REPUBLIC OF TURKEY

ADANA ALPARSLAN TÜRKES SCIENCE AND TECHNOLOGY UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DEPARTMENT OF INDUSTRIAL ENGINEERING

SMART AGRICULTURE APPLICATIONS; A SMART GREENHOUSE DESIGN

Merve YILDIZ

MSC THESIS

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SUPERVISOR
PROF. DR. TOLUNAY GÖÇKEN

ADANA, 2023

DECLARATION OF CONFORMITY

In this thesis study, which was prepared following the thesis writing rules of Adana Alparslan Türkeş Science and Technology University Institute of Graduate School, I declare that I provide all the information, documents, evaluations and results in accordance with scientific ethics and moral codes without resorting to any means or assistance that would be contrary to scientific ethics and traditions. I also declare that I refer to all of the articles I used in this study with appropriate references and accept all moral and legal consequences if a situation is found contrary to my statement regarding my work.

03/04/2023

Merve YILDIZ

ÖZET

AKILLI TARIM UYGULAMALARI; AKILLI SERA TASARIMI

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Danışman: Prof. Dr. Tolunay GÖÇKEN
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Çalışmamızda Akıllı tarım teriminin tanımı yapılmış, akıllı tarım bileşenleri ve uygulamaları hakkında bilgi verilmiştir. Tarım 4.0 bileşenleri ile donatılmış tam otomatik bir çilek serası tasarlanmıştır. Akıllı seranın Çukurova bölgesine bağlı Ceyhan ilçesinde yer alması planlanmıştır. Bölgenin iklim koşulları incelenmiştir. Sera bileşenlerinin seçimi yapılırken birden fazla kriter bulunduğu için çok kriterli karar verme yöntemlerinden biri olan Analitik Hiyerarşi Süreci uygulanmıştır. Bu yöntem için uzman görüşlerinden ve literatür taramaları sonucunda bulunan sayısal verilerden yararlanılmıştır. Akıllı seramızda Tarım 4.0'ın tek bir bileşeni değil, birden çok bileşeni entegre edilerek tasarım yapılmıştır.

Anahtar Kelimeler: Tarım 4.0, Akıllı Tarım, Seracılık, Otomasyon.

ABSTRACT

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In our study, the definition of the term smart agriculture has been made and information has been given about the components and applications of smart agriculture. A fully automatic strawberry greenhouse equipped with Agriculture 4.0 components is designed. The smart greenhouse is planned to be located in Ceyhan district of Çukurova region. The climatic conditions of the region are examined. Analytical Hierarchy Process, which is one of the multi-criteria decision-making methods, has been applied since there are more than one criterion while selecting the greenhouse components. For this method, expert opinions and numerical data found as a result of literature reviews are used. Our smart greenhouse is designed by integrating not a single component of Agriculture 4.0, but multiple components.

Keywords: Agriculture 4.0, Smart Agriculture, Greenhouse, Automation.

To my mother and father who make my life important...

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INGREDIENTS

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ABBREVIATIONS

AHP : Analytical Hierarchy Process

1. INTRODUCTION

The fact that the current ecological footprint of the world exceeds the biological capacity of the world creates serious destruction and pressure on natural resources. It is estimated that the world population will reach 9.7 billion people in 2050.

Global food system; It is responsible for 60% of the world's biodiversity losses, 24% of greenhouse-gas emissions, 33% of soil degradation, 61% of tradable fish stocks (extinction), and 20% overuse of the world's groundwater. It is feared that these pressures on the environment will increase with population growth, urbanization and changes in dietary patterns. In 2050, 40% of the world's population is expected to live in water-stressed river basins and greenhouse gases from agriculture are expected to increase from 24% to 30%. 75-80% of usable water in the world is used in agriculture. 89% of usable clean water in Turkey is used in agriculture (Guy et al., 2014) and when agricultural irrigation is done unconsciously, it causes serious environmental problems. It is predicted that agricultural production should increase by 70% in order to meet the nutritional needs of the world population.

Floods caused by climate change caused by global warming, unusual extreme natural events such as storms, drought, frost, seasonally changing precipitation affect the product quality and production amount in agriculture negatively, and how to increase agricultural production under these conditions and how to make it sustainable is an important question today. Agricultural areas are gradually decreasing due to soil erosion, deforestation, misuse, overgrazing, improper crop rotation and unbalanced fertilizer use. In addition, climate changes cause a decrease in yield and production in agriculture.

Deterioration of arable land in the world over time and the decrease in usable water resources have led to the focus on agriculture with climate changes. Even the scenarios where there may be wars over food and water in the future reveal the importance of the issue.

Technology is developing rapidly and is gaining more and more place in all stages of the agri-food-supply chain. Due to population, income growth and urbanization in developing countries, food demand increases and causes serious changes in consumption patterns.

The problems and new opportunities created by these developments at the global and regional level are pushing the smart specialization and Industry 4.0 technological transformation in the agricultural sector. In this great transformation, the future of the agricultural sector is shaped by technological applications.

The new era is called Agriculture 4.0, also known as the age of digital and smart agriculture. All agricultural machines used in the agricultural production process are equipped with sensors (sensors), and the Internet of Things (IoT) also enters the agricultural sector, ensuring that the machines are in communication with each other throughout the entire production process.
With digitalization, data is collected and analyzed with smart tools. Tracking, how much and what kind of fertilizers should be given to which areas, the weather conditions, the needs of the facilities is called smart agriculture.

Smart farming technologies are used not only to improve food quality or production but also to enable farmers to better see the needs of crops and adjust their nutrition accordingly. Greenhouses are production areas covered with plastic and glass, and they are enterprises in which technology is also included.

It is thought that greenhouse cultivation, which was developed as a result of the search for maximum efficiency from the unit area, will come to a more prominent and more strategic position within the technological agricultural production techniques in the future.

Greenhouse cultivation has many advantages. First of all, more products can be obtained per unit area. While the production is kept under control, healthy, reliable, traceable and standard products can be obtained. From the point of view of the producer's income, it is a very profitable activity to grow the products outside the periods when they are grown in the open field. Our country is in an extremely favorable position in terms of greenhouse cultivation.

In modern greenhouses where all the possibilities of technology are used, automation takes place at every stage of production. Our country ranks 4th in the world and 2nd in Europe in greenhouse cultivation.

The biggest limiting factor for greenhouse operation is the fuel used to provide the most suitable temperature for plant growth in the greenhouse and the maintenance costs of the heating systems. For this reason, greenhouses are mainly concentrated on our southern coastline. In addition, greenhouse cultivation is also carried out in the Aegean, Marmara, Black Sea Regions and regions with suitable microclimates. In terms of greenhouse existence; our provinces of Antalya, Mersin, Adana, Muğla, Samsun, İzmir, Aydın, Hatay and Burdur stand out.

In this study, "Smart Strawberry Greenhouse Design" equipped with Agriculture 4.0 outputs will be explained. Industry 4.0 and agriculture 4.0 are mentioned. The components used are indicated. In order to measure Agriculture 4.0 awareness in Turkey, a survey was conducted with the participants living in the Çukurova region and the results were evaluated. A greenhouse design equipped with Agriculture 4.0 components is described. Analytical Hierarchical Process Method is used in the selection of greenhouse components.

It is thought that modern greenhouse applications made using the components of Agriculture 4.0 are handled in one dimension in the literature and not enough components are used in a single greenhouse design. It has been seen that concrete examples, one of the most important effective learning techniques, are insufficient to explain smart agriculture outputs in current studies. Based on these shortcomings in the literature, it is aimed to design a strawberry greenhouse equipped with Agriculture 4.0, to give a concrete example that will enable the user to choose the most suitable and most efficient options in cases where there are more than one alternative, to increase concrete examples and to gain a more general perspective on the subject

2. LITERATURE REVIEW

Ercan, Öztep, Güler and Saner's (2019) study called Agriculture 4.0 and its Applicability in Turkey, based on the information they received from different companies and their SWOT analysis, raises the awareness of farmers on smart agriculture. They interpreted factors such as inadequacy of infrastructure works and policies and foreign dependency as weaknesses in the applicability of Agriculture 4.0 in Turkey.

Kılavuz and Erdem (2019) stated that the application of digital technologies in the agricultural sector leads to increased product yield, reduced costs, less product loss, minimum use of water, fuel and fertilizer, which means cheaper and higher quality products for consumers. They argued that there is a need for a comprehensive agricultural regulation that includes practices such as transitioning to high-tech agricultural practices that will reduce costs and increase productivity, train manpower in this area, and provide information and technical assistance to the farmer at every stage of production.

Duman and Özsoy (2019) said that although there are good hopes for integrating Industry 4.0 technologies, practices and mentality with the agricultural field, their adoption will take time. Although Industry 4.0 is very advanced today in terms of both scientific and research and practical attitude, Agricultural 4.0 is still limited and remains in theory. They stated that smart agriculture, when applied with all its components, will provide great benefits to life and environmental problems through more efficient use of water or optimization of processes and inputs. As a result of the study, it was emphasized that Smart Agriculture should be made economical, useful and more accessible for all users.

Pakdemirli et al. (2021) stated that Turkey is among the top 10 agricultural economies in the world and is the largest agricultural producer in Europe. It has been stated that the agricultural area owned, its relatively young population and its proximity to markets such as the Middle East, Europe and Central Asia have significant potential. It was said that the dissemination and support of digitalization in the agricultural sector is extremely important in order to benefit from the agricultural potential at the maximum level. It was concluded that investment in infrastructure and technology is needed to increase productivity in agriculture, as well as to support small farmers and promote sustainable agricultural practices that support their equal access to land, technology and markets.

Sahin (2022) said that food/agriculture, clean water and renewable energy will emerge as the three most important strategic resources in the future, and that it is a necessity to use these resources more efficiently in order to ensure sustainable agricultural development. He argued that in order to increase productivity, traditional agriculture and energy approaches should be abandoned, digital and smart technologies should be developed rapidly and offered to the service of farmers, and smart agricultural technologies should be developed by realizing agricultural digital transformation. It was stated that new technologies such as communication of agricultural machinery and robots (IoT), big data (Big data), artificial intelligence (AI), unmanned aerial vehicles (UAV), unmanned ground vehicles (UGV) and robotics will make agricultural processes more efficient. According to the research; considering the agricultural needs of our country, the digital technologies needed in agricultural mechanization should be determined and the loss of national income should be prevented by preventing unnecessary technology imports.

Üye and Durmuşoğlu (2016) emphasized in their study that our country has not fully achieved a modern identity in greenhouse activities. They stressed the importance of not regularly checking the temperature and humidity of the indoor air of greenhouses. They determined that the most important criterion in increasing plant productivity is to achieve optimum growth temperature and humidity, and they examined remote-controlled irrigation systems in the prototype greenhouse design in their study. They stated that these mechanisms can be easily applied to all greenhouses with minor changes.

Alpay (2018), developed a smart greenhouse system in his study and the results of the system were evaluated and analyzed. In the study, the traditional method used to heat the greenhouse, the designed ANN model and the developed fuzzy logic system were compared with the heating requirement The most important features of the study are that the hardware elements and methods used in greenhouse control systems are determined according to the product characteristics and that they have the most appropriate operating value ranges, and that the proposed systems and methods give appropriate results.

Özturk, Çelik and Kırıcı (2021) made a prototype of a greenhouse that can be opened and closed with a sensor application. In this way, it is possible to take advantage of both sunlight and ambient temperature by opening the top when necessary. In order not to damage the roots of the greenhouse floor, the ground was prepared from pumice stone with equivalent properties. The system, which was created in accordance with the prepared prototype, was made controllable with software by adding all the components. To control the system, software control was provided with Arduino to make the greenhouse operational. Prepared according to the result obtained, Smart Greenhouse has made a positive difference in the development of plants. In addition to all these, it has been seen as a useful study in terms of both controllability and usefulness of our Smart Greenhouse system.

Yılmaz (2013) study, it was aimed and succeeded to develop smart greenhouse automation control systems and software that can be used in our country and international markets, providing user diversity, flexible, multifunctional, easy to install, easy to install according to the differences in greenhouse equipment. As a result of the studies and researches; He stated that the costs of labor, electricity, fuel, water, fertilizer, medicine have decreased and labor productivity has increased by 15% or more. It has been emphasized that the production of such systems in our country will enable thousands of greenhouse producers to purchase these systems.

With the system designed by Söyler et al (2018) in their studies, the heat distribution in the greenhouse is homogenized with the automation system depending on the type of plant grown in the greenhouse. automatically given to the plant. The automation system used in the greenhouse primarily disables the human decision factor, monitors the values such as greenhouse ground temperature, proportional humidity, and ambient temperature with sensors, keeping the optimum temperature, humidity and air ratio, increasing the efficiency up to 40-50% in the greenhouse, It has been concluded that it makes it possible to buy quality products for export with less pesticides and hormones.

Baysal et al. (2018) mentioned in their studies that greenhouse automation systems can support producers in monitoring the environmental effects that are important in greenhouse cultivation and in making decisions at harvest time. Data from wireless sensors can be read and recorded and monitored over the internet without the need for a specific place and time. In case these factors go outside the predetermined ranges, the risk of damage to the product is minimized by alerting the authorized person via e-mail and/or text message (SMS) according to his/her preference. Tools such as , fan and irrigation system can be activated. They stated that after these are done, the greenhouse automation can be transformed into a "Smart Greenhouse" system.

Dayıoğlu (2013) said that temperature and relative humidity occurring in different environments around the greenhouse are the most important climatic factors. They stated that the plant growing in the greenhouse is affected by constantly changing physical and physiological conditions and that the greenhouse should be managed as an industrial facility in order to control these effects. In this study, a wireless communication system based on Bluetooth technology is designed to measure data around the greenhouse and transmit control signals. In addition to the material and energy flow in the greenhouse, the control of the information flow based on Bluetooth is also important. Environmental factors should be known and kept under control while growing plants. Therefore, the use of wireless technologies will provide effective and flexible management. It is concluded that the wireless system proposed in this study can provide a flexible and inexpensive solution for automation in greenhouses.

In their study, Kürklü and Cağlayan (2005) examined simple, inexpensive and easy-to-use control methods and mechanisms that will ensure that the indoor climate conditions are kept at an appropriate level against the effects of the external environment in a model greenhouse under laboratory conditions. They stated that by using DTMF (Dual Tone Multi-Frequency) and radio signals, a much more remote and wireless control opportunity compared to the computerized control system can be provided. They explained in their studies that if this system is implemented, cable pulling and labor costs will be eliminated and thousands of greenhouse producers can purchase these systems. They argued that this would create a more modern understanding of greenhouse cultivation in our country as well as in developed countries.

The reviews and analyzes by Lezoche et al. (2020) make it clear that the integration of new technologies allows smart agriculture to address key farming goals such as water conservation, soil conservation, limiting carbon emissions and increasing productivity They mentioned that the future of agriculture lies in the creation of a durable and sustainable farming system. They concluded that new technologies have had a major impact in reducing uncertainty, as they enable precise data to be obtained in real time and real-time information tools provide new opportunities for companies to react more quickly to changing conditions in the supply chain.

Dayıoğlu and Türker (2021) ,they said that using smart agriculture technologies and data-based techniques, how water, chemicals and energy are used in the production of healthy food and animal feed, and what environmental effects the applied agricultural. They concluded that the energy used in agriculture is clean and sustainable, the water is chemically unpolluted, it is vital for everyone to have access to fresh water and clean energy, and for better reconstruction after the COVID-19 pandemic.

In t their study, Quy et al. (2022) presented an overview of IoT and big data for the smart agriculture sector. The benefits of applying IoT and big data in agriculture were discussed. In addition, they also pointed out the challenges they need to overcome to be able to accelerate the deployment of IoT in smart agriculture. In addition, security technologies need to be continuously improved, but in their opinion, the application of IoT solutions for smart agriculture is inevitable and will enhance productivity, provide clean and green foods, support food traceability, reduce human labour, and improve production efficiency. On the other hand, this survey also points out some interesting research directions for security and communication technologies for IoT.

Maroli et al. (2021 aimed to provide a holistic understanding of the current IoT scenario through a comparative analysis of the current literature on agricultural IoT applications. The study proposes a framework for IoT adoption in the case industry. The results emphasized that research efforts on the applications of IoT in agriculture have matured from the initial conceptual stages and now reached the implementation stage.

