role of soft skills in adapting to technological change. Overall, the analysis reveals that significant changes are taking place and will continue to do so in the context of a wide range of jobs in the sector resulting from the types of technological change described in the previous chapter.

5.1 Technology-related occupations

Identifying emerging jobs and skills needs

Technology-related occupations are those which involve competent employees managing and using a given technology. The key assumption is that the growing interest in a certain technology (as expressed by patents filed, discussion in scientific papers, and so on) is associated with a growing need for skills associated with the use of that technology. The scale of skills demand will depend on the adoption or diffusion of the technology, which may vary for a number of reasons (e.g. capital constraints), and the strategic decisions companies make regarding the organisation of work.

There are various possible ways to link the information on technologies derived from text mining to the possible future skills needs. The following procedure was used. The list of relevant technologies extracted from the literature (see Section 4.3) was compared, using semantic matching algorithms (i.e. algorithms able to find semantic connections between different concepts based on contextual information), to the occupations listed by ESCO. Each occupation in the ESCO database includes a description and a list of competences, skills and knowledge considered relevant (either essential or optional) for that occupation. The semantic algorithm looked for matches of each technology with all the concepts associated with an occupation. When a match was found, the occupation was considered associated with the technology. The entire procedure was automated by using ESCO's

Application Programming Interface (API), which allowed occupational data to be downloaded. Table 5.1 provides a few examples of the matching process.

TABLE 5.1 EXAMPLES OF THE MATCHING PROCESS FROM PATENT TOPICS TO ESCO SKILLS AND OCCUPATIONS

Topic from patents	Matched ESCO skill	Related ESCO occupation
Robotics	Robotics	Automation engineer
Robotics	Robotics	Electrical engineer
Robotics	Robotics	Industrial robot controller
Robotics	Robotics	Equipment engineer
Control+ system	Control systems	Electrician
Control+ system	Control systems	Electrical engineer
Control+ system	Control systems	Instrumentation engineer
Control+ system	Operate control systems	Mechanical engineer
Irrigation	Maintain irrigation controllers	Water engineer
Irrigation	Compute irrigation pressure	Irrigation technician
Agricultural+ machinery	Agricultural equipment	Agricultural equipment design engineer

Instead of starting from technologies (as extracted from patents) and then matching these with job profiles, an alternative methodology involved extracting profiles directly from papers about Israel's agri-tech sector. In detail, the way this can be achieved was by using a list of skills, tools and technologies found in the O*NET classification (this information can be easily downloaded from the online database) and then each one was searched for in the text of the scientific papers. Once skills, tools and technologies were extracted from the latter, it was then possible to refer to the O*NET occupations.

The following list collects the technical professional and associate professional occupations (i.e. ISCO groups 21 – science and engineering professionals; 25 – ICT professionals; 31 – science and engineering associate professionals; and 35 – information and communications technicians) that emerged from the data mining (merging matches from both ESCO and O*NET) – please note that the list does not imply a ranking of relevance or intensity; occupations are grouped simply according to their discipline:

- Automation engineer/technician
- Robotics engineer/technician
- Electronics engineer/technician
- Microelectronics engineer/technician
- Electrical engineer/technician
- Industrial robot controller
- Sensor engineer/technician
- Remote sensing technician
- Industrial engineer/technician
- Photonics engineer
- Software developer
- Data warehousing specialist
- Bioinformatics scientist
- Statistician
- Agronomist
- Biologist

- Optical engineer/technician
- Optoelectronic engineer/technician
- Mechanical engineer/technician
- Irrigation engineer/technician
- Water engineer/technician
- Drainage engineer/technician
- Agricultural equipment design engineer
- Aerospace engineer
- Microsystem engineer
- Solar energy systems engineer
- Wind turbine service technician
- Equipment engineer/technician
- Instrumentation engineer/technician
- Chemist and biochemist
- Botanical technician
- Biotechnical technician
- Soil and plant scientist
- Hydrologist
- Water resource/water treatment specialist
- Desalination technician
- Risk management specialist
- Information security analyst
- Geographic information systems (GIS) technician
- Radio-frequency identification specialist
- Atmospheric and space scientist
- Meteorologist

Many of the occupations listed above can be grouped according to three main branches of the occupational classification:

1. engineers and technicians in various fields: automation, robotics, electronics, electricity, mechanics, agricultural equipment, irrigation, water and drainage;
2. computer scientists (software developers) and various types of data scientists which include bioinformatics; and
3. agricultural professionals such as agronomists, biochemists, and plant and soil specialists.

There are also various occupations which have a clear relationship with agriculture but are generally associated with other fields, such as meteorologists and statisticians.

As well as looking at professional and associate professional occupations, i.e. highly skilled workers, it is also possible to look at medium-skilled occupations, in particular skilled workers (ISCO group 6 – skilled agricultural, forestry and fishery workers), tradespeople (ISCO group 7 – craft and related trades workers) and machine operators (ISCO group 8 – plant and machine operators and assemblers). The occupations listed below emerged as being related to technological change in agri-tech:

- Automated optical inspection operator
- Agricultural machinery technician
- Land-based machinery operator/technician
- Land-based machinery supervisor
- Surface-mount machine operator
- Vineyard machinery operator
- Mechatronics assembler
- Precision device inspector
- Irrigation system installer
- Sprinkler fitter
- Vineyard supervisor
- Arboriculturist
- Hop farmer
- Horticulture worker
- Pesticide mixer
- Pesticides sprayer
- Pest management worker
- Fertiliser mixer

The above lists highlight an important finding: digitalisation is not the only technological area that has a significant impact on skills. On the contrary, the picture which develops is one of various specialisations being in demand, from biotechnologies to engineering, plus a demand for those occupations traditionally associated with agriculture such as agronomists.

Skills required by technological professions

As well as looking at the occupations associated with technological change, there is a need to know which skills within those occupations are likely to be in demand. One can achieve this by looking at the skills listed for the occupation in ESCO. This is a straightforward exercise and is illustrated in Table 5.2.

TABLE 5.2 OCCUPATIONAL SKILLS NEEDS RELATED TO A TECHNOLOGY: THE EXAMPLE OF PULSE DRIP IRRIGATION

Starting technologies	Related occupations (ESCO match)	Related skills (ESCO match)
Pulse drip irrigation	Water engineer/irrigation technician	Design irrigation systems
		Operate irrigation systems
		Monitor irrigation systems
		Install irrigation systems
		Maintain irrigation systems

There are limitations to using ESCO. In many cases, it lists general skills (e.g. irrigation systems), while specific competences (e.g. knowledge of pulse drip irrigation) which effectively distinguish between more traditional roles and those pertinent to the new technologies are less well covered. Additionally, the competence level required (e.g. how much knowledge/ability in irrigation systems is required for each of the various occupations it appears in) is another critical factor which is not specified in existing classification systems such as ESCO. In addition to this, the technologies that are likely to be increasingly adopted in agri-tech may result in a demand for people to work in jobs or occupations which are new and not classified in ESCO, ISCO or other job classifications.

To address the limitations described above and obtain a more complete picture of the knowledge needed to master a given technology, additional information was obtained from Wikipedia (chosen for its accessibility, the comprehensive amount of information it contains, and the structured way it presents information). More precisely, for every topic (most recurrent terms found in patents) the corresponding Wikipedia page was downloaded using web scraping. Reversing the strategy, it was then possible to provide a more in-depth analysis of the specific skills that will be required in various technical jobs (as shown in Table 5.3).

As in the previous example, the drip irrigation technology was matched to the occupation of irrigation technician and its associated skills (according to ESCO), but here the occupation was further linked to more detailed information about the skills required to master drip irrigation and other irrigation systems.

It is important to note that not all topics/technologies which emerged from the patent analysis were matched to ESCO competences and occupations. For example, there was no direct match for the technology of charging stations for electrical vehicles. It is another indication that existing classifications may not as yet encompass references to all the new technologies.

That said, to complement the above analyses, job profiles related to technologies could also be extracted from online job postings in an automated way, i.e. through web scraping. More specifically, it was possible to search for all job offers (for this task, the global employment website Monster.com was used) which mention, say, charging stations, and extract details of the occupations where this technology was mentioned. Since this approach leads to results which are not readily cross-classified with standard occupational classifications (e.g. ESCO or ISCO), it was not pursued further in this study, but Table 5.4 illustrates the possible outcomes using the example of charging stations.

TABLE 5.3 EXPANDING OCCUPATIONAL SKILLS DATA PROVIDED IN ESCO: THE EXAMPLE OF PULSE DRIP IRRIGATION

Starting ESCO occupation	Skills associated by ESCO	Required knowledge inferred from Wikipedia
Irrigation technician	Design irrigation systems	Pulse drip irrigation
	Operate irrigation systems	Micro-irrigation
	Monitor irrigation systems	Nutrient film technique
	Install irrigation systems	Pressure regulator
	Maintain irrigation systems	Sprinklers
		Subsurface drip irrigation

TABLE 5.4 SELECTION OF JOB PROFILES EXTRACTED FROM ONLINE JOB POSTINGS RELATED TO CHARGING STATIONS AND ELECTRIC VEHICLES (WEB SCRAPING FROM MONSTER.COM, TECHNOLOGIES FROM PATENT ANALYSIS)

Technology not matched in ESCO	Matched occupational profiles in job postings
Charging stations and electric vehicles	Construction engineering project manager
	Facilities manager
	Electrician
	Survey instrument operator
	Software engineer
	Program manager
	Technician
	Electronic data interchange analyst
	Provider data configuration analyst
	Engineering manager for electric vehicles
	Shop equipment mechanic
	Diesel mechanic/technician
	Diesel or hybrid bus technician
	Power system engineer
	Electrical engineer
	Road technician
	Project manager
	Materials coordinator
	Functional safety software calibration engineer
	Controls engineer

Trends about skills levels and specialisation and the expected impact on labour demand

As is clear from the above discussion, almost all of the technology-related occupations require highly skilled or at least medium-skilled profiles. This, in turn, leads to the issue of how to train the required professionals, given that demand for them is expected to grow over the medium term (in line with the diffusion of the technologies) and the competences they must possess are very specific. Discussions with stakeholders and companies revealed the existence of two trends:

1. a tendency to be specialised in a specific technology but have the capacity to apply it transversally over different jobs (defined by one stakeholder as a 'T' profile); and
2. the merging of more than one occupational profile, or at least of the related competences, into one individual profession. As a consequence, the level of competence required by each worker will increase (or at least be broader), shifting the occupational structure towards more highly skilled profiles.

It is also worth noting that many of the technical occupational profiles are not only required in the agricultural sector (i.e. working 'on the field'), but are also required in those companies producing devices, machinery and technologies that are then used in agriculture. They are also important in delivering the services accompanying the deployment of the technologies, such as national and international sales and consultancy. As a consequence of the above, the volume of demand is expected to grow.

One recurring theme touched on by stakeholders concerns the risk of job losses due to substitution by software and/or robots. Technology-related profiles require, as discussed, a high level of expertise in very specific topics coupled with the ability to adapt to different scenarios and applications. Such jobs, therefore, are not likely to be at risk of substitution by automation.

Ranking occupations according to potential demand

In the case of technology-related occupations or jobs, it is possible to use data mining results not just to list occupations but also to estimate their relative relevance in the future labour market based on the technological trends described in Chapter 4. To do this, an assumption is made about the relevance of an occupation depending on:

- the technological transversality of the occupation (see Table 4.3), i.e. its importance grows if it has skills related to more than one technology or topics;
- whether the associated skills are essential or optional (as defined in the ESCO classification); and
- the weight of the technologies to which it has been matched, in terms of potential future use, as expressed by the normalised number of patents it appears in.

To assign an importance value to each job profile, the three conditions must be intersected as shown by the following formula:

$$\text{Importance of job profile } j\ (y_j) = \sum_{i=1}^{m} T_{ij}\, E_{ij}\, W_i$$

Where:

$$T_{ij} = \begin{cases} \mathbf{1} & \text{If technology/topic } i \text{ is linked to job profile } j \\ \mathbf{0} & \text{otherwise} \end{cases}$$

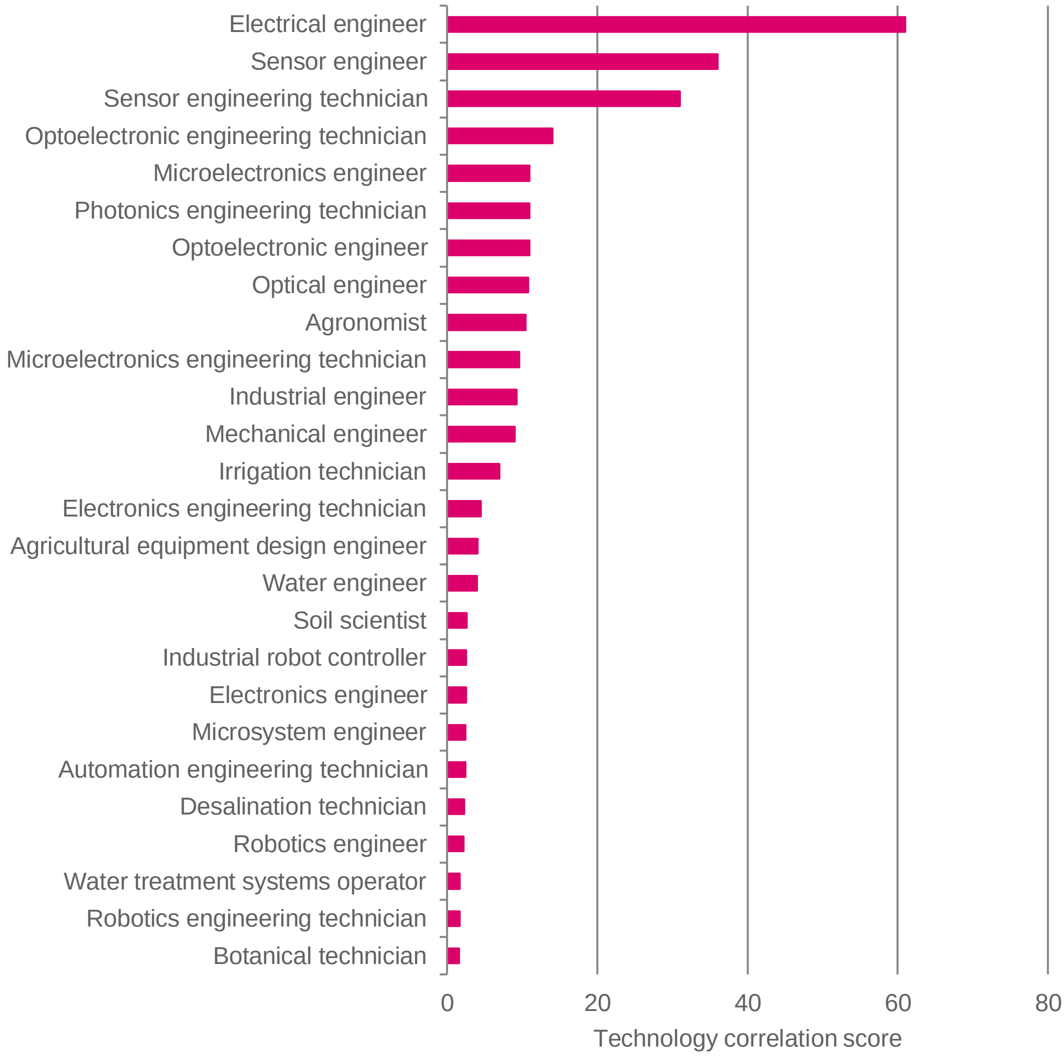
$$E_{ij} = \begin{cases} \mathbf{1} & \text{If technology/topic } i \text{ is essential to job profile } j \\ \mathbf{0.5} & \text{otherwise} \end{cases}$$

$$W_i = \text{Importance of the technology/topic } i$$

The values of t_{ij} are based on the analysis of Tables 4.3 and 5.1, the values of e_{ij} are based on a sensitivity analysis[6], and the values for w_i are derived from the intensity of the signal for the given technology derived from the patent analysis (see Section 4.3 and Figure 4.5). Once the scores have been calculated for all occupations, it is possible to visualise them using a bar plot which provides a visual understanding of the most relevant occupations in the agri-tech sector. The output is shown in Figure 5.1 (cut to relevancy score above 1). The ranking shown in this figure is indicative of which job profiles are of potential interest but not for the exact order or score. A full-scale analysis of the demand for jobs would require a deeper investigation, use a range of different approaches, and is beyond the scope of the present study. Yet it provides interesting insights: from the plot, it is clear that there will be a high demand for occupations such as electrical engineers, sensor engineers and sensor technicians, while occupations such as agricultural inspectors will still be needed in the future but perhaps less so than the more technology-oriented occupations mentioned.