In the study by Ateş and Şahin (2021), the transition process from Industry 4.0 to Agriculture 4.0 and new technologies of digital agriculture are mentioned. In this context, this study aims to close a gap by presenting an AHP-based decision-making approach on digital agriculture technologies for the agriculture and livestock sectors. As a result of the study, it was decided that soil sensor technology is the best alternative for the agricultural sector, where the availability of technological infrastructure and necessary information brings cost advantage. Likewise, in the livestock sector, sensor technology attached to animals is obtained as the best alternative with its cost advantage and fast return. While sensor technology is the backbone of Agriculture 4.0, it has become the primary alternative with its cost advantage.

Liu et al. (2020), this article first reviews the current state of industrial agriculture, along with lessons learned from industrial agricultural production models, industrial agricultural production processes, and the industrial agri-food supply chain. In addition, five emerging technologies for Agriculture 4.0, namely Internet of Things, robotics, artificial intelligence, big data analytics and blockchain are discussed. Specifically, the focus has been on the key applications of these emerging technologies in the agricultural sector and their corresponding research challenges. As a result of this article, it is aimed to open new research opportunities for readers, especially industry practitioners.

Özdoğan et al. (2017) stated in their study that Tanzer Bilgen claimed that the average age of farmers in Turkey is between 50-55, and that the use of mobile and smart devices, which form the basis of digital agriculture applications, has decreased in this age group. They emphasized that it is especially important for young farmers to have competence in agricultural technologies and digital agriculture applications, which are considered as sources of agricultural productivity and economic added value. Technopolises and incubation centers of universities stated in the study that they can transform the accumulated scientific knowledge into business and create an ecosystem focused on digital agriculture. They concluded that enriching higher education curricula and other educational options will accelerate digital transformation to increase the competence of young farmers in digital farming practices, which will begin to increase in the sector in the coming years.

Spanki et al. (2021) presented the concept of Data Sharing Agreements (DSAs) as a fundamental way and a template for AI data management practices among various actors. based access control. As they explored the data sharing challenges in Agriculture 4.0 gradually, they conveyed it to the readers with a smart farm scenario. Data management and sharing practices said that defined contextual policies should be applied for access control. When the study is examined in its entirety, it is concluded that role-based data management should constitute policy for data sharing agreements, especially in the context of Industry 4.0 in broad terms and Agriculture 4.0 in particular.

As a result of the literature research, the fact that only the subjects are dealt with in the context of objectivism/positivist approaches shows that the studies cannot go beyond being copies of each other. When it comes to smart greenhouse design, scientific studies have only been done on sensor systems. Studies in which other important components of Agriculture 4.0 were used in an integrated manner could not be carried out. The issue needs to be studied more extensively. In order to close this gap in the literature, a smart greenhouse design has been made in which Agriculture 4.0 components are integrated.

3.AGRICULTURE 4.0

In the future, agriculture will face challenges such as producing more food, feed, fiber, and fuel at sustainable affordable prices, which will be provided with fewer resources for a growing world population. Smart Agriculture will play an important role in meeting these challenges. The use of Smart Agriculture components increases benefits while reducing costs and offers solutions that can help farmers overcome environmental challenges and sustain levels of food production to feed a growing population while developing more sustainable agriculture.
Small farms are the engine to support rural employment and to make a considerable contribution to territorial development. Even though they have always been considered a cornerstone of agricultural activity in the European Union (EU), this sector most often suffers from very low efficiency and effectiveness, sensitivity to weather, market disruptions, and other external factors, such as poor agriculture supply chain, stakeholders’ linkages and communication, especially at the food processing level.

Agriculture 4.0 emerges to provide advanced technologies to the farmers to meet agri-food production challenges, hence, to achieve more affordable prices for open market and the minimum cost for farmers. Thus, the expectation for the further coming years is that Agri-Food 4.0 should help to meet sustainable challenges by increasing the agri-food supply chain stakeholders revenues as well as decreasing their pressure for handling complex and external factors they cannot control, such as weather, market behaviors and policies, but also to react on time by visualizing current trends in needs.

Technological innovation is not a new concept for agriculture. Portable gadgets became the standard hundreds of years ago. With the industrial revolutions, chemical fertilizers, tractors and even satellite images began to be used in agriculture. Taking agriculture to the next level takes place with the internet of things. Thanks to drones and sensors in smart agriculture, which has become common among farmers, high-tech agriculture is rapidly increasing. It is a great reality that the applications of the Internet of Things (IoT) in agriculture will help farmers meet the world's food demands in the coming years.

With precision and smart farming practices, farmers have started to use some high-tech farming techniques and technologies to increase the efficiency of their daily work. E.g; Sensors placed in agricultural fields allow farmers to obtain detailed information about the topography and resources in the area, as well as variables such as soil acidity and temperature. They also have access to climate forecasts to predict weather conditions for the coming days and weeks.

Farmers can use their smartphones to remotely monitor their crops and livestock, as well as plan for the future by compiling statistics on feeding and producing their animals. By monitoring the temperature values of the soil instantly, more efficient decisions can be made about the planting, irrigation and harvesting process of the agricultural product. In a study, OnFarm determined that with the solutions of Industry 4.0, the yield for an average farm increased by 1.75%, energy costs were reduced by $7-13 per acre, and water use for irrigation was reduced by 8%. Collecting and analyzing big data in agriculture has become a great need to maximize productivity in agriculture.

After industrial areas such as mechanization, chemistry and biotechnology, there is a great change in the field of agriculture and agriculture 4.0 is emerging. it can help farmers, consultants and researchers develop more flexible and idiosyncratic farming strategies, making them less dependent on external inputs and more economical (reducing costs).Agriculture 4.0 can combine various applications to meet different needs.

Smart agriculture mostly uses internet technology. Various sensors placed on the equipment or in the field provide data to a platform (cloud-based) that allows the creation of an information system for users (agrisupply specialists, farmers, consultants, researchers, etc.). Examples include sensors embedded in machines that use artificial intelligence to detect weeds to target local destruction.

Based on the same technology, climate-smart agriculture seeks to enable more sustainable agriculture while keeping in mind the challenges of climate change. Its three main goals are: "to increase agricultural productivity to support increased incomes, food security and development, to increase adaptive capacity at multiple levels (from farm to nation) and to reduce greenhouse gas emissions and increase carbon sinks."

Geographic information systems (GIS) is another form of agriculture 4.0 characterized by the significant use of GPS technology. it allows mapping of terrains for increased precision during technical operations. For example, mapping the nitrogen requirements of a chart allows inputs to be tailored not only at the plot level but also for different regions defined by the satellite.
Another interesting area is co-farming or mutual agricultural aid. The term was developed by companies using digital platforms to help farmers connect for business relationships (equipment rental, feed sales, etc.) or share knowledge and experience without intermediaries.
In these few examples, agriculture 4.0 appears to address the needs of productivity, sustainability, adequacy or socio-economic issues.

Agriculture 4.0 reduces the amount of inputs needed (fertilizers and phytosanitary products) and at the same time optimizes movement to reduce mechanization loads through greater precision. These technologies help reduce farm costs by making farms more affordable at a time when farm income is declining, below average population income, and highly dependent.
The farmer also gains decision-making power through tools that allow field research and access to some of the data on specialized platforms. Like any new technology, agriculture 4.0 raises many questions among users. This encourages information exchange and sharing among farmers in groups operated by different networks: chambers of agriculture, agricultural credit cooperatives, provincial and district agriculture and forestry directorates, associations, unions, producer cooperatives, etc. In short, new technologies are not intended to replace agricultural consulting, but to provide new tools.

While there are some challenges, such as the interoperability of the various platforms or short-term concerns about the ownership of the data collected, agriculture 4.0 is a promising tool. It can improve the analysis and precision of the technological solution provided by farmers, consultants, technical and research organizations to achieve a more sustainable and resilient agriculture.

In the future, with advanced technology smart agriculture (agriculture 4.0) systems applied today; with the help of a cloud-connected and camera drone, we will have the opportunity to monitor our farm, to control elements such as humidity, temperature, pH with digital sensors, to prevent the waste of our inputs such as water and electricity, and to reduce the pollution in other water bodies, especially in groundwater. In addition, farmers will be able to analyze their resources in detail by making real-time yield assessments with agriculture 4.0.

With Agriculture 4.0, cheap and easy soil analysis, seeing and managing the farm via mobile phone, unmanned tractors, green energy, harvesting the products with the desired quality, taste and aroma are among the main objectives of all companies in the agricultural sector or must be. Thanks to the ever-developing technology, better quality and efficient agriculture will be possible.

In the field of animal husbandry, fully automated "monitoring and control systems" developed based on the latest developments in the world of technology contributed to the development of animal husbandry. It has emerged as a livestock management system that constantly monitors the reproduction of animals, animal production, the health and welfare of animals and their interaction with the environment. It predicts important events such as birth or disease before they occur via different modeling methods, and ensures that necessary precautions are taken in this context. In addition, in recent years, the process of applying robotic, automatic control and artificial intelligence techniques in dairy cattle has begun, and automation applications and robotic milking methods have developed further. Using smart farming techniques, farmers can better monitor the needs of individual animals and adjust their diet accordingly, prevent disease and improve herd health.

Plant production, smart agriculture is also at every stage of animal production processes; It is an application that can be directed and managed not only at the production site but also remotely, via satellite, in internal or external agricultural activity areas.

Factors that cannot be controlled with the effect of climate change in the agricultural sector increase crop losses. The researches carried out are taking into account the quality and organic structure of the soil, drainage and irrigation practices, seed selection and planting method, soil & plant nutrition practices, plant protection practices, harvesting techniques, etc. shows that traditional methods do not offer the opportunity to monitor professionally.

The information collected from the channels is stored systematically and on a location-based basis, the cause and effect relationships can be reported by using various algorithms, and appropriate data can be transmitted as instant information from mobile phones. Digital technologies that entered our lives with Industry 4.0 act as intermediaries that provide data to decision support platforms.

In our world, where agricultural areas are shrinking instead of expanding, we reduce the input costs, and the need to increase efficiency is clear. One of the most effective solution methods for this is to be aware of the problem and take preventive, timely and correct intervention against application errors.

In this sense, the agriculture industry is keeping up with the changing world conditions within the scope of Industry 4.0 and the term "Smart Agriculture" emerges. It is also referred to as Agriculture 4.0. Smart Agriculture represents the application of modern Information and Communication Technologies (ICT) to agriculture and can also be called the Third Green Revolution.

Mentioned after the plant breeding and genetic revolutions, this Third Green Revolution has brought new technologies such as precision equipment, Internet of Things (IoT), sensors and actuators, geo-positioning systems, Big Data, Unmanned Aerial Vehicles (UAV), Robotics etc. It addresses the agriculture industry based on the aggregation of ICT solutions.

It provides several benefits like preventing diseases and negative consequences such as deformity and poor quality in products. The solution also helps prevent insufficiency of grafting and unhealthy growth problems in flowers that can occur when temperature and humidity are unbalanced.

There are energy savings due to the elimination of the necessity of going to the greenhouse with the logic of remote management and monitoring by sending a warning message to the relevant people in case of alarm in the enterprises engaged in greenhouse agriculture and automatically putting the air conditioning systems into operation.

Smart Agriculture refers to agricultural practices aimed at achieving high productivity with less input amount. Smart agriculture technologies offer many opportunities to increase the performance of agricultural activities and to make fast and optimum decisions in different agricultural processes.

In other words, smart agriculture focuses on environmental data such as precision agriculture, soil structure, air condition, water and humidity ratio and the impact of these data on agricultural activity and product quality. In this direction, it is the whole of the process to analyze the special conditions in the fields in the best way and to determine the use of inputs at the right time and at the right place by using the most advanced technologies.

With the integration of precision agriculture technologies into the agricultural production process:

- Reduction of production cost;
- Determination of the optimum amount of water, fertilizer and other chemicals needed;
- Minimizing the negative environmental impacts of agricultural activities by reducing the use of fertilizers, chemicals and water;
- Developing innovative environmental solutions and minimizing the ecological footprint;

- Increasing soil fertility and ensuring its sustainability;
- To be able to make accurate yield estimation in agricultural production and to understand the agricultural consumption pattern in general terms;
- Increasing the competitiveness of small and medium farms will be possible.

Accordingly, innovative Precision Agriculture technologies are used in the following different processes of agricultural activities:

3.1 Artificial Intelligence

Artificial intelligence is a research area that aims to examine the mental functions related to intelligence in humans with the help of computer models and to apply them to artificial systems after making them formal. Since artificial intelligence has different application areas, there are many definitions depending on the application areas.

New technologies that cultivate, sow, irrigate, harvest the soil and analyze the soil and plant condition are adding a new one to traditional agricultural activities every day. Artificial intelligence, which adapts quickly to agricultural processes, especially in developed countries, attracts attention from most producers. Determining the future of agriculture depends on the solutions to be produced against the problems in this field. Artificial intelligence applications used to support agricultural production enable more efficient production by detecting problems in production. By determining the conditions such as the development status of plants, the number of pesticides to be used, and disease threats; methods of dealing with any possible negativity can be determined. Thus, efficiency-oriented production is supported, saving time and labor.

Within the framework of traditional agricultural activities, the factors that cast a shadow on plant production are illuminated with artificial intelligence technology, and the sustainability of agriculture is shed light on. Farmers can instantly follow their products in their agricultural fields. Moreover, artificial intelligence applications, which can make sense of many parameters such as temperature, humidity, light, and water/thirst levels by processing big data, enable the determination of the needs of plants and suggest solutions for the necessary intervention. Thus, by maintaining the necessary temperature and humidity level in greenhouses, productivity and product quality can be increased.

3.2 Weed Control

Getting rid of weeds is a top priority for farmers. This task is getting more and more difficult as known weeds become resistant to drugs. Automation technology comes to the fore as a more efficient way for farmers to protect their crops from weeds. While it detects and monitors weeds and prevents them with adequate pesticides (herbicides), it reduces the use of chemicals by 80% - 90%.

3.3 Plant and Soil Monitoring

Deep learning algorithms are drawn on to process data captured by drones and/or software-based technology to monitor plant and soil health. It is possible to follow the soil, plant and product development, whether in the field or from a distance.
Deterioration of soil quality and erosion pose a risk to food security and crops grown. Again, the growth of plants and the development of the product depend on many variables. With image recognition applications, it is possible to take action by identifying possible defects through images captured by the user's smartphone camera or built-in cameras.

3.3.1 Soil and Plant Control with Drone (UAV)

Today, farmers can use artificial intelligence and unmanned aerial vehicle (UAV) technologies to monitor crop health. The route of the unmanned aerial vehicle is determined and flights are carried out at regular intervals, and the visual data received is processed by taking into account environmental factors. Thus, farmers can easily monitor their products and appropriately intervene if there is a change in any part of the field.

Using UAVs, it is necessary to take images with cameras to be used in remote sensing system-based plant monitoring techniques used in subjects such as disease factor, pest detection, determination of their damage rates, determination of weed flora,

determination of water stress, determination of harvest time and yield estimation. Studies can be done to produce weed maps in the late season with images taken from aerial platforms or satellites (Koger et al., 2003; De Castro AI et al., 2012).
When some of the studies on agricultural areas using UAVs are examined, it is seen that different applications are made according to the agricultural product grown.

There are different applications such as monitoring the maturity of seeds, monitoring winter wheat fields grown using different fertilizers, determining and monitoring the productivity and total viability of rice fields, monitoring vineyards using different sensor systems and UAVs, and determining healthy and diseased areas.
In addition, in agricultural uses; It is seen that the control of the products can be done by these tools.

Some of the benefits of UAVs are as follows;

- The traditional pesticide sprayers used by farmers in agriculture are now being replaced by UAVs and their speed is 40 times that of conventional pesticide sprayers. With their smart irrigation systems, they save 90% water and 30-40% pesticides.
- UAVs provide more precise and reliable information by predicting the risks in large-scale lands, increasing efficiency and ensuring that product quality reaches the optimum level.
- It increases productivity by reducing the workload and time required in the management of large-scale lands.
- Areas with continuous cloud persistence or high turbidity become traceable, and high-resolution data can be obtained.
- It provides economically effective monitoring of inaccessible areas that are difficult to work due to its topography and/or areas with low visual coverage.

- ➢ It can be easily used in scientific research as it provides reliable and undisputed results.