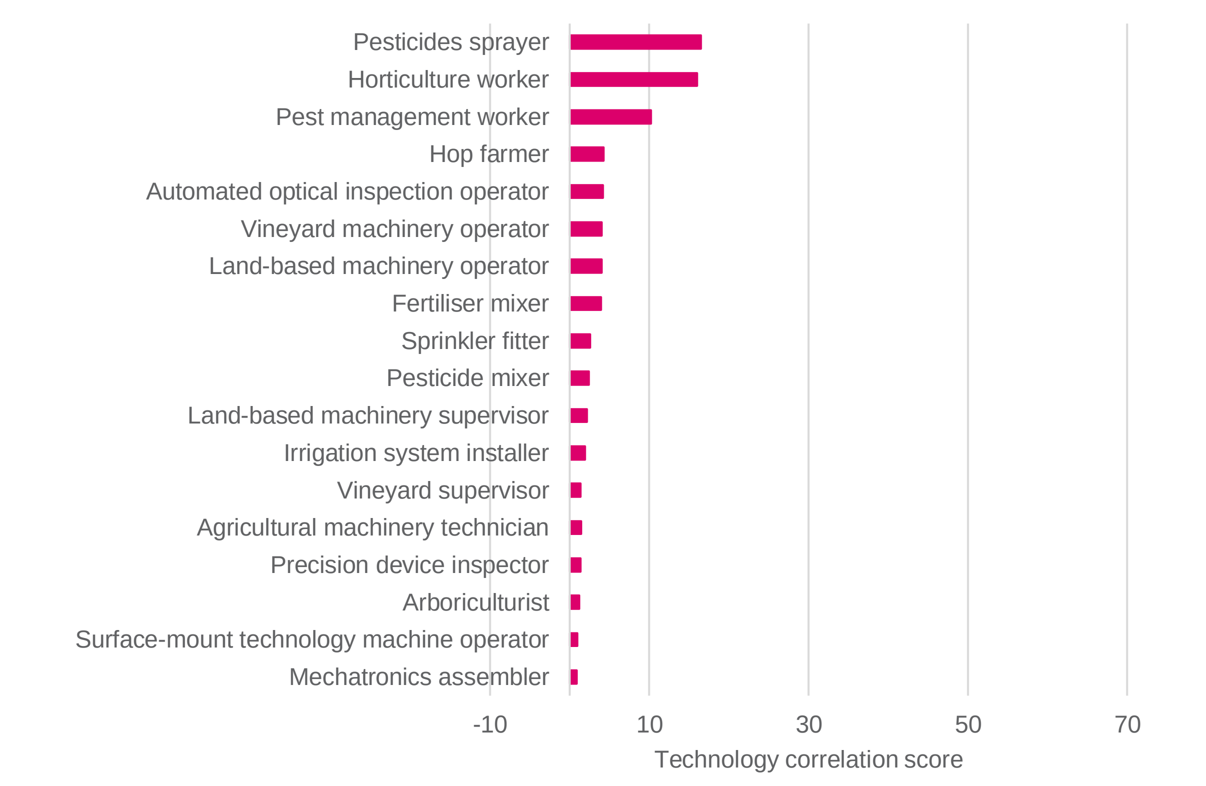
[6] Sensitivity analysis is an iterative procedure for defining the 'strength' of the link between technology/topic and job profile. In comparing the ranks obtained from the iterations, the lower value is set to 0.5 in order to generate a rank that is consistent with the association between job profiles and technologies.

FIGURE 5.1 RANKING OF RELEVANCE FOR PROFESSIONAL AND ASSOCIATE PROFESSIONAL OCCUPATIONS FROM ESCO (ON THE BASIS OF THE TECHNOLOGIES THEY CORRELATE WITH), CUT TO RELEVANCY SCORE ABOVE 1



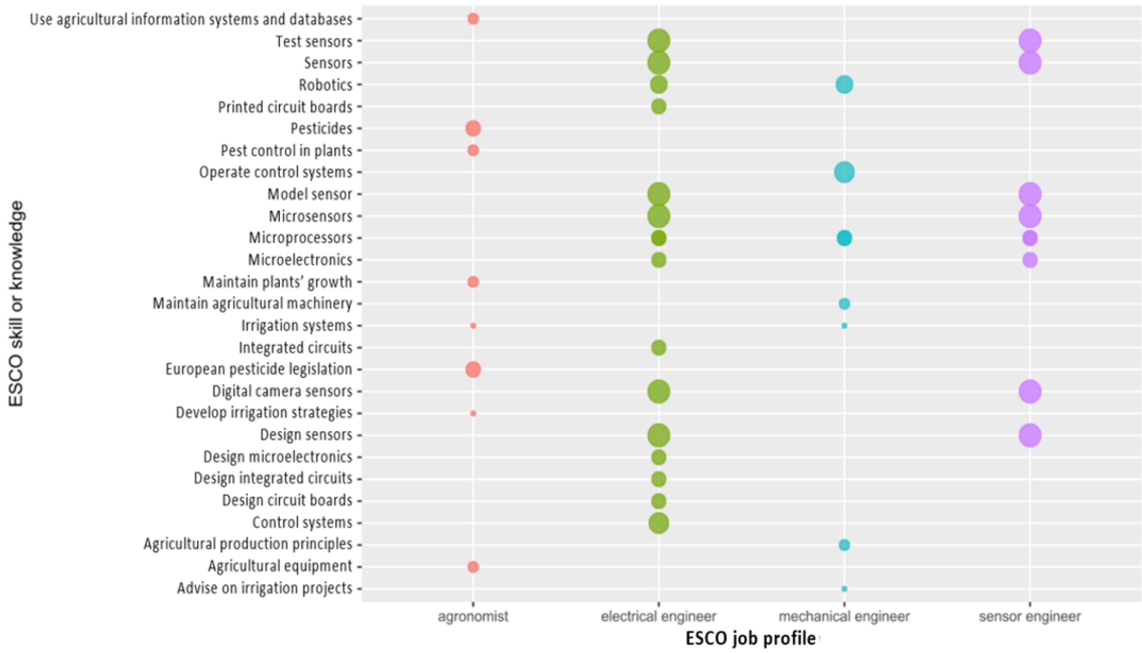
A similar analysis can be repeated for operators and tradespeople, with the same remarks about the meaning and the limitations of the ranking. The output is shown in Figure 5.2 (cut to a relevancy score above 1). In general, these occupations receive a lower score than professional occupations, yet it is still possible to assess their relative relevance: pesticide sprayer seems to receive a higher ranking than for example pesticide or fertiliser mixers, with the various types of operator in the middle with comparable scores.

FIGURE 5.2 RANKING OF RELEVANCE FOR MEDIUM-LEVEL SKILLS OCCUPATIONS FROM ESCO (ON THE BASIS OF THE TECHNOLOGIES THEY CORRELATE WITH), CUT TO RELEVANCY SCORE ABOVE 1



In addition, it is also possible to have a more detailed look at each occupation by analysing how they differ from one another based on which ESCO competence they are connected to. For instance, taking the electrical engineer (first for relevance for technical professionals) and three other more relevant occupations, agronomist, sensor engineer and mechanical engineer*,* a bubble chart can be used to visualise which skills or sets of knowledge are associated with the occupations, and how important these are based on the technology/topic to which they are connected (see Figure 5.3). In the figure, the horizontal axis lists the four ESCO occupations which are matched on the vertical axis with the competences ESCO assigns to them. Each competence is associated with a technology according to the procedure described at the beginning of the section, and the size of the bubble at the intersection indicates the relevance of the technology as determined by its occurrence in patents (the larger the bubble, the greater the relevance). Figure 5.3 provides evidence of how transversal skills affect the ranking: for example, the electrical engineer is in the top rank of the bar chart in Figure 5.1 as it has knowledge and competences related to many technologies, ranging from control systems to sensors to robotics. On the other hand, the traditional agronomist (as defined by ESCO classification) is a more vertical occupation, i.e. with skills and knowledge which do not extend beyond its field of study.

FIGURE 5.3 COMPARING FOUR JOB PROFILES IN TERMS OF THEIR SKILLS (ACCORDING TO ESCO CLASSIFICATIONS OF OCCUPATIONS AND RELATED COMPETENCES) AND WHICH COMPETENCES ARE THE MOST RELEVANT FOR EACH OCCUPATION (BASED ON THE ASSOCIATION WITH TECHNOLOGIES PROVIDED BY PATENT ANALYSIS)

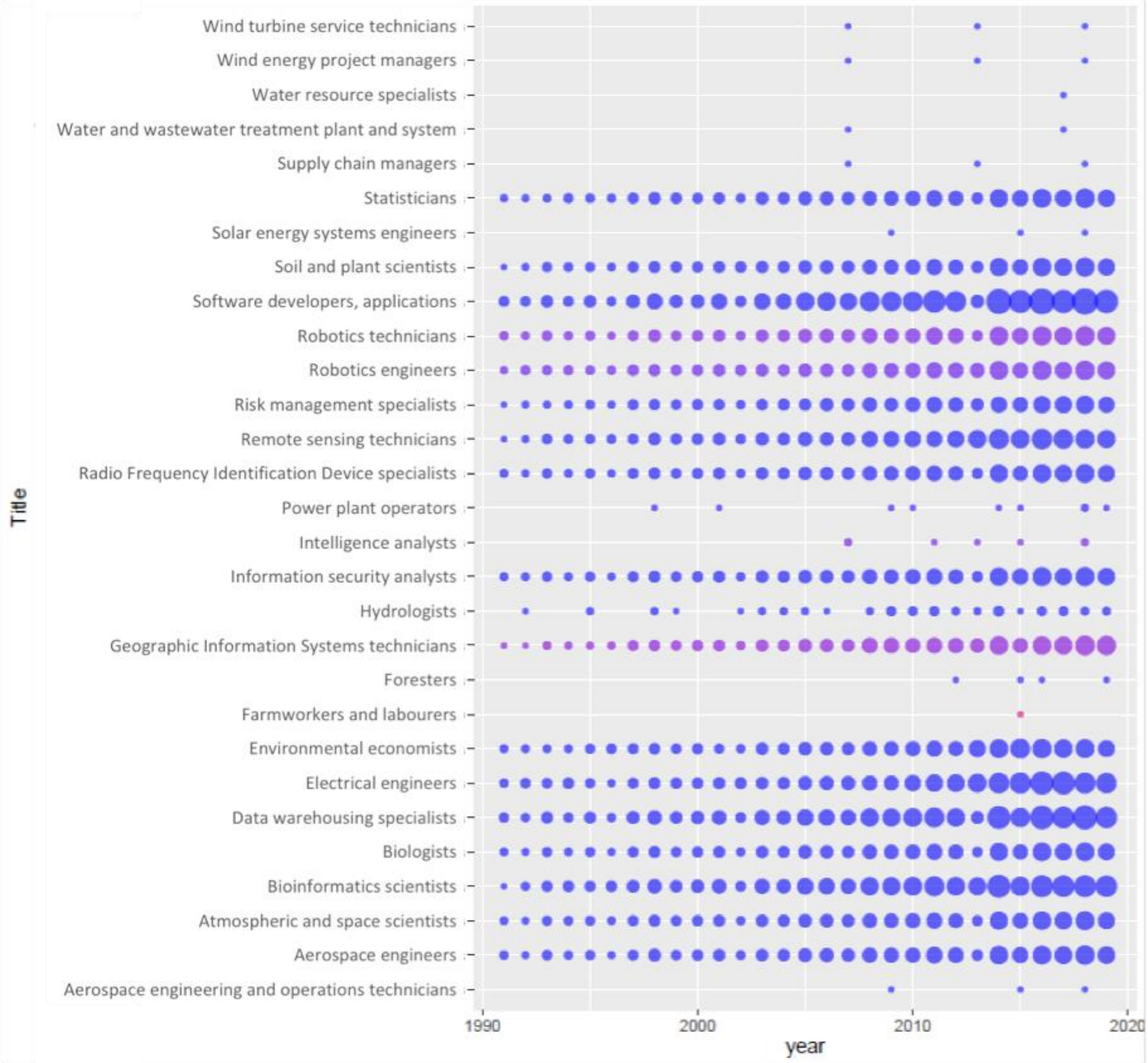


Finally, the ranking procedure applied to patents and ESCO occupations (in Figure 5.1) can also be applied to scientific papers and O*NET to obtain the results shown in Figure 5.4. This chart has a similar purpose to Figure 5.1, but instead of aggregating all contributions to create an overall ranking, an alternative visualisation has been chosen which shows the time trend of the references to each occupation. The size of each dot in the chart is proportional to the strength of the signal associated with a given occupation in a given year.

The results are consistent with those obtained through patent analysis.

The analysis using O*NET confirms the findings provided elsewhere in this section about the importance of robotics. Figure 5.4 confirms that robotics technicians and engineers seem to be of growing importance. The fact that environmental economists and atmospheric and space scientists are also growing is consistent with the analysis of scientific papers and websites, which often highlight issues surrounding climate change, pollution, carbon emissions, greenhouse gas and their impact on soil and plants. Other occupations which have emerged through the analysis shown in Figure 5.4 are aerospace engineers (probably connected with aerial vehicle technology found in patents); software developers and all profiles related to data processing (data analysis emerged in the scientific paper analysis and as a major patent cluster); and remote sensing technicians, which is evidence that remote sensing is growing. O*NET also provides for each occupation an estimate of the likelihood of its substitution by automation, indicated in Figure 5.4 by different colours. The possible obsolescence of occupations will be discussed in more detail in Section 5.3.

FIGURE 5.4 O*NET OCCUPATIONS AND THEIR GROWTH OVER THE YEARS IN THE AGRI-TECH SECTOR IN ISRAEL (AS EXPRESSED BY THEIR OCCURRENCE IN SCIENTIFIC PAPERS)



Ongoing trends for technology-related occupations

To sum up, as already stated, data for Figures 5.1, 5.2 and 5.4 is indicative of those job profiles which are likely to be associated with technological change in the future in agri-tech. According to both the data analysis and the interviews with stakeholders and companies, the technology-related job profiles most sought after are:

- software developers, algorithm developers, AI specialists, software engineers, computer engineers, data warehousing specialists;
- data scientists, data analysts, image analysts;
- bioinformatics scientists, cheminformatics scientists;
- various branches of engineering: electrical engineers, sensor engineers, remote sensing engineers, robotics engineers and aerial engineers. This also includes practical engineers (equivalent to level 5 of the European Qualifications Framework, i.e. ISCED level 5B and 4);

- agronomists, breeders, environmental economists, atmospheric and space scientists, entomologists, plant pathologists and physiologists, chemists, molecular biologists, laboratory technicians, toxicologists; and
- statisticians.

It is important to note the variety of the job profiles listed above, including many professions which can be considered as being traditional to the agricultural sector, such as agronomists and breeders, as proof that technology is reshaping all activities and processes.

There is also a second category of job profiles which are sought after. These are only indirectly related to technology. These profiles did not emerge from the analysis of technologies but are associated with the economic drivers of change. This reflects the fact that agriculture is shifting towards more efficient production, importing competences and techniques from the mass production processes commonly associated with the manufacturing sector. These job profiles are:

- industrial processes specialists, quality assurance officers, project managers, production managers and lean production specialists.

Due to their knowledge of transversal technologies (see Section 4.3), some of the job profiles are commonly sought in various agri-tech subsectors (as well as in other economic sectors), suggesting there may well be a degree of competition for people with the necessary skills. These include:

- control systems, sensors and computer vision technicians.

It is important to note that the notion of transversality has various implications for employment and skills. Since transversal technologies will likely be adopted in more subsectors, it is reasonable to expect a greater demand for related competences. For example, computer vision correlates with a wide range of applications, from disease prevention to harvesting; consequently, knowledge of computer vision is expected to be in higher demand as a skill needed within different occupations. The skill sets needed to operate transversal technologies in a practical context may be even wider due to the interconnection between transversal and subsector-specific technologies and the potential need to interact with various types of professionals (from truck drivers to satellite scientists).

The data analysis also detected some job profiles which might employ relatively few people, but they are mentioned with increasing frequency over time. These include:

- wind-related profiles (e.g. wind turbine service technicians), water resource specialists, water and wastewater treatment plant and system operators, and solar energy engineers.

Finally, there are those job profiles where demand may be diminishing because their tasks can be easily automated. These include:

- pesticide mixer and a few other types of manual operators.

The findings provided indicate how technology will shape the skills content of jobs. It is this degree of detail which is all-important to those who are responsible for anticipating future skills demand and designing training programmes. But it is not just the more technical jobs which need to be considered. As the next section reveals, the jobs of those involved in a range of business services will also be affected in the agri-tech sector.

5.2 Business services and related occupations

The analysis also identified a second category of profiles, i.e. non-technological jobs more related to business aspects such as management, marketing and sales, or export and trade. Such professions are related to particular agri-tech subsectors rather than technologies and are relevant to the business models that companies adopt and the way they organise production (cf. work organisation). These affect the adoption and use of technology in agriculture. Additionally, there is likely to be a positive employment impact on complementary activities such as advertising and management of international trade.

The same data mining analysis used to identify technology-related jobs was used to identify the business service occupations (from both ESCO and O*NET) listed below:

- Technical sales representative in agricultural machinery and equipment
- Wholesale merchant in agricultural machinery and equipment
- Wholesale merchant
- Import export manager
- Import export specialist
- Flower and garden specialised seller
- Specialised seller
- Agricultural machinery and equipment distribution manager
- Distribution manager
- Supply chain manager
- Project manager
- Farm manager
- Vineyard manager
- Crop production manager
- Agronomic crop production team leader
- Fruit production team leader
- Horticulture production manager
- Horticulture production team leader
- Agricultural inspector
- Environmental economist

In the above list, given the lower number of entries with respect to technology-related cases, high- and medium-skilled occupations have been grouped together; the list spans from managers (ISCO group 13 – production and specialised services managers) and business professionals and associated professionals (ISCO group 24 – business and administration professionals, and group 33 – business and administration associate professionals) for highly skilled profiles, to salespeople (ISCO group 52 – sales workers) and team leaders (ISCO group 61 – market-oriented skilled agricultural workers, limited to organisational and planning roles) for medium-skilled ones. Interestingly, clerical workers (ISCO group 4) are not captured by the analysis, given that their roles and competences are very likely not affected by the technological changes occurring in agricultural processes.

From the point of view of functions performed, two main distinct groups can be identified:

- salespeople, in various subsectors, both nationally and internationally, and
- management, including for processes rather than for subsectors, such as the supply chain and project management, and at all levels of the organisational structure.