3.3.2 Pest Plant Control

Pests are insects, mold, mites etc., and they threat plant health and require biological control. In addition to the damage to the plant, unnecessary pesticide usage reduces product and soil quality and causes costs. Phytosanitary and leaf status information is a reference point for us about the product. Plant images can be taken with a camera in small planting areas, or they can be collected and processed from the air with drones. Artificial intelligence support is used to process the captured images and analyze the data. With the generated report, it enables the farmer to regulate the use of pesticides by showing where and which pest has been detected.

3.4 Crop Harvest

Automation also aims to address workforce challenges. It helps farmers select and pack their produce, enabling them to do a quick and efficient job. In addition, it is possible to reduce labor and related costs by approximately 40%.

3.5 Pre-Predictive Analytics

Machine learning models are being developed to monitor and predict various environmental effects on crop yield, such as weather changes. With this technology, which is the basis of smart applications in agriculture, they help farmers make decisions by making sense of data such as temperature, precipitation, wind speed and solar radiation. Analysis of historical data facilitates better comparison of desired results.

3.6. Robots

Robots can also collect operational data on a wider range of devices than humans use. However, it allows the general advances in field robotics to cross-over between the practical needs of modern agricultural producers.

Research and Innovation Actions will focus on the design, development and testing of autonomous or semi-autonomous farm vehicles or robotic systems for precision farming, including advanced sensors and response mechanisms.
There are different types of robots that can be used in greenhouses.

3.6.1 Robots that can harvest in the greenhouse

The use of image processing software and robots has spawned new and high-tech harvesting systems for high-value crops such as tomatoes. The harvesting robots in the greenhouse corridors can harvest the ripe fruits by separating them from the unripe ones and packing them in boxes.
Benefits are;

- 24 hour harvest
- less workload
- Data analysis

3.6.2 Robots Carrying Materials in the Greenhouse

Working safely side by side with humans, robots can also perform manual tasks such as sorting plants apart. For example, they can optimize the placement of plants. The use of these types of robots can improve plant quality, provide savings in the use of water, insecticides, herbicides and fertilizers, and decrease production cost.

3.6.3 Spraying and Weed Removal Robots

Robots programmed to recognize weeds in the field clean the identified weeds or apply pesticides.
Robotic precision farming systems not only promise to increase yields by optimizing growth and harvesting processes but can also deliver significant benefits with more targeted interventions, lower fertilizer and pesticide use, and improved soil quality.

3.6.3.1 Ecorobotix

Ecorobotix is at the top of the list of robots currently in use. This solar powered robot is extremely light and has a GPS navigation system. Camera systems are used to find and remove weeds growing among plants. With these features, the robot can precisely find the weed that harms the plant. Thus, it is expected to reduce the use of herbicides used as chemical pesticides in agriculture by 90%.

3.6.3.2 Naio Technologies

Today there is a fleet of highly eco-friendly, different types of robots protecting crops on farms. These robots assist not only in harvesting but also in hoeing and weeding. The company representative of Naio, the company that created this fleet, stated that they want to contribute to the agricultural process by giving all participants access to the latest technology to help grow healthier, more abundant and environmentally friendly products.

3.6.3.3 Energid Citrus Picking Robot

This robot, which can be very productive for citrus, one of the important export products of our country, can select fruit in each of its arms every 2-3 seconds. can collect 50-100 fruits at a time. This amount can be accelerated by increasing the capacity of the robot.

3.6.3.4 Agrobot E Series

It stands out as an ideal robot for the future of strawberry plant farming, which requires special care. This robot also has wireless communication working with the AI system. The robot, which includes the advanced AI system, can determine whether the strawberries are ripe or not and collect them. While doing this, the fact that it does not harm the plant stands out as a plus feature.

3.6.3.5 Blue River Lettuce Robot

A robot that could be quite productive for lettuce in the field. This robotic machine monitors and inspects lettuce fields and prevents and cares for the surrounding weeds.

3.6.3.6 Agribotix

This robot, called Agribotix, works like a drone. Thus, it minimizes the costs. It prepares data about the field for the farmer by flying over the cultivated land. Built-in cameras and infrared sensors integrated into the robot can analyze the health of plants while the device is in the air.

3.6.3.7 Roboplant

RoBoPlant has full and semi-automatic machines as a system. With the help of the AI system, seedlings are planted optimally. It adjusts the positions of the seedlings relative to each other. In this way, the seedlings grow in a healthy way that does not affect each other.

3.7 Intelligent Irrigation Systems

With smart irrigation systems, efficient irrigation of agricultural lands can be achieved. In addition to reducing water consumption, increasing product quality is among the main objectives in smart irrigation systems (Xiao et al., 2010). Smart irrigation is the process of giving water when the soil needs water and as much as it needs. In smart irrigation, weather is one of the main factors used to irrigate by estimating the water needs of plants. The water requirement of the soil can be estimated based on local climate data using fuzzy decision-making systems (Allen et al., 1998). Smart irrigation helps better use of the world's most valuable resource, so higher and better yields can be obtained every season.

Smart irrigation delivers water and nutrients directly to the roots of each plant in metered doses that keep the root zone at optimum moisture levels. No more or less than the plant needs. Because there is no over-water application and flow rates are moderate, smart irrigation prevents runoff and deep infiltration. Designing smart irrigation systems is based on the ability of water to the soil and plant consumption, ensuring that the water stays in the active root zone and is used by the crop.

Intelligent irrigation systems help to reuse wastewater. Dirty water can become an asset. But water-borne pathogens are not always available, and flood, pivot and sprinkler systems contaminate crops. On the other hand, when drip irrigation is used, the water is delivered directly to the roots of the plant. So crop never comes into contact with contaminants, and each plant still gets the needed water to thrive. In this way, unusable waters are transformed into valuable resources.

Applying water with a pivot or other large sprinkler results in massive evaporation loss of water. If irrigation is done with one of these systems, 15-30% of the water evaporates during its journey from the emitter to the soil and never reaches the root zone of the crop. However, by applying directly to the root zone with drip irrigation, the risk of water evaporation disappears. In short, this means up to 30% more land can be irrigated with the same amount of water.

Pivot or flood irrigation systems apply large amounts of water in a short time and create conditions of oversaturation in the soil. This causes poor aeration, creating stressful conditions for plant roots that require a balance between water and air. Excess water also penetrates beneficial plant nutrients below the active root zone, causing your plant to receive fewer nutrients and also polluting groundwater. Smart irrigation helps to irrigate in the perfect amounts and timing based on the soil type and crop needs, so the air-to-water ratio in the soil is optimal, and nutrients are stored where they are needed.

3.7.1 Sprinkler Irrigation Metod

Sprinkler irrigation method, which has been used quite a lot in greenhouse cultivation recently, is realized thanks to the pipes drawn between the plants in a single row. The mini sprinklers at the end of the 30-40 cm long bars, which are fixed to the soil at certain intervals on these pipes, bring water to a certain area evenly. The most important feature that makes sprinkler irrigation different from other methods is that it affects a large area. The sprinkler irrigation method, which takes a large area under control, directly affects root spread and development. In addition, as in drip irrigation, it can bring the fertilizer needed by the plant to the soil in liquid or melted form. Another advantage of this method is that it makes a positive contribution by increasing the ambient humidity in dry weather.

3.7.2 Drip Irrigation Method

Especially in places where irrigation water is insufficient, drip irrigation is the most ideal method because of its positive effects on fruit quality. Since irrigation and fertilization can be used together in open banana orchards and banana greenhouses, it is also preferred by many modern greenhouses. In this way, both nutrients and water are brought together with the soil equally. In addition, the root zone of the plant is always kept wet, resulting in a direct increase in yield and quality. The fact that it can be controlled from a single point minimizes the labor cost.

3.7.3 Fogging

Fogging, another method that can be used in greenhouse production, is not exactly an irrigation system. But to meet the need for irrigation and winter frost and so on. It is very important to prevent damage. Thanks to the pipes placed on the roof of the greenhouse at certain intervals and the fogging nozzles placed in these pipes, the water meets the banana trees in the form of fog. It prevents the occurrence of frost damage by bringing the ambient temperature closer to its own temperature with the water, which is 15-16 degrees and sprayed from above. It can also be used to minimize the effect of extreme heat in the summer months. This irrigation method, which is carried out at regular intervals with automatic fogging nozzles, fixes the greenhouse humidity and temperature to the desired values and provides the appropriate environment desired by the plant.

3.7.4 Smart Irrigation System

With smart automatic irrigation solutions that minimize human errors, plant nutrition and protection processes are carried out exactly as planned. Intelligent fertilization is the most suitable root zone management tool that provides water and nutrient composition directly to the roots of each plant, according to product development cycles.Intelligent

fertilization protects small and well-timed doses with rain patterns and also protects the producer from leaching and groundwater pollution.
The automatic realization of the processes reduces the time spent by the producer for irrigation and fertilization. It provides an equal amount of water and fertilizer distribution to the plants, and thanks to its advanced alarm control, it prevents the plant from being damaged by making the necessary intervention in sudden developing situations.

Intelligent automatic irrigation provides significant advantages in needs that differ according to the growing conditions of different plants. For example, stress conditions can be controlled by applying different water and fertilizer applications to balance the green part development of sunflowers in the early and late periods. At the time of fertilization, it can harvest on time and with high efficiency with the right irrigation program.

3.8 Agriculture 4.0 In The Word

The concept of precision agriculture, which is emphasized today, has been replaced by smart agriculture (SMART-Farming), a new and trending concept that includes precision agriculture itself (Türker et al., 2015). It is estimated that until 2030, agricultural practices will be applied to a large extent in developed economies. To respond to the increasing food demands, farmers will begin to adopt more digital technologies. The integration of precision agriculture and digital technology will become the most influential trend in Europe.

The European Joint Research Center estimates that precision agriculture can save a great deal of carbon dioxide in European agriculture by 2030. The storage and processing of this information depend on the development of the internet network. Today, European countries are starting a digital revolution in the agriculture sector by supporting special plans and offering financial incentives to farms with Agriculture 4.0 (en.euractiv.eu, 2016).

In today's competitive environment, large companies closely follow digital agriculture technology and want to be ahead of their competitors by using these technologies. A company that aims to implement the internet of things with the connected herd system of CLASS has an important place among agricultural machinery companies. The company monitors the animals in the herd with sensors. In cases where animals are pregnant or sick, the authorities inform them via SMS and take precautions early (Kahraman, 2017).

Taiwan is a developing island country with a population of 27 million and a very large area. Agriculture is the main element of the economy in Taiwan. It has started to attach great importance to innovations and mechanization in agriculture. It has made a name for itself with the production of many technological devices used in agriculture and the execution of digital agriculture projects. Ada is an important manufacturer of all components of smart agriculture, such as IoT sensors, solar panels, drones, robots, LEDs and many agricultural technology systems. With its engineering infrastructure, it provides qualified workforce to all other components needed. Taiwan's geographical location is China. The fact that it is close to a global market such as the region and the tropical climate makes the region more attractive and creates an excellent basis for companies to invest. While raw material and labor input are cheap for companies; a product that will be produced is also easy to sell. The island of Taiwan is seen as a center for Agriculture 4.0, and it attracts SMEs and system providers to the country (Ryan, 2017).

Taiwan also ranks first in the world in the production of solar cells for the energy resources needed by large-scale agricultural projects. In smart greenhouses, it is tried to ensure that plants grow at any time of the year with special LED lights that imitate sunlight but do not burn the plants, with adjustments suitable for each plant, without infrared and ultraviolet lights. Drip irrigation systems and speeding up the harvest with tea harvesting machines not only save water but also labor and energy. It is aimed to reach optimum efficiency in water and fertilization with precision agriculture practices. YesHealth i-farm in Taoyuan has a fully controllable smart farm system. In the vertical farming facility, which has 14 floors, in addition to controllable humidity, temperature, and air flows, the absorption of nutrients by plants with classical music is investigated.

In addition, Taiwan's Advantech Company, which can actively use digital agriculture and assume the mission of a solution provider, provides serious support to the manufacturer. By expanding the remote control system, the company aimed for applicability in the whole country.

In Taiwan, the government carefully monitors the smart agriculture process. It was emphasized by the government that Taiwanese companies and foreign-based companies should work together for devices and sensors to be used in agriculture. The government is aimed to provide support such as a 5-year tax reduction for the production of systems for fertilization and pesticide control to increase Digital Agriculture practices and modernize the agricultural sector. Besides this, the government aimed to encourage organic production and the implementation of practices such as Good Agricultural Practices and Food Safety Management System (ISO 22000) to raise the agricultural sector to international standards.

The implementation of Agriculture 4.0 will ensure that agriculture will be affected by the weather conditions in the future in the least possible way. It is thought that attracting young people to agriculture in Taiwan is very important in terms of making a difference in the competitive market. For this purpose, a new agricultural training strategy is being developed for young talents in talent development. While adhering to the smart agriculture 4.0 framework, this training also aims to meet the demands of leading industries regarding on-the-job training and international expertise. To accelerate agriculture's 4.0 capacities and technical advisors, they created the "4.0 Industry Service Team" for experts and academics from industry-government-academic-research alliances. There are three professional technical groups including “Smart Production and Human Machine Coordinated Assistive Device Development”, “Agricultural Technical Expert System Application” and “Digital Service and Traceability Data Exchange Application”, as well as a technical support group “Business Management and Operation Support”.

The Netherlands, which has the smallest and most dense population in Europe, ranked 4th in the 2017-2018 Global Competitiveness Index. The most successful areas are; technological readiness, education, and innovation. Most of the income in the Netherlands comes from industry and commerce. Training programs are tailored to the demands of the job market to maintain competitiveness. It is aimed to identify and solve many problems of society and the economy with digital technologies.

In the agricultural sector, very effective water and fertilizer use is made with smart agricultural practices. The Netherlands has a foreign trade income of 100 billion Euros from the agricultural sector, although it is one-seventh of Turkey's surface area. There are many factors such as efficient production model, R&D, cooperatives, marketing and market control in achieving this success.

In the Netherlands, agricultural lands must be registered with cooperatives. Cooperatives inform the farmers about which plant should be planted in which period and guide the experts, and the experts make the necessary examinations in the fields and tell the farmers which plant will be suitable for the planting period. The purpose of this application is to prevent agglomeration in one type of product and to increase the yield to the maximum level by conscious agriculture. Then the prices of the products are determined in the rented warehouses and finally the products are put up for sale by auction and payment is made to the farmer after the required service fee is deducted.

One of the factors contributing to the development of agriculture in the Netherlands is the existence of agricultural universities in the country. The main goal of these universities is to achieve maximum quality crops with minimum input. In addition, they market this agricultural know-how and the automation systems used successfully to other countries through consultancy firms.

In short, it is clearly seen that the Netherlands has implemented Agriculture 4.0 applications, even if it is not named with this name. Five of the world's 26 largest agri-food companies have R&D facilities in the Netherlands. The Netherlands is the world's second-largest exporter of agricultural products after the United States. It is the world leader in ornamental plants and vegetable exports, the third in the world in milk and dairy products, and the fourth in the world in meat and oil-fat exports (Turkinfo, 2018).

In the Netherlands, the system works as follows; Agricultural universities research and increase productivity, the farmer produces according to these instructions, and the government gives incentives to ensure continuity. Cooperatives also play a major role in success. Cooperatives contribute to this success by facilitating cooperative legislation that adapts quickly to changes, effective management, egalitarian partnership structure, the role played by federative cooperative structures, and the way they position themselves in the food chain. The Netherlands' exports of agricultural products and agricultural technologies reached an important figure of 100.8 billion euros in 2017, and it has become one of the leading countries in agriculture worldwide, with the integration of Agriculture 4.0 applications into agriculture.

Israel has a competitive economy model with state control over sectors considered important to the country's economy. The country has an important place in the agriculture, chemistry, communication, and technology sectors in the world.
Israel, which is a country where it can be thought that no progress can be made in agriculture due to its geographical structure and disadvantage of surface area, is at the top of the list of countries that come to the fore in agriculture with its mechanization and R&D. Israel is currently a country that introduced the drip irrigation system to the world, can play on seeds, is self-sufficient in agricultural production, obtains all kinds of agricultural products even in unproductive areas with the latest technology, and can export a significant amount. Under the scarcity of soil and water, that is, in arid conditions, it has made significant progress in the agricultural sector using advanced technologies.