There are also a few occupations which can be directly related to the drivers of change identified from the analysis of scientific papers such as environmental economists.

Trends about skills levels and specialisation and the expected impact on employment

There are a wide variety of skills attached to the business service roles, more so than for the technological occupations. For instance, management roles tend to require relatively high-level skills, but salespeople tend to need lower skills levels. Given the relational nature of business occupations, there is a lower risk of a decrease in employment due to automation. More likely, the technological input on the sales and management processes will reshape tasks and competences but not replace the human factor. It may, however, result in the jobs becoming broader – i.e. covering a wider range of tasks – because technologies may assist with some of their tasks.

The same analysis on skills required for each technical profile (cf. the example shown in Figure 5.3) could be repeated for business ones but would provide less interesting results. Given the minor number of technical competences required, the list of skills will coincide more or less with that listed by ESCO.

Attempts to rank occupations according to possible demand

The ranking of relevance – as provided by the correlation with technologies, according to the formula reported in Section 5.1 – can be applied here to show which business professions are more likely to be affected as a result of technology determined from data analysis (see Figure 5.5).

FIGURE 5.5 RANKING OF RELEVANCE FOR MANAGERS, SALESPEOPLE AND SERVICE WORKERS FROM ESCO (ON THE BASIS OF THE TECHNOLOGIES THEY CORRELATE TO), CUT TO RELEVANCY SCORE ABOVE 1

The ranking in Figure 5.5 is indicative of which occupations or jobs are likely to be related to the technological changes expected over the coming years. These are important jobs to consider. By considering the information provided in this figure in the light of the information collected during the interviews with key stakeholders and employers, the business occupations which are most likely to be in demand are listed below:

- salespeople: according to interviews, these are in high demand; in some companies, they account for 50% of the workforce. In export-oriented businesses, many of them are locally based, i.e. in the export destination countries. Another important aspect is that they should have experience in agriculture or as agronomists to gain the trust of farmers (‘you must have dirty shoes and grey hair’);
- marketing people;
- intelligence officers (by country and by crops);

- financial officers (sometimes outsourced, but still important);
- country managers and country distributors; and
- project managers, operation managers and production team leaders.

5.3 Emerging skills needs and skills obsolescence

New skills for existing jobs and new emerging professions

There is evidence of new skill sets emerging. For example, according to ESCO, being an agronomist is a traditional occupation which requires knowledge of pesticides, agricultural equipment and irrigation strategies. But in the interviews, it became apparent that the new agronomists which were sought by companies needed to possess a wider range of knowledge, including precision agriculture techniques, such as sensor deployment and management, and data interpretation. Another example is the reskilling of laboratory technicians and food engineers from the food industry who are now employed in research on new plants and seeds. Similarly, it is possible to use existing skills to access new job openings which did not exist before the introduction of certain technologies, as is the case with entomologists who are now called on to study and breed insects which predate harmful ones, thus reducing the need for pesticides. It is readily apparent that new skills provide new life to old jobs, as well as leading to entirely new professions emerging.

First of all, new technologies may require the definition of new job profiles. For example, in job postings related to drone technology, it is possible to find many occupations that are not listed in the ESCO database: aviation safety specialists, flight control engineer, telemetry engineer and autonomous vehicle robotics drone architect. They can be considered new emerging jobs. New job profiles are also created at the boundary between different disciplines where there is now much more of an interrelation between them: bioinformatics scientists, precision agriculture agronomists, industrial engineers and quality managers for the mass production of beneficial insects or of new crops; LED light experts for indoor growing; and food engineers to study novel seeds. These are all new emerging jobs. Non-technological drivers of change may also lead to new professions, as in the case of environmental economists, studying issues such as sustainability, the green economy and the impact of climate change on economic activities. New professions are emerging also among business-related roles. One company has created an ad hoc profile for customer success manager, working with customers in after-sales with the objective of co-developing new opportunities based on understanding farmers' problems.

Although the signals for both the introduction of new skills in old jobs and the emergence of new profiles are clear and strong, it is not possible to produce an analysis of the kind seen in Sections 5.1 and 5.2 to determine a relative ranking or a spectrum of competences. Such analyses are based on the correspondence with ESCO or O*NET and as such, there is no information on new occupations.

All the above insights seem to indicate that a new approach to skills and profiles is taking shape. Rather than well-defined professions, the emerging profiles appear more fluid and in continuous evolution. Even jobs such as a greenhouse installer or plant inspector may be required to operate sophisticated machines and have knowledge of English, basic coding, or even mechatronics. One visible trend is the adoption of a multidisciplinary approach, combining agricultural sciences with medicine, computer science or other fields. In academia, multidisciplinary research labs are emerging, where interaction with scientists from different disciplines is now commonplace. In companies, data scientists will not just be 'number-crunchers' but will understand the agricultural value of information, and breeders and agronomists must understand data science to make decisions. A similar trend is the integration of functions across the value chain, for example with technicians employed in business development, customer care, sales and dealing with suppliers, thus needing cross-competences and soft skills. Finally, many experts expressed the notion that each worker has to become at least ‘bilingual’, i.e. master one discipline and have a deep knowledge of another.

A concluding consideration regards the degree to which technological change in the agri-tech sector will affect the final users of the technologies, such as farmers and agricultural advisers. One possible outcome is that those categories of workers will need to at least learn the basics of the technologies in order to be able to interact with the technological professions. Thus, training in advanced technologies, or at least being sophisticated users of technology, may be increasingly required. However, another direction of development is also possible: the most successful technologies will be those developed to be very accessible and simple to operate so that in the end no training would be needed by farmers. At the moment both trends are present and both outcomes are possible.

Finally, the concept itself of what a farmer is and does may be changing. As reported in the interviews, in certain areas of Israel, people with smallholdings are employed in other jobs. They rely on a variety of technologies which allow them to combine jobs. It may well be that the number of such smart, ‘part-time’ farmers in the future will grow thanks to the new technologies leading to a complete change in employment in the sector.

Skills obsolescence

New technologies will have a significant impact on the automation of many tasks, leading to a decreasing number of job profiles (e.g. robots will likely affect the demand for people harvesting goods, packing and shipping them). It is possible to review the correlation between technological trends with occupations as carried out in Sections 5.1 and 5.2; clearly, technologies declining in use implies an obsolescence of the related occupations and skills. As a complementary information source, O*NET provides for each occupation an expert-based analysis of the likelihood of its substitution by machines – an analysis that other occupational classification systems do not provide. This information can be cross-linked with the data analysis to identify the jobs and skills at risk of obsolescence. These are:

- power production plant operators, water treatment plant operators, GIS technicians, pesticide mixers, farmworkers and labourers.

The above list is likely to be incomplete but sheds light on the types of jobs which may become obsolete in the agri-tech sector. A decrease in demand for relatively low-skilled, manual work is expected. This was something that was confirmed in the interviews with companies. Such a decrease is already happening, due to both market competition with other exporting countries and the difficulty of finding workers. Only highly trained manual workers (e.g. grafters) are still considered to be safe from substitution by automation. It is not always the case that relatively low-skilled jobs are at risk of substitution. For example, GIS technicians are highly skilled but the tasks they undertake can be replaced by image analysis techniques. The same applies to various other types of operators. As suggested by some interviewees, agronomists and other experts will always be needed but with the progress in AI, there may be a need for fewer of them. Time will tell.

5.4 The role of soft skills

Soft skills are not well defined or described, even in the literature. Thus, everyone tends to understand and interpret them differently, while these skills are also in continuous evolution. Soft skills are named in the literature in different ways: transversal or soft skills, personality traits, character skills, 21st-century skills, life skills, key competences, new mindset or social/emotional skills. This is because these skills relate to individuals' attributes in many instances. They refer, among other things, to teamwork, communication, initiative, sociability, empathy, collaboration, emotional control and positivity, open-mindedness, openness to learn and to change, flexibility, curiosity, innovation, creativity, entrepreneurship, resilience, planning/organisation, responsibility and persistence.

What is certain is that assessing these skills is challenging. Work is needed to develop effective tools for measuring, recording and reporting the development of these skills. Despite the difficulty in assessing them, almost all the interviewed companies reported that soft skills were crucial factors when hiring. In fact, for some companies, they are as important as technical specialisation. Being able to work in a team is considered one of the most relevant skills, not least because it is fundamental to the growing multidisciplinarity in agri-tech jobs and the collaboration among different departments. Other soft skills useful in multidisciplinary environments are networking ones and the capacity to adapt.

The ability to handle diversity is even more important for project managers and other similar roles; indeed, managing multidisciplinary teams requires strong soft skills as the project manager has to connect colleagues with languages and attitudes as diverse as software developers, agronomists or farmers. Networking capacity, entrepreneurial attitude, flexibility and adaptability, and willingness to take risks are also considered increasingly important in a fast-developing sector. Finally, possessing a range of soft skills that complement each other is also highly appreciated. Examples provided were the need to create a balance between reflection and dynamism, or between being a scientist and possessing business acumen. Regarding the development of soft skills, the common approach was to avoid formal training. There was a view among interviewees that there are no courses available, but in many companies, a lot of time and effort was invested in improving soft skills.

Main findings of the chapter

- Two main categories of job profiles growing in demand are technology-related occupations and business-related occupations (from sales to management). Technology-related occupations usually require a high level of skills, while business-related roles cover a wider range of skill levels. Both categories seem to have a low risk of being substituted by automation: the former because of their high level of specialisation and flexibility, the latter because of the need for human interaction.
- It is apparent that new jobs are emerging which are not found in classifications such as ESCO. This is due to the pace of technological change and high level of specialisation it brings about. New profiles appear fluid, reflecting the trend towards multidisciplinarity and the need to have integrated knowledge of various technologies. The future worker will need a wider range of skills and competences, the ability to mediate and adapt to new situations and roles, and to work across disciplines.
- It needs to be recognised that it is not just about the creation of new job profiles. It is apparent that many existing agri-tech jobs – such as agronomists – will survive but the task content and skills of these jobs will evolve as a result of technological changes.
- Companies and stakeholders still very much value soft skills (especially teamwork). Thus, the debate of future skills needs is not just about technical skills but the mix of technical and soft skills.
- Some occupations show signs of obsolescence. Relatively low-skilled manual occupations are among them, but also highly skilled ones that have a relatively high level of specialisation which can be substituted by ICT.

6. MEETING THE CHANGES IN SKILLS DEMAND

Key issues covered in this chapter

- How the changes due to the introduction of technologies affect 'skills utilisation' and working conditions in the sector.
- How businesses meet their new skills needs (new hiring, retraining, etc.), and the existing initiatives/cooperation of companies with education and training providers.
- Whether the education and training system is adapting to the ongoing changes and whether it provides an adequate answer to companies' needs in terms of competences and skills

This chapter focuses on the company strategies to address and meet their new skills needs and existing initiatives and concrete actions. Please note that all findings presented in this chapter come from the in-depth interviews and focus group discussions conducted with companies and key stakeholders.

6.1 Limiting factors

Companies were asked which factors were limiting the adoption of the new technologies and in general the development of their business. Most companies indicated that the shortage of skilled workers was the main limit to their growth. The reasons for the reported shortages were various. First of all, salaries were reported as not being competitive with other sectors which had a demand for similar skills. Accordingly, it is difficult to attract those with the skills the sector needs; this is even more so if the company is located far from Tel Aviv or looks 'too traditional' to young graduates. This factor is especially important when one is looking at technology-related job profiles, but it is not limited to them. It was said that experienced managers were also difficult to recruit given that those with the ideal profiles are often reluctant to work in relatively small agricultural firms. Cultural barriers may also play a role. There are also supply-side issues to consider. It was reported that some specialised roles, such as breeders, are no longer produced by the university system (or at least in the numbers required).

The returns to be obtained from working in agri-tech was also said to be a factor limiting growth (coupled with low profit margins which prevents companies from investing directly in technologies and people). It was said that both financial investors and academic researchers tend to want short-term returns and maximum gain (whether economic or scientific) which tends to push them towards what was termed more fashionable areas such as ICT. Accordingly, agri-tech enterprises struggled to find investment capital and proved to be less attractive to young researchers who might drive change in the sector.

In relation to academia, it was said that the field was more interested in the latest cutting-edge areas of research such as molecular biology and less interested in more traditional areas such as breeding and plant physiology. Employers and stakeholders also commented on the skills of people exiting the formal education and training system. It was said that the education leavers lacked the know-how about practical issues, including how to convert data from sensors into actions in the field, how to manage climate control, and how to understand the different needs of different plants.

The research has revealed that there is not enough dialogue between academia and company stakeholders about the needs of the agri-tech sector. Moreover, there are not enough links and collaborations with universities and TVET providers. For example, some of the leading companies proposed various internships but they received no applications. A related problem is that even if an internship starts, it is difficult to create a path that motivates students to stay in the company afterwards.

The education system is just starting to adapt to the changes. As of today, there is only one dedicated Agriculture Faculty in the country, and the initiative to boost the curricula with new skills related to the agri-tech sector such as AI is left to individual deans. There is no ‘agri-tech track’ in the Israeli technical colleges and in general in the national TVET system.

The competence gap may not just be related to the way education curricula are conceived. New generations are also perceived as spending less time acquiring necessary competences: even when more diversified paths are available, the vast majority of students choose the most fashionable one. Consequently, there may be less demand for academic education, and a shift of attention from university to technical colleges or even to private players. Indeed, big companies, such as Microsoft and Google, have their own certified training programmes (online and offline), which are internationally valid and recognised. The potentially adverse effect on the academic system is twofold: students do not need to go to university to get professional training, and private companies are taking over jobs that until now have been done by universities.

6.2 Recruitment strategies

For many agri-tech companies in Israel, one of the main sources of skilled professionals is the pool of young people exiting their military service. In general terms, the role of the Israeli Defense Forces cannot be ignored in the development of the high-tech sector, as it is one of the main producers of technology as well as one of the providers of high-quality training in innovative areas. The agri-tech sector also benefits from these recruits, especially when the recruits have knowledge of ICT, drones and other competences/technologies needed in precision agriculture.

To cover business roles such as general managers and chief financial officers, a common strategy is to look for retired professionals coming from large companies. In fact, people in retirement usually appreciate tackling challenges in a new sector and the difference in salaries is no longer an issue.

For those companies that are located far from high-tech hubs or are more ‘traditional’, recruiting within their neighbourhood or in remote areas is a sort of necessity but provides access to a sizeable pool of candidates. A few companies create student positions at nearby universities in order to increase the probability of a subsequent hiring, and to select the best candidates, but this strategy is not always successful.

Many companies resort to the recruitment of foreign workers. This is common practice for manual labourers but is also becoming more common for technical professionals. Usually, companies use recruitment agencies to hire skilled manual labourers such as grafters (at least as long as automation is not yet possible for the task).

However, recruitment agencies may not be enough, especially for very specific professions. Some companies even decided to open entirely new offices in the US or EU, with all the associated costs, for the sole purpose of recruiting breeders (since they simply cannot be found in Israel anymore) or entomologists (of which there are not enough in the country).

Another strategy to attract foreign talent is to invite students from developing countries to study and do fieldwork for one year, all expenses paid, in the hope that some decide to remain at the end of the year. For example, both the Weizmann Institute and the Volcani Centre have international student programmes for studying and working in the agri-tech sector in Israel. Companies creating student positions in collaboration with universities is a valid strategy to attract young talent (also from abroad) and select the best, but as reported by the interviewees, a mechanism has to be designed to incentivise the students to remain in the company after the degree. In a similar manner, some companies participate in EU projects such as the Horizon 2020 Programme to expand the professional network.

As for the procedure to hire new people, almost all companies have at least one dedicated HR professional. However, the role of the officer is only operational, the job descriptions are defined by the management/founders, and often even the final hiring decision is made by them. Hiring through ‘word of mouth’ within the community, instead of using written vacancies, is also common.

Academic degrees have different relevance in different subsectors. In certain cases, very high education levels (postgraduate) are requested, while in others less emphasis is given to formal degrees and more is placed on practical work experience (e.g. in the army).

As a final note, the negative trend described in Section 6.1 may be showing signs of reversal: according to various interviewees, younger generations are starting to have an interest in agri-tech jobs because it contributes to solving environmental problems or to the development of a more sustainable and greener economy. In certain cases, the integration of the worker in an environment that also favours human relationships, e.g. in Kibbutz/Moshav contexts, may be a further incentive for those people who are looking for a different environment. Finally, the technological input of agri-tech is also an appealing factor. Various enterprises are actively addressing those new factors, for example promoting themselves as doing the ‘right thing’, to become more attractive.

6.3 Training strategies

The interviews revealed that almost all companies noticed a competency gap in new recruits. In some cases, the gap is not only in competences, but it extends to mindset as well. Companies respond to this gap with a mix of strategies, depending on the typology of skills that are considered: technical, managerial and soft skills. The main answer is usually internal training, customised for the company’s specific needs, with technical training mainly done by existing internal technical personnel. Approaches adopted vary depending on the size of the company. They go from training on the job and ‘learning by example’, up to structured yearly programmes for individual development, including mentoring and training on various different skills. Some companies also use, or would like to use, specific learning and e-learning tools. One company reported that they also conduct training on soft skills.

Reskilling is used as a way to compensate for skills gaps in hiring (e.g. neurobiologist re-trained in entomology), and upskilling is also done (e.g. lab technicians or breeding assistants are trained to become breeders). When internal training is not sufficient, or not cost-effective, companies resort to external offers. Usually, they prefer to go to private actors, for example to dedicated formative agencies for topics related to operations or processes (e.g. total quality or lean management). Big players such as Amazon or Google are also organising very popular courses, both online and offline, on ICT themes. Some tasks are even directly outsourced (e.g. intellectual property rights, legal elements and parts of finance).