Many successful studies have been carried out such as sweet cherry tomatoes, drip irrigation systems, seed varieties resistant to drought and harsh conditions, post-harvest resistance processes. Israel has become one of the world's leading countries in agricultural technologies today using technological smart farming methods instead of old-style agricultural activities. Despite adverse terrain and climatic conditions, Israel manages to produce 95 percent of its food requirements. Underlying this success is the close collaboration between farmers, Israel's agricultural industry, and technological research. 17 percent of the Israeli budget is allocated to R&D for agriculture. Technological achievements include computer-controlled drip irrigation, computerized early-warning systems for leaks, thermal imaging for crop water stress detection, biological pest control, and new fruit and vegetable varieties. In addition, water shortages are alleviated by water reuse (86%) and desalination facilities.

Israel's growth targets are three important areas such as mobile applications, sensors, data collection hardware, and advanced analysis software. Israel is at the forefront in the sub-sectors of water management, data science, drones, and sensors.

An irrigation software called CropX is synchronized to smartphones, allowing real-time data acquisition on soil and weather conditions. In the greenhouses in the agricultural center called Arava, located in the desert in Israel, irrigation and fertilization are carried out via computers, plant pests are combated with different methods, costs are reduced using the energy obtained with solar panels, and in short, high technology is used to increase yield. Due to the desert climate, the day and night temperature values change suddenly. As a solution to this, Israeli scientists apply cooling during the day and heating at night. The Arava-type agricultural centers are financed by the National Jewish Fund and the farmers are trained.

Israel started precision agriculture with the drip irrigation system. The most important development in modern agriculture, the drip irrigation method, invented by Simcha Blass and his son Yeshayahu in 1959, increases crop yield, quality, and consistency while using less water. The multinational company, founded under the name Netafim, is a world-renowned name in the field of irrigation technologies. With the achievements of drip irrigation techniques, the export of necessary materials contributes 500 million dollars per year to the Israeli economy.

Israel has several agrochemical companies that offer a wide range of products, from liquid fertilizers to biopesticides, from fungicides to potassium nitrate and phosphate salts. Intelligent fertilizer management software enables farmers to maximize crop yields, reduce costs and increase profits. Israel Chemicals Ltd (ICL) is a leading supplier of potash, fertilizers, and technology-rich specialty fertilizers, all critical inputs for Israel's agriculture. ICL is the 6th largest potash producer in the world and the 2nd largest in Western Europe.

Phytech, an agricultural technology company in Israel, helps farmers use the Internet of Things (IoT). IoT is accelerating the implementation of digitalization, smart sensors, and efficient applications in agriculture that will help farmers optimize production. The company stays in constant contact with the farmers and assists their demands in all aspects such as farm management, use of machinery, irrigation, and planting method.
When the studies are evaluated, Israel is the country that develops itself under impossible conditions by making the best use of technology and selling drip irrigation systems, improved seeds, fertilizers, and agricultural technologies to many countries including Turkey. It is an exemplary country.

3.9 Agriculture 4.0 In Turkey

Turkey is one of the rare countries in the world in terms of plant diversity, but agriculture has not made much progress because it is made only for subsistence purposes. The majority of agricultural enterprises in our country are family-run, which leads to subsistence farming, low productivity, and low production for the market. In addition, food prices increase as a result of decreased production with high input costs, and imports are made due to the decrease in the ratio of production to consumption.

For Turkey's sustainable agriculture, a comprehensive policy, digitalization in agriculture, R&D and scientific studies, and government support are needed as in the examples of Taiwan, the Netherlands and Israel mentioned earlier. It is inevitable for Turkey to become the world's granary and the number one vegetable and fruit exporter with extensive R&D studies, conscious cooperatives, smart agriculture training, and mechanization in agriculture.

Agricultural supports applied today include diesel, fertilizer, soil analysis, difference payment, animal husbandry, certified seed/sapling use, and seed production, participation in the Farming Accounting Data Network system, organic and good agriculture, biological and biotechnical control, agricultural extension and consultancy services. However, it is seen that these supports are not very sufficient in terms of improving agriculture, ensuring that producers stay in rural areas, and increasing productivity in production. In addition to applications such as digital agriculture practices, efficient use of water, consolidation agriculture, training of farmers and consultancy, the transition from partial production structure to mass production structure, to become a cooperative, the government must support important investments. In this way, in the long run, while Turkey will be a net exporter of agricultural products, the burden of agricultural support on the budget will be minimized.

Unlike other sectors, agriculture needs government support, but this support should not be direct income support but supports in the form of agricultural R&D, water management, digital agriculture practices, farmer training, and guidance. It should be accepted that in today's world, where climate changes are experienced, optimal production and price will not occur in agriculture with the market mechanism and that agriculture is too important a strategic sector to be left to the market mechanism.

TA "Basin Based Production and Support Model" has been adopted in agriculture since 2010, and it has been decided to support 16 products of strategic importance if they are planted in the specified basins. It consists of different supports such as interest discount, difference payment, agricultural insurance, seed, seedling and sapling supports, land protection and R&D supports, diesel, fertilizer, and soil analysis support. Among the purposes of this model more effective use of agricultural supports, increasing production in products with a supply deficit, increasing farmer income, and creating demand forecasts by taking into account the needs of the agriculture-based industry are included.

One of the most important production problems of Turkey is that the inputs in production are dependent on imports or they are produced expensively. Therefore, efforts to reduce production costs should be supported rather than product support. Both cost and efficiency should be increased with holistic approaches such as reducing energy and fertilizer costs, preventing water loss and appropriate recycling of water, fertilizing with sensors and IoT, digital agriculture practices in irrigation and pest control, and organization in agriculture. Otherwise, supporting inefficient and expensive production at home will not only be a burden on the state but also will reduce its competitiveness in the face of cheaply produced products abroad. The farmer will stay and invest in the agricultural sector as a result of long-term stable policies. Agricultural producers who can't see their way, who produce at a high cost, who are in need of government support, and whose income level is very low, will give up on agricultural production.

Although incentives such as young farmer projects are given for young people to do this profession, these are short-term solutions. Solving the scale problem, consolidation, digitalization, agricultural education, and restructuring of cooperatives should be the target of the state. Despite being geographically small, the countries that are in a good position in the Global Competitiveness Index, especially in the fields of innovation, education and R&D, which we mentioned above, have achieved significant technological achievements in agriculture.

With a growing global population, food demand pressures are expected to reach 7.5 to 10.5 billion by 2050. However, over time, the severity of global warming will increase, and the demand for food will become unmet. This will undoubtedly lead to a rise in food prices. In addition, when factors such as the rapid aging of the countryside and declining birth rates are included, the agricultural sector will lose momentum continuously.

The new use of renewable and/or clean energy sources relatively reduces environmental pollution. In addition, scientists are testing their applicability in sectors by identifying new techniques and strategies. Because with the use of clean energy, Government expenditures and costs for many diseases will decrease. The contribution of this to the national economy will undoubtedly be great.

The collection, examination, processing, and analysis of data from the air and the ground regarding precision agriculture applications of the smart agriculture feasibility project jointly realized by TÜBİTAK and Ankara University are provided. Within the scope of the project, 400 hectares of land in Ankara University Faculty of Agriculture Haymana Research and Application Farm is used for 16 agricultural products. Within the scope of this project, it is aimed to handle and evaluate data such as yield mapping, irrigation, fertilization, and disease detection with remote sensing systems (Akay, 2018).

It is a Tarla company operating in the field of smart agriculture, which has been serving throughout Turkey for five years, and has now opened its products to the European market. The company produces information services for both individual farmers and all institutions related to agriculture and agriculture by making use of harvesting, agricultural control, irrigation, planning software, greenhouse systems, unmanned vehicles and digital mechanization technologies. These services are used in the insurance and finance sector to prevent economic losses and to create added value for existing customers (Tarla.o, 2019).

Türk Telekom carries out studies in the field of smart agriculture with IoT and M2M. It offers solutions with applications in Cultivation Area/Greenhouse Control and Management, Intelligent Irrigation, Animal Tracking and Coop/Shelter Monitoring, Flow and Depth Measurement.

Doktar Firm is established in Izmir and has been operating for seven years. Thanks to the geographical and climatic features, every field of agricultural activity is included in the region. Important agricultural products such as figs, tobacco, cotton, corn and wheat are grown in the region. Ege University, which has an important place among the Faculties of Agriculture, is located in the region constitutes an advantage. The company uses geographic information systems, remote sensing, image analysis, image processing, big data management and analysis, phenological modeling, sensor, internet of things, agricultural control technologies, planning software, marketing information systems, greenhouse systems, digital mechanization technologies and transforms the data coming from technology into action with agricultural algorithms. In addition, it provides end-to-end service by providing 24/7 expert agricultural consultancy for all of these (Doktar, 2019).Turkcell Filiz is a mobile application that provides instant data about its cultivated area and can be used together with an air-ground station.

Tabit Smart Agricultural Technologies Inc. is in a position to be the first to initiate studies on the meeting of agriculture with technology in Turkey and continues its activities in this regard. It has been operating for fifteen years on the spread of smart agricultural technologies. The headquarters of the company is in Istanbul, and there is also a 300-acre smart campus (Vodafone Smart Village) belonging to the company in Aydın Koçarlı. The reasons why this region was chosen for the campus were the suitability for the application of the technologies developed by the company authorities, the fact that 93% of the products produced in Turkey in herbal production can be grown in this region, as well as being sufficient in animal husbandry, and the social structure of the farmers who will use the technology is in the average of Turkey. Factors such as how technologies can be applied in the development, what resistances they may encounter, and easy observation of situations are specified. Harvesting, agricultural control, irrigation, planning software, marketing information systems, greenhouse systems, unmanned vehicles and digital mechanization technologies are developed together with its business partners and tests how these applications can be used at the farmers level (Tabit Smart Tarım Teknolojiler A.Ş., 2019).

3.9.1 Agriculture 4.0 Awareness Survey In Turkey

In order to measure the awareness of Agriculture 4.0, a survey was created by taking the opinions of expert agricultural engineers. 100 person were interviewed in our survey. The people are selected completely independently.

3.9.1.1 Survey Result

Table 1. Survey Question 1

Do you know the term Smart Agriculture (Agriculture 4.0)?	
YES	47%
NO	53%
TOTAL	100%

In our first question in the survey, the question "Do you know the term Agriculture 4.0" was asked of the participants. 47% of the participants answered yes because they knew this term, while 53% answered no by stating that they did not know.

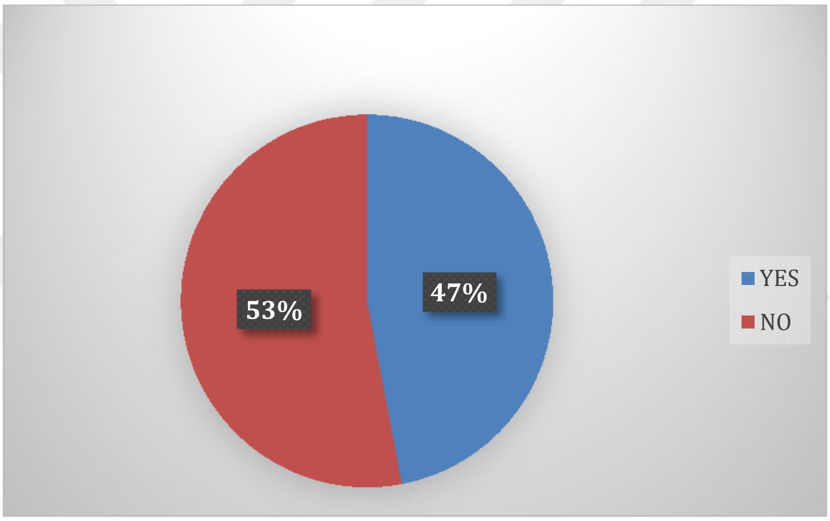

Figure 1. Survey graphic 1

Table 2. Survey Question 2

Do you know the term Smart Agriculture (Agriculture 4.0)?			
	YES	NO	TOTAL
MALE	17	15	32
FEMALE	30	38	68
TOTAL	47	53	100

The majority of our participants, such as 68%, were women. Among the female participants, there were 30 people knew the term Agriculture 4.0, and 38 of them stated that they had not heard of the term. Of the men, who made up 32% of the participants, 17 people knew this term, while 15 people stated that they had not heard of the term.

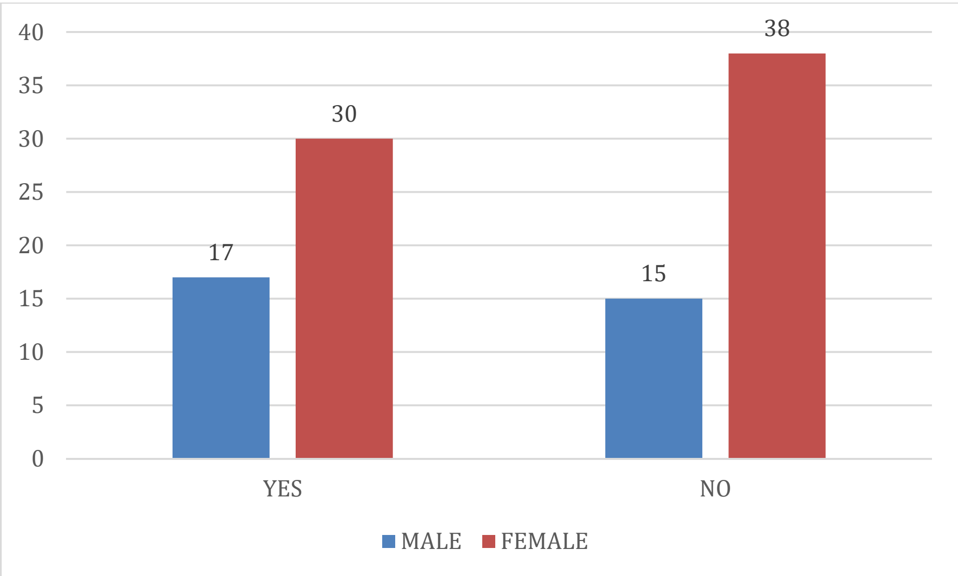

Figure 2. Survey graphic 2

Table 3. Survey Question 3

Do you know the term Smart Agriculture (Agriculture 4.0)?			
AGE	**YES**	**No**	**TOTAL**
18-38	23	38	61
39-59	**22**	**15**	**37**
60+	2	0	2
TOTAL	**47**	**53**	**100**

23% of the respondents were between the ages of 18-38 and knew the term. When the age range of 39-59 was examined, it was seen that 22% knew the term "Agriculture 4.0", and when 60 years and older were examined, it was seen that none of the participants knew the term.

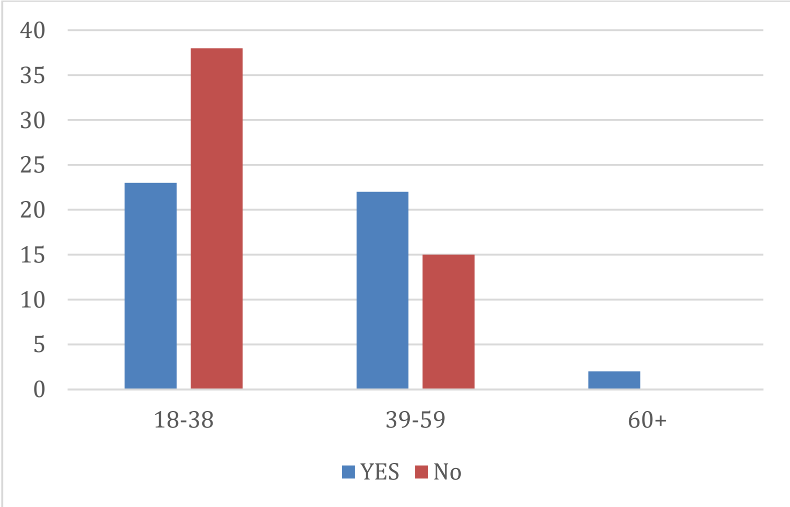

Figure 3. Survey graphic 3

Table 4. Survey Question 4

Education Level	YES	NO	TOTAL
Primary school	1	2	3
High school	**4**	**13**	**17**
Middle School		1	1
University	**42**	**37**	**79**
TOTAL	47	53	100

When the education levels of the participants are examined, it is revealed that 79% of them have university graduates, and 17% have high school graduates. 53% of university graduates and 24% of high school graduates know agriculture 4.0. The rate of primary and secondary school graduates is very low.

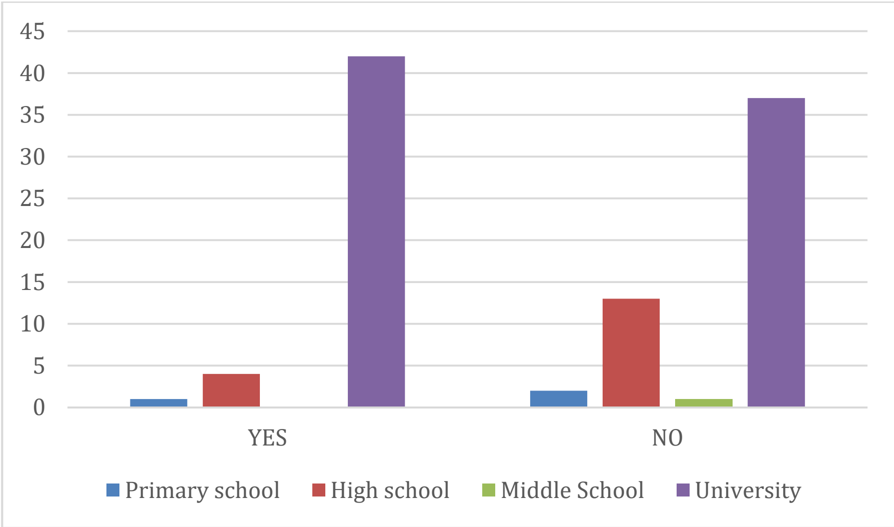

Figure 4. Survey graphic 4

Table 5. Survey Question 5

Do you use any of the Smart Agriculture applications or do you use it in your environment?	
there are users in around me	42
I use it myself	**4**
I don't use it and there is no one around me	54
TOTAL	**100**

"Do you use any of the Smart Agriculture applications or do you use it in your environment?" As an answer to this question, 54% answered "I don't use it and there is no one around me". 42% of the participants answered "there are people which use this system equipment around me". As small as 4% of them mentioned that they use it themselves.

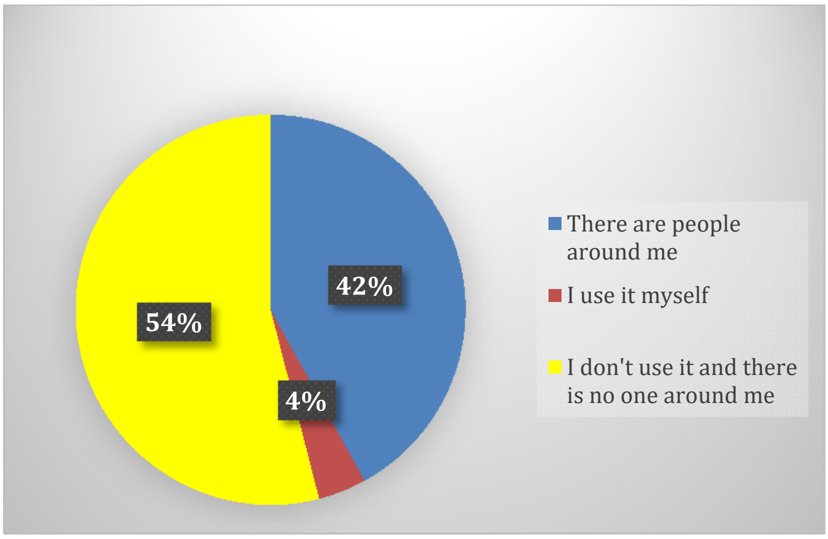

Figure 5. Survey graphic 5

Table 6. Survey Question 6

Which Smart Agriculture applications do you know?	
Smart Greenhouses	70
Intelligent Irrigation Systems	77
Agricultural Robots	25
Agricultural Sensors	27
Driverless Tractors and Autonomous Agricultural Vehicles	28
Hydroponic Plant Growing	62
Use of Agricultural Drones and UAVs	34

"Which Smart Agriculture applications do you know?" As an answer to the question, the number of people who say that they know smart greenhouse systems is 70 out of 100 people. The number of people who know Intelligent Irrigation Systems is 77, the number of people who know Agricultural Robots is 25, the number of people who know Agricultural Sensors is 27, the number of people who know Driverless Tractors and Autonomous Agricultural Vehicles is 28, the number of people who know Hydroponic Plant Growing is 62, and the number of people who know Use of Agricultural Drones and UAVs is34.

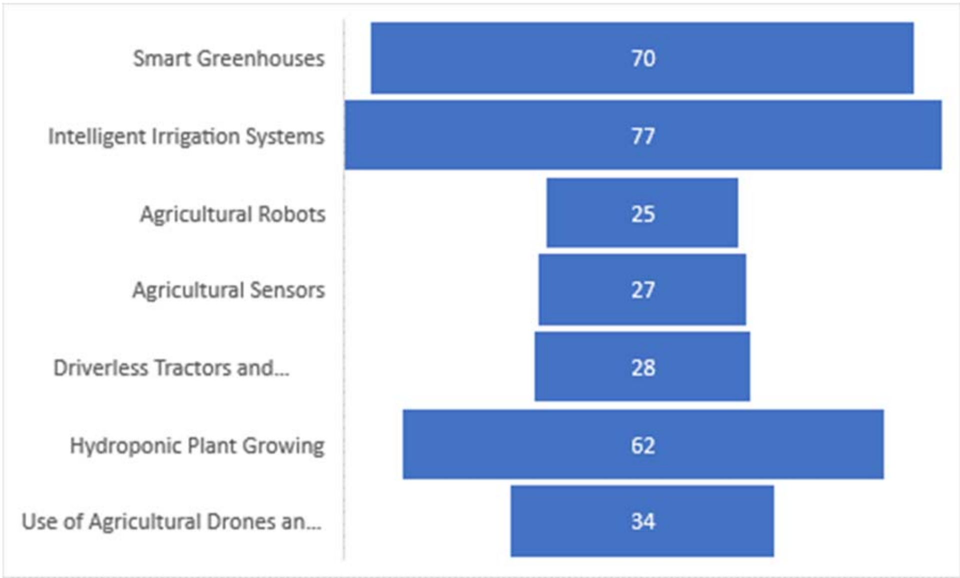

Figure 6. Survey graphic 6

4. MATERIALS AND METHODS

In the second part of the study, it is decided to choose 4 main components to be used in the greenhouse using the AHP method, which is one of the multi-qualified decision-making methods. 4 different criteria are determined for each component. While determining these criteria, opinions and comments are received from agricultural engineers and greenhouse companies. For each component a selection is made among 5 different alternative components.

The literature has been carefully scanned, projects and theses related to the subject have been examined. All greenhouse studies equipped with Agriculture 4.0 have been meticulously examined and the most suitable use in the greenhouse for the production of strawberry to be established from these components has been selected by consulting agricultural engineers who are experts in the field of smart agricultural technologies and companies in the sector.

4.1. Analysis of the Region where the Study will be carried out

The climatic and geographical features of the Ceyhan district, where the greenhouse will be established, are explained in detail using the necessary resources and obtaining information from the district agricultural organizations.

4.1.1. Climate

Climate is the name given to the average of meteorological events such as temperature, humidity, air pressure, wind, and precipitation observed in a place over a long period. The climatic characteristics of an area affect human and economic activities both directly and indirectly. Climate is a very important factor, especially in terms of agricultural activities. The climatic conditions that regulate the natural plant life also affect the plants grown by humans. Therefore, climate deeply affects agricultural activities and the type and distribution of these activities. The climatic conditions in any area play an important role in determining the variety and distribution of agricultural products grown in that area. In addition to these, it also determines the sowing, growing, and harvesting times of the products.

The region selected for the study has its characteristics in terms of climate characteristics and the patterns of the products grown are shaped accordingly. Mediterranean climate characteristics prevail in the region. The summers are quite hot and dry; winters are warm and rainy. Precipitation in summer is considerably less. Therefore, agricultural irrigation is of great importance in this period. In the Ceyhan River, water channels are opened for irrigation of the plain. However, the extreme drought in the summer season causes these canals to dry out from time to time and affects agricultural activities in areas where irrigation cannot be done. The suitability of the climatic conditions in the selected region ensures that the agricultural production process continues for a whole year without interruption. The main thing in this continuity is the irrigation carried out to get rid of the summer drought.

It is known that the type of products that love heat in summer and demand moisture and precipitation in winter are grown in the working area. Greenhouse activities are also carried out because the temperature, which is one of the climate elements, makes greenhouse cultivation economical in the region. The data of the Ceyhan Meteorology Station of the General Directorate of Meteorology was used in the examination of the climate elements in the region selected for the greenhouse establishment.

4.1.2. Heat

Temperature is one of the factors that directly affect agriculture among the climate elements. Ceyhan district reflects the temperature characteristics of the Mediterranean basin. According to the Köppen-Trewartha climate classification of the temperature values of Ceyhan, the summers are very hot, the winters are cool, the subtropical dry summer climate reflects the characteristics of the Mediterranean climate (Bölük and Kömüşçü, 2018). It offers a hot and arid climate in summers, rainy in winters, and a humid and cool climate.

The annual average temperature in the region is 18°C. When the course of temperature throughout the year is examined, the hottest month is August, and the coldest month is January. While the monthly average temperature reaches its lowest value in January, it reaches its highest value in August. Monthly average temperatures rise regularly from January and reach their maximum value in August. When the high and low temperature values in the selected region are examined, the highest temperature is 44 °C in July, and the lowest temperature is recorded in January at -11.3 °C. Low and high temperatures have very important effects on agricultural activities. Low temperatures are very important in plant life. The low values recorded affect the yield and quality of that year.

4.1.3. Sun exposure times

The highest number of sunshine hours per day is measured in June on average in Adana. There is an average of 10.95 hours of sunshine per day in June and a total of 339.45 hours of sunshine during June. The lowest number of sunshine hours per day in January is measured on average in Adana. In January, there is an average of 7.07 hours of sunshine per day and a total of 219.21 hours of sunshine. In Adana, approximately 3367.77 hours of sunshine is counted throughout the year. There is an average of 110.64 hours of sunshine per month.

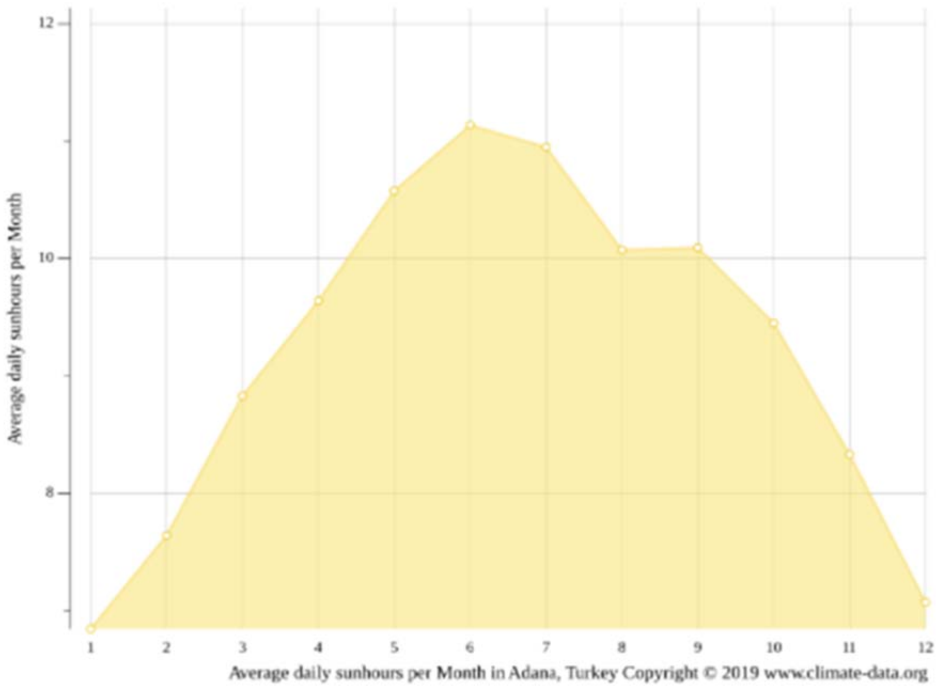

Figure 7. Sun exposure times

4.1.4. Precipitation Characteristics

Precipitation is a factor that has a very important effect on agricultural activities. All plants need water to survive. The fact that the plant reaches the water it needs during the growing period is effective on its yield and quality. In addition to the amount of precipitation, factors such as the type, intensity and distribution of precipitation throughout the year are of great importance on agricultural activities. The fact that the amount of precipitation is less or more than the amount needed by the plant is effective on yield and quality. Precipitation characteristics are one of the factors that affect the diversity of agricultural activities and the growing period.

The average annual precipitation in the region is 653.6 mm. The distribution of precipitation during the year, in other words the precipitation regime, is as important as the total amount of precipitation on agricultural activities. When the distribution of precipitation over the seasons is examined; It is seen that the season with the least precipitation is summer, and the season with the highest precipitation is winter. 45% of the total annual precipitation is recorded in winter, and only 6% of the total annual precipitation is recorded in summer. 29% of the annual precipitation falls in the spring and 20% in the autumn season. The scarcity of summer precipitation and the excess of precipitation in winter are typical features of the Mediterranean climate. The scarcity of precipitation in summer increases the importance of irrigation in plant life.

4.1.5. Pressure and Wind Conditions

Winds, which are air movements between pressure centers, have a number of positive and negative effects on agricultural activities. It has negative effects such as, accelerating the evaporation of moisture in the soil, causing the fruits to fall before they are ripe, and causing a decrease in the amount of annual product obtained by providing early drying of the crop areas. On the other hand, it has positive effects such as increasing the sugar rate in fruits, facilitating fertilization and helping the product to mature on time.

The prevailing wind direction in Ceyhan is in the north-south direction. The research area, which is under the influence of north-dominant winds in winter and south-dominant winds in summer, was affected by winds from different angles. In winter, the winds coming from the north sometimes create a blow-dry effect by rubbing against the Taurus Mountains and cause floods in Çukurova by melting the snow in the Taurus Mountains. The speed of the winds as well as the direction and frequency of the winds are of great importance to agricultural activities. High-speed winds have a devastating effect on plants. It is observed that the monthly average wind speed is relatively high in July and June. However, these values are not very high damaging values at the point of causing mechanical damage to plants.

Figure 8. Ceyhan Windmill

4.2. Selection of Components to be Used in the Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) Approach is an approach developed by Thomas L. Saaty in the early 1970s, which includes criteria organized according to a certain hierarchy, evaluates the weights of these criteria, compares the alternatives according to the criteria and enables ranking (Hu and Peng, 2008).

AHP is a descriptive approach that basically supports the decision maker. The developer of the method, Thomas Saaty, explains that the emergence of the AHP stemmed from the need to measure intangible and therefore unmeasurable items while he was serving at Arms Control and Disarmament Agency (Pirinçci and Güngör, 2019).

AHP is a multi-criteria decision-making technique that handles problems in a hierarchical structure and is based on pairwise comparison logic. Pairwise comparisons are found by comparing the priorities of the elements in the decision problem with each other (Timor, 2011).

AHP, one of the multi-criteria decision-making methods, tries to answer the problem systematically by breaking it down into small sub-items. With the help of subjective evaluations, by making pairwise comparisons, priorities are developed for each hierarchy and the logical process is organized (Güner, 2003). By weighing and synthesizing different levels, AHP provides them with the best solution perceived by decision makers (Quaddus and Siddique, 2001).

AHP involves breaking down a hierarchical model with different levels of common features of the decision problem into elements. Each level in the hierarchy corresponds to the common feature of the elements at that level (Ramanathan, 2001).

AHP is applied in decision problems where a group or commission has to decide together (Harker and Vargas, 1987). AHP combines the weights of nested features and provides convenience to the decision maker by reducing the size (Yıldırım & Önder, 2015).

To make the right decisions, it is necessary to know the problem, the need and the reason for the decision, the criteria affecting the decision, the sub-criteria, if any, the stakeholders affected by the decision and the available alternatives for the decision (Saaty, 2008).

AHP is suitable for comprehensive, understandable and complex decision problems and allows sensitivity analysis, so it is used too much (Ünal, 2011).