At the same time, some companies appreciate and make positive use of all courses and advice offered by the Ministry of Agriculture, especially on R&D. Very few companies resort to universities, because they are perceived as offering courses only on frontier topics, neglecting the more basic training needed by working professionals. There are nevertheless experiences of fruitful collaboration; for example, various companies send their personnel to learn AI techniques applied to agriculture at the Volcani Centre. Also, new multidisciplinary labs have been set up in various universities (e.g. at the Weizmann Institute), where scientists can collaborate and exchange ideas with people from other disciplines; this is an example of how the challenges presented by the new world can be addressed and turned into translational research and combined multidisciplinary products.

Other initiatives worth mentioning have been put in place by two of the interviewed companies. The first has established a programme to open its laboratories to other enterprises, to favour the exchange of ideas and cross-pollination, and is willing to support universities in extending this model to their students. The second company has launched a programme in which its experts and professionals go to high schools to teach a specific topic and attract the students' interest on critical issues; the company has also opened its experimental fields to students at dedicated times.

In general, the bureaucracy needed to get training from institutional sources is judged as being so cumbersome that companies prefer to pay private courses, even abroad, to get what they need.

Training activities may not be limited just to hard skills. Many companies have programmes for management skills or soft skills, with sessions such as storytelling or presentations. Other programmes are aimed at aligning employees with the company vision, improving engagement and team building, or bringing in fresh ideas from external collaborations.

Finally, it has to be noted that start-ups do not usually have resources to invest in training and need to deliver results quickly. Thus, start-ups just hire employees that are already operational.

6.4 A final word on the findings

Some good practices emerged during the meetings with stakeholders and companies to meet the future skills needs of companies. They vary from the development of multidisciplinary laboratories to advanced courses for personnel at research centres, and opening companies' laboratories to students. These examples of collaboration show that universities and TVET providers have a role to play in supporting the agri-tech ecosystem. Despite some concerns that education and the needs of companies are not always well aligned, it was noted that many agri-tech start-ups benefit from research activities carried out in universities, while others referred to their preparedness to work more closely with education and training institutions.

While new providers are emerging to provide missing skills and training, it was suggested that certification of providers and recognition of acquired skills should also be tackled by institutions. With regard to the educational curricula available, there are some positive trends to note: in 2019, for the first time there were more technical students than social science students in Israeli universities, and the shift from basic research to applied research is another general trend which benefits industry (interview with the Ministry of Education). Interviewees pointed out that closer collaboration between enterprises and academia about the content of curricula would result in improved alignment. The introduction of transversal subjects (statistics or data science) being taught in traditional curricula and attention given to the portability of skills were also suggested as helpful. The interlinkages between sectors occurring as a consequence of the introduction of new technologies can also lead to cross-sectoral collaborations in terms of education and training.

As mentioned above, it is important to note that there is no ‘agri-tech track’ in Israeli technical colleges and in general in the national TVET system. The Ministry of Education might consider creating such a dedicated education track. However, more innovative approaches to training could be developed, also as a pragmatic way to equip workers with the right skills for the jobs in the sector. Indeed, there are some profiles (e.g. drone specialists) that do not need long academic paths: they can follow a shorter education route, provided it is combined with field experience. The activation of quick courses would be worth for the consideration of education and training providers. Colleges and other TVET entities could fill the gap, offering short paths to practical knowledge (combined with higher TVET). It was noted that the boundary between university and TVET is becoming more blurred. It is likely that collaboration and cross-fertilisation between the two entities will be beneficial to agri-tech.

It is hoped that these findings will raise policy-makers’ and practitioners’ awareness about the changing skills needs in the agri-tech sector and provide food for thought, especially in relation to the ability of the education and training system to face these changes and to prepare workers who will be fit for the new jobs and occupations. Possible actions could include:

- the development of learning units (modules) for upskilling/reskilling professionals in the field;
- the identification of gaps in the existing curricula;
- the development of new qualifications in partnership with the universities, TVET providers and companies in the sector;
- better career guidance and information about job and career opportunities;
- the systematisation of existing good practices; and
- the establishment of mechanisms to enhance the collaboration between enterprises and education providers.

Main findings of the chapter

- There are various factors which may be constraining growth in agri-tech with regard to skill shortages. Most companies indicated that a shortage of skilled workers was the main limiting factor to growth. This is because the sector is relatively less attractive to many people who possess the skills it needs but also due to global shortages in some professions.
- Companies have sought to widen their recruitment strategies by, for example, recruiting young people leaving military service or professionals retiring from large companies. Some companies search for workers internationally.
- The education and training system is seen to be producing people with competences which are not sufficiently in line with the needs of the sector. Companies have responded to shortages mainly through internal training of the existing workforce.
- Links with universities and the TVET system were regarded as limited. Academic courses were considered to be too far removed from the actual needs of the sector, neglecting practical and basic knowledge or more traditional skills, while TVET tracks need to be reviewed and new ones introduced. Closer dialogue and cooperation between enterprises, academia and the TVET system will enable the design of training programmes that are better matched to the future needs of the labour market (also including delivery of practical training).
- Many companies do not use the courses provided nationally through formal education and training institutions because the amount of bureaucracy involved in doing so is considered too cumbersome.
- It is not enough to just identify the skills needs of the sector; rather, one needs to develop policies and practices to ensure that emerging skills needs are met. There is scope for developing some medium-level skills through the provision of new initial TVET tracks and continuing professional development and training of the workforce.

ANNEX: KEY STAKEHOLDERS CONSULTED

All the stakeholders met during the project, either in the focus group discussions or in bilateral face-to-face interviews in Israel, are listed below.

No	Organisation (alphabetical order)
1.	Agricultural Research Organisation – Volcani Centre
2.	COPIA VC
3.	Farmers in Bnei Netzarim moshav
4.	Farmers in Kfar Kish moshav
5.	Galilee Research Institute
6.	IsraelAgri
7.	Israel Central Bureau of Statistics
8.	IVC Research Centre
9.	Kfar Galim School
10.	Kibbutz Industries Association
11.	Manufacturers' Association of Israel
12.	Ministry of Agriculture and Rural Development
13.	Ministry of Education
14.	Sadot Innovation
15.	Shorashim Nursery
16.	Start-up Nation Central
18.	The Hebrew University – Faculty of Agriculture; Yissum
19.	The TVET National Committee
20.	The University of Tel Aviv
21.	The Weizmann Institute of Science

ACRONYMS AND ABBREVIATIONS

CBS	Central Bureau of Statistics
ESCO	Multilingual classification of European Skills, Competences, Qualifications and Occupations
ETF	European Training Foundation
EU	European Union
GDP	Gross domestic product
GIS	Geographic information systems
HR	Human resource
ICT	Information and communications technology
ILS	New Israeli shekel (currency)
ISCED	International Standard Classification of Education
ISCO	International Standard Classification of Education
ISIC	International Standard Industrial Classification of all Economic Activities
NACE	Nomenclature générale des activités économiques dans les Communautés européennes (European Classification of Economic Activities)
NGOs	Non-governmental organisations
O*NET	Occupational Information Network
OECD	Organisation for Economic Cooperation and Development
R&D	Research and development
TVET	Technical and vocational education and training

GLOSSARY

Agri-tech covers every solution in the technological fields of information and communications technology (ICT) and mechanisation for cultivation, with cultivation intended as every step from planning the field to harvesting the crops. In a broader sense, it indicates every use of technology to increase the yield, efficiency and profitability of agriculture. Chapter 2 contains a more detailed discussion of the topic.

API stands for Application Programming Interface, a computing interface that defines and allows interactions between multiple software without the need for human intervention.

Artificial Intelligence (AI) is a general term used to describe a variety of technologies and approaches that allow computers to solve complex tasks (usually associated with higher cognitive levels), for example recognition of objects or patterns; classification of entities; simulation and modelling of situations; predictions of future behaviours; and generation of constructs similar to existing ones.

Bioinformatics is an interdisciplinary field of science that combines biology, computer science, information engineering, mathematics and statistics to understand and interpret biological data that is too complex to be analysed with traditional tools (e.g. identification of genes).

Cognitive bias is a systematic pattern of deviation from norm or rationality in judgement. Cognitive biases are considered by many authors as linked to the normal functioning of the human brain and thus can arise in any activity involving human judgement.

Competence means 'the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development' (Cedefop, 2014). While sometimes used as synonyms, the terms skill and competence can be distinguished according to their scope. The term skill refers typically to the use of methods or instruments in a particular setting and in relation to defined tasks. The term competence is broader and refers typically to the ability of a person – facing new situations and unforeseen challenges – to use and apply knowledge and skills in an independent and self-directed way.

Computer vision is a general term used to describe various technologies and approaches (and the related interdisciplinary field) that allow computers to understand, elaborate and extract information from digital images or videos. From the perspective of engineering, it seeks to automate tasks that the human visual system can do, such as pattern or object recognition. Certain techniques of computer vision involve the use of AI.