The application areas of AHP can be listed as choosing between alternatives, cost-benefit analysis, distribution, planning and development, determining priorities, decision making and estimation problems (Özdemir and Özveri, 2004).

AHP determines the relative order or priority of decision alternatives (Lee et al., 2007). At the top of the hierarchy is the macro decision goal of making the best decision (or choosing the best alternative). Lower levels of the hierarchy contain attributes (goals) that contribute to the quality of the decision. The details of these attributes increase at the lower levels of the hierarchy (Zahedi, 1986).

At the beginning of the application, the criteria and sub-criteria of the problem are compared by filling out the questionnaires prepared using Saaty's 1-9 scale. Afterward, the order of importance is established for the decision alternatives by evaluating these criteria (Önder and Önder, 2015).

While making decisions, decision makers make pairwise comparisons at every stage of the hierarchy, and the consistency of the decision matrices obtained by pairwise comparisons can be checked with the Consistency Ratio-CR. While constructing the pairwise comparison matrix, if the decision maker states that A is 2 times more important than B and B is 3 times more important than C, then the decision maker's A is 6 times more important than C (2x3=6) is expected to be expressed. When the CR ratio calculated with this logic is less than 0.10, it is stated that the decision matrix obtained is consistent (Belton, 1986).

In practice, the hierarchy of AHP can show complex structures from time to time. AHP can be applied effectively even in complex structures and can use both qualitative and quantitative data. The method developed by Saaty is applied as follows (Saaty, 1980).

Step 1: Define the decision problem and determine the purpose.

In the first step, the decision problem is defined and its purpose is determined.

Step 2: Determining the criteria and sub-criteria and creating the hierarchical structure of the problem.

In the AHP approach, all quantitative and qualitative factors affecting the decision process are determined by using a survey or by consulting the opinions of experts on this subject. As a result of the information obtained afterwards, a hierarchical structure is formed by determining the criteria, sub-criteria and alternatives. The hierarchical structure is determined. In this structure, the purpose, main criteria, (if any) sub-criteria and again (if any) alternatives are determined.

Step 3. Making Pairwise Comparisons Between Criteria and Calculating Priority Vectors: Pairwise comparisons between criteria and classes are made with the method used by decision makers on a specified scale.

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgement slightly favour one activity over another
5	Essential importance	Experience and judgement strongly favour one activity over another
7	Very strong importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values	When compromise is needed between two

Figure 9. AHP basic scale

In the evaluation set, which is also called the comparison matrix, the degree of importance is determined by revealing which of the two criteria is stronger. In AHP, a basic scale of 1-9 (Likert scale) is used as an ordinal to convert pairwise comparison judgments into numerical values. This degree of importance is established with the help of the scale in the table above.

The principles on which the theoretical infrastructure of the AHP is based are summarized by Saaty (1986) in the 4 items listed below:

The principle of being two-sided/reciprocity: If item A is 3 times more important to B, then B can be expressed as 1/3 important to A (Kuruüzüm and Atsan, 2001). When this principle is not applied, it means that the pairwise comparisons used in the evaluation are not sufficiently accurate or explained (Kargı, 2015).

The principle of independence: The criteria are independent among themselves and from the lower levels (Timor, 2011: 34). Evaluations of one level of the hierarchy are independent of items at other levels. If a new option is added or removed, it means that the priorities of the higher-level criteria will not change (Kuruüzüm and Atsan, 2001).

Expectations principle: All alternative proposals that can match expectations must be fully included in the hierarchy. Otherwise, the researcher is deemed to have not addressed all expectations and the intended result cannot be achieved. Every element affecting the current problem should be included in the hierarchy (Timor, 2011:34, Kargı, 2015).

Step 4: Determination of the Eigenvector: In order to reveal the percent importance distributions of the expressed criteria, the vectors of the milk are used. B column vector of type “n x n” is created. In the calculation of B column vectors, the following equation is used in 1 (Saaty, 1994).

Pairwise comparison values using the scale are created on the matrix frame and the local priority vector is determined by the eigenvector obtained by solving the equation A.w = λmax.w.

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \tag{1}$$

By arranging n number of B column vectors in matrix format, C matrix is obtained.

$$C = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ c_{n1} & c_{n2} & \cdots & c_{nn} \end{bmatrix} \tag{2}$$

With the created C matrix, there are percentile importance distributions that reveal the importance values between the criteria. To achieve this result, the arithmetic average of the row components must be taken using Equation 2. The W column vector specified as the Priority Vector is reached.

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n}$$

(3)

Step 5: Calculation of the Consistency Ratio: In the AHP method, calculating the Consistency Ratio (CR) obtained, for each matrix, the eigenvalue vector and the maximum eigenvalue are calculated. The consistency indicator CI is then calculated.

The basis of the CR calculation is the comparison of the number of criteria and a coefficient called the Base Value (l). In order to calculate l, firstly, the D column vector is obtained from the matrix multiplication of the comparison matrix A and the priority vector W. The basic value (E) for each evaluation criterion is obtained from the division of the reciprocal elements of the obtained D column vector and the W column vector specified in Equation 3. The arithmetic mean of these values, Equation 4, gives the basic value (l) for the comparison.

$$D = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} x \begin{bmatrix} w_1 \\ w_2 \\ \cdot \\ \cdot \\ \cdot \\ w_n \end{bmatrix}$$

(4)

After calculating the” λ” value, the Indicator of Consistency (CI) is calculated by

$$\lambda = \frac{\sum_{i=1}^{n} E_i}{n}$$

(5)

$$CI = \frac{\lambda - n}{n - 1}$$

(6.1)

When it comes to the last step, CI is divided by the standard correction value expressed as Random Indicator (RI), and the CR value is obtained with Equation 6.

$$CR = \frac{CI}{RI}$$

(6.2)

However, it is necessary to obtain data to ensure that the answers given in the study are consistent. The fact that the CR value is less than 0.1 as a result of the analyzes with the AHP method shows that the participants who answered the questionnaire responded consistently and the study was reliable. If the CR value is greater than 0.10, it indicates that there is a calculation error in the AHP method or that the respondents gave inconsistent answers. For these reasons, it may be possible to repeat the AHP analysis (Saaty, 1980; Karaatlı and Davras, 2014).

Greenhouse covers are of great importance in terms of light transmittance and energy efficiency. Choosing the wrong greenhouse cover can cause great harm to the producers. Choosing the right material directly affects the profitability of the producers. The 5 most preferred greenhouse cover types were selected to choose the most suitable greenhouse cover for a strawberry greenhouse.

These cover types are named as Glass Greenhouse Cover, Polycarbonate Greenhouse Cover, Polyethylene Greenhouse Cover, Fiberglass Greenhouse Cover and PVC Greenhouse Cover.

4.2.1. Glass Greenhouse Cover

Glass greenhouses are the best exterior option, they fail in energy efficiency and are costly. Glass does not scatter light enough, so a diffusion method is needed for plants. There are two main types of glass greenhouses: single-pane and double-pane.

4.2.1.1 Single Section

Single-pane glass greenhouses are not suitable for northern regions where crops are grown in colder climates. Single-pane glass greenhouses are fragile, break often, and cannot withstand the weight of snow. A single compartment greenhouse is also the least energy efficient greenhouse because a single compartment allows heat to escape. Single-pane greenhouses are great for light transmission, but this can still be an issue in areas where too much sun will burn your plants. These disadvantages, combined with the cost of glass, mean that single-pane glass greenhouses are better suited to form than function.

Also, heating costs can be double or even triple the amount of double glazing or PVC-based fabric greenhouses. The thermal insulation value, or R-value, of a single-pane glass greenhouse is about 0.9.

4.2.1.2. Dual Split

Double-glazed greenhouses are designed to be more energy efficient without sacrificing traditional style. Double glazing can cut the heating cost in half. These greenhouses have an R-value of 1.5 to 2.0, which makes them better than single glass for insulation. Double-glazed greenhouses may have a coating applied inside to reflect heat and add more insulation to the greenhouse.

4.2.2. Polycarbonate Greenhouse Cover

Polycarbonate greenhouses are made of thick plastic, making them cheaper and more versatile than most glass greenhouses. These greenhouses usually come with a single-wall or double-wall polycarbonate sheet.

4.2.2.1. Single wall

Although single-walled polycarbonate is more durable than glass, it creates problems in terms of thermal insulation and light transmission. Single-walled polycarbonate sheets do not diffuse light or insulate heat well. While the R-value of the single-walled polycarbonate material is 0.83, the R-value of the greenhouse glass is 0.93. The light transmittance of the single-walled polycarbonate is also lower than the glass. About 94-

96 percent of the light passes through the single-walled polycarbonate; 97-98 percent of the greenhouse glass can pass through the greenhouse glass. On the other hand, single-walled polycarbonate is a highly flammable material, and extreme caution should be exercised if used in hot climates with long periods of sunshine.

4.2.2.2. Double wall

Double-walled polycarbonate is better than single-walled polycarbonate in almost every way.Double-layer polycarbonate has an R-value of 1.42, which makes it better than single-glazed or single-layer polycarbonate. Double-walled polycarbonate also diffuses light, but 80-84 percent of the light passes through the panels. Also, polycarbonate panels are known to cloud over time. This turbidity is called the yellowing effect. It also creates a yellowing effect as it reduces the light passing through the panels.

4.2.3. Polyethylene Greenhouse Cover

Polyethylene is inexpensive and lightweight, which makes it easy to use. Thanks to its flexibility, it can be easily shaped during the installation of the cover.

Polyethylene film is usually made of one or two layers. Oxygen and carbon dioxide can pass through this material. Because; It is porous and allows plants to breathe even in a tightly closed greenhouse. Polyethylene greenhouse cover is perfect for growers because you can customize the material with different coverings. A UV stabilizer can be used on polyethylene film to reduce sun degradation and yellowing, while an anti-drip coating will prevent excessive condensation.

Polyethylene glass diffuses light and allows growers to maximize the sun's efficiency on the site by ensuring that all plants receive sunlight. Compared to glass, polyethylene film reduces heat loss by 30-40 percent. In addition, the R-value of the single-layer polyethylene film is 0.87, while the double-layer films range from 1.5 to 1.7.

Finally, unfortunately, polyethylene films are still moderately flammable. More than glass materials in terms of flammability, but; we can say that it has less value than polycarbonate materials.

4.2.4. Fiberglas Greenhouse Cover

Fiberglass Reinforced Plastic (FRP) is a good option for greenhouses. FRP scatters sunlight, provides good diffusion and light transmission throughout the greenhouse, and can last up to 10 years. It is efficient in terms of heat saving.
Fiberglass panels have an R-value of 0.89, which is slightly better than glass. However, UV rays can break down the fiberglass over time, making the cover brittle. To maintain the strength of fiberglass panels, a new UV coating is needed to be applied every few years.

4.2.5. PVC Greenhouse Cover

Polyvinyl Chloride (PVC) fabric is the best choice in terms of durability. Some PVC fabrics can withstand heavy snow loads and offer higher insulation, making them good for growers in cold climates. Translucent PVC fabrics with UV treatments, including types designed with UV stabilizers, provide good light diffusion for plants. UV treatment also prevents the yellowing effect on the fabric.
For safety purposes, PVC fabric can also be made flame retardant. Another advantage of PVC fabric is that it is easy to install and does not require special skills.

4.2.6. Greenhouse Cover Selection with AHP

Evaluation of the five alternative greenhouses covers and four criteria is done by analytical hierarchical process. For the most appropriate greenhouse cover selection decision, interviews were held with expert 3 agricultural engineers and the most appropriate criteria were determined in the light of evaluation elements. Then, the criteria were compared in order of importance in line with the importance scale developed by Saaty. By taking the geometric mean of the answers given by the experts, comparison matrices were created for the determined criteria as indicated in the table.

Table 7. Comparison Matrix

COMPARISON MATRIX - (Decision Maker -1)				
DECISION CRITERIA	Light Transmittance	Cost	Energy-saving	Lifetime
Light Transmittance	1	1/5	1/5	1
Cost	5	1	1	5
Energy-saving	5	1	1	9
Lifetime	1	1/5	1/9	1
COMPARISON MATRIX - (Decision Maker -2)				
DECISION CRITERIA	Light Transmittance	Cost	Energy-saving	Lifetime
Light Transmittance	1	1/3	1/7	1/5
Cost	3	1	1	9
Energy-saving	7	1	1	9
Lifetime	5	1/9	1/9	1
COMPARISON MATRIX - (Decision Maker -3)				
DECISION CRITERIA	Light Transmittance	Cost	Energy-saving	Lifetime
Light Transmittance	1	1/9	1/9	3
Cost	7	1	1	7
Energy-saving	9	1	1	9
Lifetime	1/3	1/9	1/9	1

COMPARISON MATRIX				
DECISION CRITERIA	**Light Transmittance**	**Cost**	**Energy-saving**	**Lifetime**
Light Transmittance	1	1/5	1/7	1
Cost	5	1	1	7
Energy-saving	7	1	1	9
Lifetime	1	1/7	1/9	1
SUM	14,000	2,343	2,254	18,000

After the pairwise comparison matrix was made, the matrix normalization was performed. In the normalization process, all column values are divided by the sum of each matrix column. By using the normalized matrix, the average of each row value was taken and thus the eigenvector was found for each determined criterion.

Table 8. Normalized Matrix

NORMALIZED COMPARISON MATRIX					**Eigenvector**
DECISION CRITERIA	**Light Transmittance**	**Cost**	**Energy-saving**	**Lifetime**	
Light Transmittance	0,07	0,09	0,06	0,06	0,069
Cost	0,36	0,43	0,44	0,39	0,404
Energy-saving	0,50	0,43	0,44	0,50	0,468
Lifetime	0,07	0,06	0,05	0,06	0,059

After prioritization is made, whether the decision makers are consistent when making comparisons between the criteria is measured. In order to find the consistency ratio, first, the eigenvalue is found. The eigenvalue is found by multiplying the columns of the comparison matrix with each priority value and summing the results over the rows. The x-value is then divided into its corresponding priority values. The λmax value was found by taking the average of the results obtained.

If the consistency ratio is less than 0.1, the matrix is considered to be consistent. As a result of a study, randomness indicators for matrices in size 1-15. The large number of criteria in the problems considered weakens the possibility of obtaining consistent results when all the criteria are evaluated together. After finding λmax, the consistency index is calculated.

Table 9. Consistency Index

λmaks	4,022155083	**LARGEST EIGENVALUE**
CI	0,007385028	**CONSISTENCY INDEX**

After the CI was found, the consistency ratio is calculated. The consistency ratio is calculated as follows:

CR=CI/RI (7)

Table 10. Consistancy Ratio

CR	0,008297784	**CONSISTENCY RATIO**

The result is expected to be less than 0.1. If it is lower than this rate, the result is consistent, if it is higher, the result is inconsistent. Our prioritization is consistent with the 0.008 ratio.

Table 11. Consistency Ratio

COMPARISON MATRIX								
DECISION CRITERIA	**Light Transmittance**	**Cost**	**Energy-saving**	**Lifetime**		**Eigenvector**		**Eigenvalue**
Light Transmittance	1	1/5	1/7	1	X	0,069	=	0,276
Cost	5	1	1	7		0,404		1,632
Energy-saving	7	1	1	9		0,468		1,888
Lifetime	1	1/7	1/9	1		0,059		0,238

Priority values are found to be 1.888 for energy saving criterion, 1.632 for cost criterion, 0.276 for light transmittance, 0.072 for repair service and 0.238 for lifetime. According to the comparison result, the criterion with the highest priority value is **the energy saving criterion**; lowest priority is the lifetime criterion.

In the pairwise comparison matrix given for the decision criteria ligt transmittanece in the table below, Fiberglass Reinforced Plastic (FRP) has the highest percentage weight in terms of ligt transmittance criteria, while Polycarbonate Greenhouse Coverhas the lowest percentage weight.