CRISPR gene editing is one of the various genetic engineering techniques by which the genomes of living organisms may be modified. Its main feature is greater precision: a cell's genome can be cut at a desired location, allowing existing genes to be removed and/or new ones added in vivo, thus bypassing many of the risks associated with other techniques. The editing can be done without foreign DNA, but just suppressing or enhancing existing genes, thus certain restrictions and regulations against genetically modified organisms do not apply.

Cross-sectoral knowledge, skills or competences is one of the four levels of skills reusability identified by the ESCO initiative, whereby reusability shows how widely a knowledge, skills or competence concept can be applied in different working contexts. Cross-sectoral knowledge is relevant to occupations across several economic sectors, whereas sector-specific or occupation-specific knowledge is restricted to one specific sector or occupation. See also transversal knowledge.

Cross-sectoral technology – adopting the concept of cross-sectorality from ESCO's skills reusability levels, the term indicates a technology that finds application in many different economic sectors (e.g. drones).

Drip irrigation is a type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface. The goal is to place water directly into the root zone and minimise evaporation.

Energy harvesting is the process by which energy is captured from ambient background sources and stored in order to power small autonomous devices, like those used in wearable electronics or in wireless sensor networks. This way it is possible, for example, to operate a network of sensors in an area, such as a field, without the need to access grid electricity.

ESCO is the multilingual classification of European Skills, Competences, Qualifications and Occupations. ESCO works as a dictionary, describing, identifying and classifying professional occupations, skills and qualifications relevant for the EU labour market and education and training, in a format that can be understood by electronic systems. It lists over 3 000 occupations and 13 000 skills and competences. For more info, see https://ec.europa.eu/esco/portal/home

A **genetically modified organism** is any organism whose genetic material has been altered using genetic engineering techniques. New genes can be introduced, or endogenous genes can be enhanced, altered or removed.

Indoor farming (or growing) is a practice where crops are grown inside buildings or containers, in controlled environmental conditions (including light exposition – by substituting sunlight with LED lights – and climate), and often combined with soilless farming techniques such as hydroponics, aquaponics and aeroponics. The goal is to increase yield and at the same time reduce the consumption of resources.

ISCO stands for International Standard Classification of Occupations and is an International Labour Organisation classification structure for organising information on labour and jobs. It is part of the international family of economic and social classifications of the United Nations. It contains around 7 000 detailed jobs, organised in a four-level hierarchy that allows all jobs in the world to be classified into groups, from 436 lower-level groups up to 10 major groups.

A **job** is a set of tasks and duties performed, or meant to be performed, by one person (ISCO).

A **job profile** is the description of a particular work function, developed by the employer or by the HR department of a company, that includes all the elements deemed necessary to perform the corresponding job. In particular, it includes general tasks, duties and responsibilities, and the required qualifications, competences and skills needed by the person in the job.

A **job title** is the identifying label given by the employer to a specific job, usually when looking for new candidates. In the absence of standardised nomenclature, it can coincide with either a description of the job or the occupation group the job belongs to.

A **kibbutz**, meaning 'gathering' or 'clustering', is a collective community in Israel that was traditionally based on agriculture.

MEMS stands for **microelectromechanical systems**, and constitutes the technology of microscopic devices, particularly those with moving parts. Their microscopic size allows the introduction of operating devices and sensors into biological structures or the diffusion in environments.

Molecular delivery systems refer to approaches, formulations, technologies and systems for transporting a beneficial compound into a biological system in an efficient and localised way, as needed to safely achieve its desired effect. For example, drugs ingested orally affect the organism globally and higher quantities are needed to ensure that the site of action is reached, whereas drugs delivered at the molecular level can be targeted on the site.

A **moshav**, meaning 'settlement' or 'village', is a type of cooperative agricultural community of individual farms in Israel.

NACE (Nomenclature générale des activités économiques dans les Communautés européennes; the European Classification of Economic Activities) is a four-digit classification providing the framework for collecting and presenting a large range of statistical data according to economic activity in the fields of economic statistics, provided by Eurostat. Economic activities are divided into 10 or 11 categories at high-level aggregation, while they are divided into 38 categories at intermediate aggregation. The United Nations uses **ISIC**, the International Standard Industrial Classification of all Economic Activities.

Natural language processing (NLP) is an interdisciplinary field at the intersection of linguistics, computer science and information engineering. NLP deals with the interactions between computers and human (natural) languages, in particular how to program computers to process and analyse large amounts of natural language data, starting from the identification of the grammatical and logical parts of speech within a sentence, up to the complex representation of semantic relationships between words.

O*NET stands for Occupational Information Network, a free online database of occupational requirements and worker attributes. Currently the online database contains 1 016 occupational titles, each with standardised and occupation-specific descriptors, covering the entire US economy. It describes occupations in terms of the skills and knowledge required, how the work is performed, and typical work settings. It can be used by businesses, educators, jobseekers, HR professionals, etc. It is a program to facilitate the development and maintenance of a skilled workforce, developed under the sponsorship of the US Department of Labour/Employment and Training Administration. For more info, see www.onetcenter.org/ and www.onetonline.org/

Occupation – According to ESCO, an occupation is 'a grouping of jobs involving similar tasks, and which require a similar skill set'. Occupations should not be confused with jobs or job titles. While a job is bound to a specific work context and executed by one person, occupations group jobs by common characteristics (for example, being the 'project manager for the development of the ventilation system of the Superfly 900 aircraft' is a job. 'Project manager', 'aircraft engine specialist' or 'heating, ventilation, air conditioning engineer' could be occupations, i.e. groups of jobs, to which this job belongs).

Occupational profile is an explanation of the occupation in the form of description, scope, definition, and list of the knowledge, skills and competences considered relevant for it. Each occupation in the ESCO database also comes with an occupational profile that further distinguishes between essential and optional knowledge, skills and competences.

Precision agriculture is a farming management concept based on the use of technologies such as satellite imaging and sensors to observe and measure the situation of fields and crops, and then operate with targeted interventions with the goal of optimising returns on inputs while preserving resources. Precision agriculture has two key features: (i) using digital techniques for modern farming (e.g. satellite navigation and positioning systems; automated steering systems; geo-mapping, sensors and remote sensing; and agricultural robots); and (ii) environmental sustainability of farming (e.g. less and smarter use of herbicides, pesticides, fertilisers; reducing erosion risks; and increasing animal welfare). For example, rather than applying the same amount of fertilisers over an entire agricultural field, or feeding a large animal population with equal amounts of feed, precision agriculture would measure variations in conditions within a field and adapt its fertilising or harvesting strategy accordingly.

Profession is an occupation requiring a set of specific skills and dedicated training.

Qualification is the 'formal outcome of an assessment and validation process which is obtained when a competent body determines that an individual has achieved learning outcomes to given standards' (Cedefop, 2014).

Regulated profession – A profession is called regulated if its access, scope of practice or title is regulated by law.

Semantic matching is a technique used in computer science to identify information which is semantically related.

Skill means 'the ability to apply knowledge and use know-how to complete tasks and solve problems' (Cedefop, 2014). Skills can be described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments). While sometimes used as synonyms, the terms skill and competence can be distinguished according to their scope. The term skill refers typically to the use of methods or instruments in a particular setting and in relation to defined tasks. The term competence is broader and refers typically to the ability of a person – facing new situations and unforeseen challenges – to use and apply knowledge and skills in an independent and self-directed way.

Soft skills are usually associated with transversal skills, and considered the cornerstone of personal development, also within the context of labour and employment. To distinguish them from other knowledge-based basic skills, they are often referred to as social or emotional skills. They can be further classified into personal skills (e.g. problem-solving and adaptability) or interpersonal ones (e.g. teamwork and leadership).

Spectrometry refers to techniques (and the related discipline) for the observation and measurement of wavelengths of light or other electromagnetic radiation. The capability of spectroscopy to determine chemical compositions is one of its primary uses.

Text mining is a general term indicating a variety of techniques that enable computers to extract, discover or organise relevant information from large collections of different written resources (such as websites, books and articles). The first part of any text mining process implies the transformation of texts in structured representations useful for subsequent analysis through the use of NLP tools. Sometimes AI techniques are used to perform text mining tasks more effectively.

The **transversal knowledge, skills or competence level** is the highest of the four levels of skills reusability identified by the ESCO initiative. Transversal skills are relevant to a broad range of occupations and sectors. They are often referred to as core skills, basic skills or soft skills, the cornerstone of personal development. Transversal knowledge, skills and competences are the building blocks for the development of the 'hard' skills and competences required to succeed in the labour market.

Transversal technology – Adopting the concept of transversality from ESCO's skills reusability levels, a transversal technology is relevant to a broad range of occupations and sectors and it is a building block for more specific technologies (e.g. computerised image analysis).

Vertical farming (or growing) is a technique of indoor farming, where crops are vertically stacked into layers to maximise the use of space, thus allowing for an even greater yield compared to horizontal indoor farming.

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