Table 12. Normalized Comparison Matrix

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Light Transmittance**					
Alternatives	**Fiberglass Reinforced Plastic (FRP)**	**PVC Greenhouse Cover**	**Glass Greenhouse Cover**	**Polycarbonate Greenhouse Cover**	**Polyethylene Greenhouse Cover**	**Eigen vector**
Fiberglass Reinforced Plastic (FRP)	0,498	0,660	0,324	0,288	0,238	0,402
PVC Greenhouse Cover	0,166	0,220	0,540	0,288	0,238	0,290
Glass Greenhouse Cover	0,166	0,044	0,108	0,370	0,333	0,204
Polycarbonate Greenhouse Cover	0,071	0,031	0,012	0,041	0,143	0,060
Polyethylene Greenhouse Cover	0,100	0,044	0,015	0,014	0,048	0,044

In the pairwise comparison matrix given for the decision criteria cost in the table below, Polycarbonate Greenhouse Cover has the highest percentage weight in terms of cost criteria, while Glass Greenhouse Cover has the lowest percentage weight.

Table 13. Normalized Comparison Matrix 2

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Cost**					
Alternatives	**Fiberglass Reinforced Plastic (FRP)**	**PVC Greenhouse Cover**	**Glass Greenhouse Cover**	**Polycarbonate Greenhouse Cover**	**Polyethylene Greenhouse Cover**	**Eigenvector**
Fiberglass Reinforced Plastic (FRP)	0,074	0,247	0,226	0,058	0,075	0,136
PVC Greenhouse Cover	0,025	0,082	0,226	0,082	0,125	0,108
Glass Greenhouse Cover	0,011	0,012	0,032	0,045	0,053	0,031
Polycarbonate Greenhouse Cover	0,519	0,412	0,290	0,408	0,374	0,401
Polyethylene Greenhouse Cover	0,371	0,247	0,226	0,408	0,374	0,325

In the two comparison matrix, the alternative with the highest percentage weight in terms of Energy-saving criteria is Fiberglass Reinforced Plastic, and the greenhouse cover with the lowest percentage weight is Glass greenhouse cover.

Table 14. Normalized Comparison Matrix 3

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Energy-saving**					
Alternatives	**Fiberglass Reinforced Plastic (FRP)**	**PVC Greenhouse Cover**	**Glass Greenhouse Cover**	**Polycarbonate Greenhouse Cover**	**Polyethylene Greenhouse Cover**	**Eigen vector**
Fiberglass Reinforced Plastic (FRP)	0,560	0,674	0,429	0,304	0,434	0,480
PVC Greenhouse Cover	0,187	0,225	0,333	0,391	0,434	0,314
Glass Greenhouse Cover	0,062	0,032	0,048	0,043	0,029	0,043
Polycarbonate Greenhouse Cover	0,080	0,025	0,048	0,043	0,017	0,043
Polyethylene Greenhouse Cover	0,112	0,045	0,143	0,217	0,087	0,121

In the last pairwise comparisons matrix given in table 15, the alternative glass greenhouse cover has the highest percentage weight in terms of lifetime criterion and the greenhouse cover with the lowest percentage weight is the policarbonate greenhouse cover.

Table 15. Normalized Comparison Matrix 4

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Lifetime**					
Alternatives	**Fiberglass Reinforced Plastic (FRP)**	**PVC Greenhouse Cover**	**Glass Greenhouse Cover**	**Polycarbonate Greenhouse Cover**	**Polyethylene Greenhouse Cover**	**Eigenvector**
Fiberglass Reinforced Plastic (FRP)	0,374	0,456	0,417	0,246	0,143	0,327
PVC Greenhouse Cover	0,053	0,065	0,060	0,246	0,333	0,151
Glass Greenhouse Cover	0,374	0,456	0,417	0,443	0,333	0,405
Polycarbonate Greenhouse Cover	0,075	0,013	0,046	0,049	0,143	0,065
Polyethylene Greenhouse Cover	0,125	0,009	0,060	0,016	0,048	0,051

The final stage is calculating the values of the final values. The values of the values of these criteria criteria and the values of the criteria of the alternatives are multiplied exactly and the criterion value of each alternative is found. The alternative with the highest value is the best alternative for the decision problem.

Table 16. Comparison alternative

COMPARISON OF ALTERNATIVES						
	Light Transmittance	**Cost**	**Energy-saving**	**Lifetime**	**Selection Scores**	**selection**
Fiberglass Reinforced Plastic (FRP)	0,402	0,136	0,480	0,327	0,326	**1**
PVC Greenhouse Cover	0,290	0,108	0,314	0,151	0,219	2
Glass Greenhouse Cover	0,204	0,031	0,043	0,405	0,071	5
Polycarbonate Greenhouse Cover	0,060	0,401	0,043	0,065	0,190	4
Polyethylene Greenhouse Cover	0,044	0,325	0,121	0,051	0,194	3
Importance Weight	0,069	0,404	0,468	0,059		

The priority value of Fiberglass Reinforced Plastic (FRP) is 0.326, the priority value of PVC Greenhouse Cover is 0.219, the priority value of Glass Greenhouse Cover is 0.071, the priority value of Polycarbonate Greenhous Cover is 0.190, and the priority value of Polyethylene Greenhouse is 0,194. According to this result, Fiberglass Reinforced Plastic (FRP) should be chosen as the greenhouse cover.

The priority order of the alternatives is Fiberglass Reinforced Plastic (FRP), PVC Greenhouse Cover, Polyethylene Greenhouse Cover, Polycarbonate Greenhouse Cover and Glass Greenhouse Cover.

4.2.7. Types of Greenhouses according to Their Structures

The greenhouses according to the greenhouses structures, can be classified into four; Kuonset, Gothic, Traditional (Triangle Roof), Foldable and shading, and A-Frame.

4.2.7.1 Kuonset Greenhouses

Inspired by the Kuonset huts popular during WWII, Kuonset-style greenhouses are semi-circular structures that look like large, clear barrels cut in half. This structure features a curved roof and military hut-style design. Pulleys are usually made of aluminum or PVC pipes and are glazed with a polyethylene film or panels for better insulation. The side walls pretty much limit the storage space and headroom. It is the cheapest and easiest type to build under most conditions.

Kuonset-style greenhouses are often used when building individual greenhouses. The main advantage is that it has much more sunshine duration than other greenhouse types. This extremely high amount of sunlight is best for growing from seedlings to fully grown mature plants. Another advantage of Kuonset-style greenhouses is the simplicity of construction when built using Kee Klamp fixtures. Thanks to the interlocking fixtures, it can be installed in the area where it is. Thus, it can be built simply without the need for carpentry skills.

4.2.7.2 Gothic Greenhouses

The design is inspired by the windows of Gothic cathedrals all over the world. It is built with sloped walls to create a pointed roof. These greenhouses are a derivative of Kuonset greenhouses, and they are more durable and have more air space. It can be built more easily and cheaply than traditional greenhouses.

The gothic arch design is famous for its ability to withstand strong winds and heavy snowfall. The half-teardrop shape of the roof is ideal for allowing snow and rain to drain easily and preventing damage from significant precipitation or debris buildup.

The Gothic arch has more height than the high profile of the central ridge, which creates space for many tropical trees as well as growers who specialize in or want to try taller specialties (like tomatoes and cucumbers).The arched roof of the Gothic greenhouse eliminates the need for structural beams. This technique not only helps to reduce costs; it also makes construction faster and easier and requires fewer materials.

4.2.7.3 Traditional (Triangle Roof) Greenhouses

Gable-roof greenhouses are one of the most common types of greenhouses because they receive the maximum amount of sunlight while also providing ample space within the structure to grow a large number of plants.

Thanks to the flat walls and higher roof, you can roam freely inside while taking care of your plants. The design is pretty simple. However, its construction requires more effort than other greenhouse types. Depending on the materials used for the framing and cladding, construction costs can also be quite reasonable.

4.2.7.4 A-Frame Greenhouses

The A-frame greenhouse requires very little materials and is fairly inexpensive and easy to construct. If a wooden frame and plastic sheeting are used, such greenhouses can be built without the need for another support structure and require little construction experience. It's a little more difficult to maneuver indoors due to the wide base and narrow apex, and airflow is often not ideal on low sides and tight corners.

4.2.7.5 Foldable and Shading Greenhouses

These greenhouses are foldable, have the maximum ventilation rate, and work fully automated at the desired opening. In addition to its shading feature, it can be completely closed in rainy or cold weather. Construction structure is completely steel hot-dip galvanized coating. It is the most suitable greenhouse type for seed breeders and early fruit growers. If it is warm enough outside, the roof is opened completely to bring the plants to unfiltered, direct sunlight, allowing the plants and soil to warm up. If it is very hot outside, the roof is closed 80% - 90% in the middle of the day.

For the most appropriate greenhouse type selection decision, interviews are held with expert agricultural engineers and the most appropriate criteria are determined in the light of evaluation elements. Then, the criteria are compared in order of importance in line with the importance scale developed by Saaty. Comparison matrices are created for the determined criteria as indicated in the table 17.

Table 17. Comparison matrix

COMPARISON MATRIX - (Decision Maker -1)				
DECISION CRITERIA	Light Transmittance	Cost	Energy-saving	Indoor Utilization Rate
Light Transmittance	1	1/5	1/3	1/5
Cost	5	1	9	1
Energy-saving	3	1/9	1	1/7
Indoor Utilization Rate	5	1	7	1
COMPARISON MATRIX - (Decision Maker -2)				
DECISION CRITERIA	Light Transmittance	Cost	Energy-saving	Indoor Utilization Rate
Light Transmittance	1	1/3	1/3	1/7
Cost	3	1	7	1
Energy-saving	3	1/7	1	1/3
Indoor Utilization Rate	7	1	3	1
COMPARISON MATRIX - (Decision Maker -3)				
DECISION CRITERIA	Light Transmittance	Cost	Energy-saving	Indoor Utilization Rate
Light Transmittance	1	1/7	1/3	1/9
Cost	7	1	5	1
Energy-saving	3	1/5	1	1/5
Indoor Utilization Rate	9	1	5	1

DECISION CRITERIA	Light Transmittance	Cost	Energy-saving	Indoor Utilization Rate
Light Transmittance	1	1/5	1/3	1/7
Cost	5	1	7	1
Energy-saving	3	1/7	1	1/5
Indoor Utilization Rate	7	1	5	1
SUM	16,000	2,343	13,333	2,343

After the pairwise comparison matrix is constructed, the matrix normalization is performed. In the normalization process, all column values are divided by the sum of each matrix column. By using the normalized matrix, the average of each row value is taken and thus the eigenvector is found for each determined criterion.

Table 18. Comparison matrix 2

NORMALIZED COMPARISON MATRIX				
DECISION CRITERIA	**Light Transmittance**	**Cost**	**Energy-saving**	**Indoor Utilization Rate**
Light Transmittance	0,06	0,09	0,03	0,06
Cost	0,31	0,43	0,53	0,43
Energy-saving	0,19	0,06	0,08	0,09
Indoor Utilization Rate	0,44	0,43	0,38	0,43

After prioritization is made, it is measured whether the decision makers are consistent when making comparisons between the criteria. To find the consistency ratio, first the eigenvalue is found. The eigenvalue is found by multiplying the columns of the comparison matrix with each priority value and summing the results over the rows. The x-value is then divided into its corresponding priority values. The λmax value is found by taking the average of the results obtained.

Table 19. Consistency Index

λ maks	4,190535126	**LARGEST EIGENVALUE**
CI	0,063511709	**CONSISTENCY INDEX**

After the CI is found, the consistency ratio will be calculated. The consistency ratio is calculated as follows.

Table 20. Consistency Ratio

CR	0,07136147	**CONSISTENCY RATIO**

The result is expected to be less than 0.1. Our prioritization is consistent with the 0,0713 ratio.

Table 21. Comparsion Matrix

COMPARISON MATRIX								
DECISION CRITERIA	**Light Transmittance**	**Cost**	**Energy-saving**	**Indoor Utilization Rate**		**Eigenvector**		**Eigenvalue**
Light Transmittance	1	1/5	1/3	1/7		0,058		0,237
Cost	5	1	7	1	X	0,423	=	1,847
Energy-saving	3	1/7	1	1/5		0,102		0,421
Indoor Utilization Rate	7	1	5	1		0,417		1,760

The priority values are found to be 0.237 for the light transmittance criterion, 1.847 for the cost criterion, 0.421 for the energy saving criterion and 1.760 for the indoor utilization rate criterion. According to the comparison result, the criterion with the highest priority value is the cost criterion; the lowest priority is the light transmittance criterion.

Table 22. Normalized Comparison Matrix1

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Light Transmittance**					
Alternatives	Gothic Greenhouses	Traditional (Triangle Roof) Greenhouses	Kuonset Greenhouses	A-Framed Greenhouses	Foldable And Shading Greenhouses	Eigenvector
Gothic Greenhouses	0,133	0,548	0,2	0,075	0,122	0,215
Traditional (Triangle Roof) Greenhouses	0,044	0,183	0,28	0,374	0,366	0,249
Kuonset Greenhouses	0,027	0,026	0,04	0,053	0,024	0,034
Framed Greenhouses	0,664	0,183	0,28	0,374	0,366	0,373
Foldable And Shading Greenhouses	0,133	0,061	0,2	0,125	0,122	0,128

In the pairwise comparison matrix given in the table above, Framed Greenhouses has the highest percentage weight in terms of Light Transmittance criteria, while **Kuonset Greenhouses** has the lowest percentage weight.

Table 23. Normalized Comparison Matrix2

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Cost**					
Alternatives	Gothic Greenhouses	Traditional (Triangle Roof) Greenhouses	Kuonset Greenhouses	A-Framed Greenhouses	Foldable And Shading Greenhouses	Eigenvector
Gothic Greenhouses	0,374	0,369	0,417	0,211	0,259	0,326
Traditional (Triangle Roof) Greenhouses	0,075	0,074	0,06	0,211	0,185	0,121
Kuonset Greenhouses	0,374	0,517	0,417	0,493	0,333	0,427
Framed Greenhouses	0,125	0,025	0,06	0,07	0,185	0,093
Foldable And Shading Greenhouses	0,053	0,015	0,046	0,014	0,037	0,033

In the two comparison matrix, the alternative with the highest percentage weight in terms of cost criteria is Kuonset Greenhouses, and the greenhouse cover with the lowest percentage weight is Foldable and Shading Greenhouses.

Table 24. Normalized Comparison Matrix3

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Energy-saving**					
Alternatives	**Gothic Greenhouses**	**Traditional (Triangle Roof) Greenhouses**	**Kuonset Greenhouses**	**A-Framed Greenhouses**	**Foldable And Shading Greenhouses**	**Eigenvector**
Gothic Greenhouses	0,374	0,369	0,382	0,294	**0,28**	**0,34**
Traditional (Triangle Roof) Greenhouses	0,075	0,074	0,055	0,294	**0,2**	**0,139**
Kuonset Greenhouses	0,374	0,517	0,382	0,294	**0,28**	**0,369**
Framed Greenhouses	0,125	0,025	0,127	0,098	**0,2**	**0,115**
Foldable And Shading Greenhouses	0,053	0,015	0,055	0,02	**0,04**	**0,036**

In the pairwise comparisons matrix in table 24, the alternative Kuonset Greenhouses with the highest percentage weight in terms of energy saving criterion and the lowest percentage weight is the Foldable and Shading Grenhouses

Table 25. Normalized Comparison Matrix4

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Lifetime**					
Alternatives	**Gothic Greenhouses**	**Traditional (Triangle Roof) Greenhouses**	**Kuonset Greenhouses**	**A-Framed Greenhouses**	**Foldable And Shading Greenhouses**	**Eigenvector**
Gothic Greenhouses	0,055	0,079	0,13	0,03	0,027	0,064
Traditional (Triangle Roof) Greenhouses	0,382	0,55	0,304	0,743	0,409	0,477
Kuonset Greenhouses	0,018	0,079	0,043	0,03	0,019	0,038
Framed Greenhouses	0,273	0,11	0,217	0,149	0,409	0,231
Foldable And Shading Greenhouses	0,273	0,183	0,304	0,05	0,136	0,189

In the last pairwise comparisons matrix, the alternative Traditional (Triangle Roof) Greenhouses has the highest percentage weight in terms of lifetime criterion and the Gothic Greenhouses has the lowest percentage weight.

The final stage is the values of these criteria and the values of the criteria of the alternatives are multiplied exactly and the criterion value of each alternative is found. The alternative with the highest value is the best alternative for the decision problem.

Table 26. Comparison Matrix4

COMPARISON OF ALTERNATIVES						
	Light Transmittance	**Cost**	**Energy-saving**	**Indoor Utilization Rate**	**Selection Scores**	**Selection**
Gothic Greenhouses	0,215450753	0,326173803	0,339811887	0,064090919	0,212	3
Traditional (Triangle Roof) Greenhouses	0,249275124	0,120936032	0,139457565	0,477407759	0,279	1
Kuonset Greenhouses	0,034081331	0,426883297	0,369368538	0,037870467	0,236	2
Framed Greenhouses	0,37316893	0,092879214	0,114899529	0,231428277	0,169	4
Foldable And Shading Greenhouses	0,128023862	0,033127654	0,036462481	0,189202579	0,104	5

The priority value of Gothic Greenhouses is 0,212, the priority value of Traditional (Triangle Roof) Greenhouses is 0,279, the priority value of Kuonset Greenhouses is 0,236, the priority value of Foldable and Shading Greenhouses is 0,104, and the priority value of Framed Greenhouses is 0,169. According to this result, Traditional (Triangle Roof) Greenhouses should be chosen as the greenhouse type.

4.2.8 Determining the Type of Energy to be Used in the Greenhouse

Recent rapid developments in the industry have increased energy consumption significantly. The energy sources used to respond to this increase consist of fossil fuels. Fossil fuels are non-renewable energy sources and are, therefore, rapidly depleted.

The use of fossil fuels such as oil, coal, and natural gas causes air pollution with the carbon emissions and greenhouse gases they emit. Polluted air turns into acid rain after a while, and these rains cause the destruction of the surrounding vegetation. Destroyed vegetation will begin to disappear over time. In addition to all these, since acid rains also flow into streams and rivers, living things here are destroyed by acid rain.Nuclear energy sources are shown as an alternative to fossil energy sources, but they create major problems in terms of environmental pollution and security.

This negative structure, which is experienced on a global scale and whose effects are increasing as a result of the change in climate conditions, leads to the emergence of policies aimed at reducing fossil fuel consumption and increasing the share of renewable resources in total energy production (Ergun, 2020). For a sustainable environment, renewable energy sources should be preferred instead of fossil fuels. In short, renewable energy sources can be called sustainable or clean, natural, and inexhaustible energy resources. Renewable energy sources are also called 'Green Energy Sources' or 'Sustainable Energy Sources' (https://www.wwf.org.tr/). Renewable energy means the energy that can be obtained through the resources available in nature and that nature can produce permanently (Keskinkiliç, 2019). The greenhouse gas emissions of renewable energy sources are very low compared to fossil energy sources, so they do not cause environmental pollution. They do not pose any threat to human health. Safe energy supply is important for areas such as, heating, lighting, industrial equipment, transportation, etc., in all economies (Owusu and Sarkodie, 2016).

There are three main factors driving the growth of clean energy technologies. These are, energy security, economic factors and reduction of carbon dioxide emissions (Abolhosseini et al., 2014). It is estimated that the use of clean energy sources, which are considered as alternative energy sources, will increase between 30% and 80% until 2100 (Panwar et al, 2011).

Renewable energy sources, which can be found in many different forms in nature, listed as wind, solar, biomass, wave power, geothermal, water power (hydraulic power), are basic renewable energy sources (Mahmutoğlu, 2013).

The main purpose of greenhouse cultivation is to maintain the indoor temperature at the optimum level. To obtain the highest efficiency expected from facility production carried out in greenhouses, the greenhouse should be heated during periods when the outdoor temperature is low.

Today, since energy costs are very high, heating is started in greenhouses only during periods of frost threat. This causes a serious decrease in productivity. Heating costs constitute the largest part of production expenditures in greenhouse cultivation.

One of the measures to be taken to reduce the energy needed in greenhouse businesses is heat conservation in greenhouses. With heat preservation measures, heating costs can be reduced and benefits can be maximized (Yağcıoğlu, 1999). With the reduction of this cost, the profit share of the producer in the greenhouse sector will increase. To reduce costs, renewable energy sources should be used instead of fossil fuels. Some of the renewable energy sources used in greenhouse heating are; solar energy, geothermal energy and biomass energy.

4.2.8.1 Solar energy

In recent years, the use of solar energy, one of the renewable energy sources instead of fossil fuels, for the purpose of greenhouse heating has become increasingly widespread. In our country, which has an important potential in terms of solar energy, it has been determined that the average annual total sunshine duration is 2623 hours, and the average total radiation intensity is 1303 kWh/m² (Kendirli and Çakmak, 2010).

A part of Turkey is also located in a region called the sun belt and is moderately rich in solar energy. Studies on the utilization of solar energy in Turkey gained momentum especially after the 1970s. Total solar radiation measurements are made continuously at many stations by the General Directorate of State Meteorology (Şahanet al., 2010)

Greenhouses are one of the most common examples of passive use of solar energy. Its primary purpose is to provide a suitable environment and temperature for the supply of high quantity and quality agricultural products (Karataş, 2009).

If the solar energy system will be used in the greenhouse, it must contain elements that will collect the radiative energy from the sun, store it and distribute it in the desired environment when needed for the systems to fulfill their functions. First of all, factors such as the placement of the greenhouse, the slope of the roof, the light transmittance of the covering material used, and the thickness of the greenhouse skeleton material should be chosen so that the most incoming sunlight enters the greenhouse (Kendirli and Çakmak, 2010).

With active solar heating systems, 40-90% of the greenhouse heat requirement can be met for an indoor temperature of 17 ºC at night and 25 ºC during the day, and the product yield increases compared to greenhouses where traditional heating systems are applied (Fuller et al., 1983). Since 46% of the solar energy coming to the earth is only absorbed by the soil, heating using solar energy is a very profitable use.

4.2.8.2 Wind Energy

Wind energy,a renewable energy type, is produced by establishing wind power facilites in regions with high and stable wind potential. Wind energy meets 4.7% of the total energy consumption in the world (www.encazip.com, 2022).

According to the data of Turkey Wind Energy Potential Atlas (REPA-V1) prepared in 2006, it has been accepted that 5 MW wind power facilities per square kilometer can be established in usable areas 50 meters above ground level and with annual average wind speeds of over 7.5 m/s. It has been determined that the total capacity of wind power facilites is 47,849.44 MW(https://enerji.gov.tr). The wind energy potential in our country is higher than in all European countries.

Wind energy has a very low cost compared to other energy sources. Since the actual area occupied by the turbines in the wind power facility is 1-1.2% of the total area of the power facility, agriculture and livestock can be done between the turbines, and since there is no land loss, it does not prevent farming activities in agricultural areas (Arslan et al. , 2019).

Wind significantly increases the heat consumption of the greenhouse. Therefore, the idea of using wind energy to meet the heat requirement of the greenhouse is naturally attractive. The minimum annual wind speed must be 5 m/s on average to benefit from wind energy economically in any region (Kendirli and Çakmak, 2010)..

It is a clean energy source. As with some other energy sources, it does not contain radioactive waste (or even any waste), does not create greenhouse gases, and, therefore, acid rain. It even leads to an indirect reduction in their formation. Because it reduces the use of fossil fuels that will be spent to produce equivalent energy, and thus the waste that will arise (Hayli, 2001).

4.2.8.3 Biomass Energy

Biomass energy, produced from biomass energy sources such as energy forestry products and forest and wood product residues, energy agriculture (facilities), vegetable and animal wastes in the agricultural sector, urban wastes, and agriculture-based industrial wastes, has made significant progress recently and is directly related to the agricultural sector (Taşyürek and Acaroğlu, 2007).

Biomass is the source of organic matter, which is formed as a result of the storage of solar energy by green facilites by converting it into chemical energy through photosynthesis and emerging as the origin of living organisms. All-natural substances of vegetable or animal origin, the main components of which are carbohydrate compounds, are defined as biomass energy sources, and the energy obtained from these sources is defined as biomass energy (Kapluhan, 2014).

Biomass, which constitutes an important part of the renewable energy resources on earth, consists of living or non-living biological materials consisting of vegetable, animal and organic origin urban wastes (Baka, 2012). Among domestic and renewable energy sources, biomass energy stands out with its potential (general and regional) and environmental friendliness. However, it is seen that the targets related to biomass are far behind (Kapluhan, 2014).

Bioenergy means the production of solid, liquid, and gaseous fuel and electricity produced in different ways from biomass sources such as agriculture, forest, animal, and domestic wastes (Vardar, 2014).

Biomass is an important energy source as it constitutes the fourth largest energy source in the world. Many developed countries see bioenergy as the main energy source of the future. The biomass cycle of dry matter in the biosphere is approximately 250x109 tons/year and its carbon content is 100x109 tons/year. Its energy content is 2x1021 J/year (0.7x1014 W). 0.5% by mass of the total biomass produced is provided by human food (Kapluhan, 2014).

4.2.8.4 Geothermal Energy

Geothermal energy is the temperature created by the accumulated heat in various depths of the earth's crust, which is above the regional atmospheric average temperature and which is constantly transported to the surface through hot water and steam (fluid) under pressure, which may contain more dissolved minerals, various salts, and gases than the normal underground and surface waters around it (İğdeli, 2014).

It is used in application and evaluation areas such as drinking water production containing minerals (Tunçbilek, 2015). In addition to its longevity and low-cost factors, geothermal energy has indisputable advantages over fossil energy sources in terms of environmental problems.

Heating greenhouses with geothermal resources will not only provide an economical aquaculture opportunity that will minimize heating costs, but also will help to increase our greenhouse areas if some technical and environmental precautions are taken (Karaman and Kurunç, 2004).

It is known that the greenhouse areas heated by geothermal energy are 1000 ha in the world (Kılıç and Kılıç, 2009). It is estimated that approximately 17174 MWt of geothermal energy in the world is used for greenhouse heating for early vegetable growing, fruit growing, and floriculture (Karacabey, 2008).

By heating greenhouses with geothermal energy in various countries of the world, early vegetable growing, fruit growing and floriculture are carried out (Demirel, 1998).

For the most appropriate energy type selection decision, interviews are held with 3 expert agricultural engineers and the most appropriate criteria are determined in the light of evaluation elements. Then, the criteria are compared in order of importance in line with the importance scale developed by Saaty. By taking the geometric mean of the answers given by the experts, comparison matrices are created for the determined criteria as indicated in the table 28.

Table 27. Comparison Matrix 5

COMPARISON MATRIX - (Decision Maker -1)				
DECISION CRITERIA	Cost	Efficiency	Reliability	Service life
Cost	1	3	9	7
Efficiency	1/3	1	9	9
Reliability	1/9	1/9	1	1
Service life	1/7	1/9	1	1
COMPARISON MATRIX - (Decision Maker -2)				
DECISION CRITERIA	Cost	Efficiency	Reliability	Service life
Cost	1	3	3	5
Efficiency	1/3	1	7	9
Reliability	1/3	1/7	1	1
Service life	1/5	1/9	1	1
COMPARISON MATRIX - (Decision Maker -3)				
DECISION CRITERIA	Cost	Efficiency	Reliability	Service life
Cost	1	3	5	9
Efficiency	1/3	1	5	9
Reliability	1/5	1/5	1	1
Service life	1/9	1/9	1	1

COMPARISON MATRIX				
DECISION CRITERIA	Cost	Efficiency	Reliability	Service life
Cost	1	3	5	7
Efficiency	1/3	1	7	9
Reliability	1/5	1/7	1	1
Service life	1/7	1/9	1	1

SUM	1,676	4,254	14,000	18,000

After the pairwise comparison matrix is constructed, the matrix normalization is performed. In the normalization process, all column values are divided by the sum of each matrix column. By using the normalized matrix, the average of each row value is taken and thus the eigenvector is found for each determined criterion.

Table 28. Normalized Comparison Matrix 5

NORMALIZED COMPARISON MATRIX					Eigenvector
DECISION CRITERIA	**Cost**	**Efficiency**	**Reliability**	**Service life**	
Cost	0,60	0,71	0,36	0,39	0,512
Efficiency	0,20	0,24	0,50	0,50	0,358
Reliability	0,12	0,03	0,07	0,06	0,070
Service life	0,09	0,03	0,07	0,06	0,060

After prioritization is made, it is measured whether the decision makers are consistent when making comparisons between the criteria. To find the consistency ratio, first the eigenvalue is found. The eigenvalue is calculated by multiplying the columns of the comparison matrix with each priority value and summing the results over the rows. The x-value is then divided into its corresponding priority values. The λmax value was found by taking the average of the results obtained.

If the consistency ratio is less than 0.1, the matrix is considered to be consistent. After finding λmax, the consistency index is calculated.

Table 29. Consistency Index 5

λ maks	4,26351	**LARGEST EIGENVALUE**
CI	0,08784	**CONSISTENCY INDEX**

After the CI is found, the consistency ratio is calculated. The consistency ratio is calculated as follows.

Table 30. Consistency Ratio 5

CR	0,09869	**CONSISTENCY RATIO**

The result is expected to be less than 0.1. If it is lower than this rate, the result is consistent, if it is higher, the result is inconsistent. Our prioritization is consistent with the 0,09869 ratio.

Table 31. Comparison matrix 5

COMPARISON MATRIX								
DECISION CRITERIA	**Cost**	**Efficiency**	**Reliability**	**Service life**		**Eigenvector**		**Eigenvalue**
Cost	1	3	5	7	X	0,512	=	2,354
Efficiency	1/3	1	7	9		0,358		1,555
Reliability	0	1/7	1	1		0,070		0,283
Service life	0	0	1	1		0,060		0,243

The priority values are found to be 2,354 for the Cost criterion, 1,555 for the Efficiency criterion, 0,283 for the Reliability criterion and 0,243 for the Service life criterion. According to the comparison result, the criterion with the highest priority value is the reliability criterion, the criterion with the lowest priority is the Efficiency criterion.

Table 32. Normalized Comparison matrix 5

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Cost**					
Alternatives	**Solar energy**	**Wind power**	**Geothermal energy**	**Biomass Energy**	**Biofuel Energy**	**Eigenvector**
Solar energy	0,064	0,306	0,391	0,027	0,027	0,163
Wind power	0,013	0,061	0,391	0,037	0,037	0,108
Geothermal energy	0,021	0,02	0,13	0,561	0,561	0,259
Biomass Energy	0,451	0,306	0,043	0,187	0,187	0,235
Biofuel Energy	0,451	0,306	0,043	0,187	0,187	0,235

In the pairwise comparison matrix given in the table above, Geothermal energy has the highest percentage weight in terms of Cost criteria, while Wind power has the lowest percentage weight.

Table 33. Normalized Comparison matrix 6

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Efficiency**					
Alternatives	**Solar energy**	**Wind power**	**Geothermal energy**	**Biomass Energy**	**Biofuel Energy**	**Eigenvector**
Solar energy	0,55	0,66	0,373	0,368	0,368	0,464
Wind power	0,183	0,22	0,522	0,263	0,263	0,29
Geothermal energy	0,11	0,031	0,075	0,263	0,263	0,148
Biomass Energy	0,079	0,044	0,015	0,053	0,053	0,049
Biofuel Energy	0,079	0,044	0,015	0,053	0,053	0,049

In the comparison matrix in table 34, the alternative with the highest percentage weight in terms of efficiency criteria is Solar energy, and the alternative with the lowest percentage weight is Biomass Energy.

Table 34. Normalized Comparison matrix 7

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Reliability**					
Alternatives	**Solar energy**	**Wind power**	**Geothermal energy**	**Biomass Energy**	**Biofuel Energy**	**Eigenvector**
Solar energy	0,061	0,061	0,12	0,083	0,032	0,072
Wind power	0,061	0,061	0,12	0,083	0,032	0,072
Geothermal energy	0,02	0,02	0,04	0,064	0,025	0,034
Biomass Energy	0,429	0,429	0,36	0,578	0,682	0,495
Biofuel Energy	0,429	0,429	0,36	0,193	0,227	0,327

In the pairwise comparisons matrix in table 35, the alternative with the highest percentage weight in terms of Reliability criterion is Biomass Energy and the alternative with the lowest percentage weight is the wind power.

Table 35. Normalized Comparison matrix 8

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Service life**					
Alternatives	**Solar energy**	**Wind power**	**Geothermal energy**	**Biomass Energy**	**Biofuel Energy**	**Eigenvector**
Solar energy	0,048	0,048	0,111	0,02	0,02	0,049
Wind power	0,048	0,048	0,111	0,02	0,02	0,049
Geothermal energy	0,238	0,238	0,556	0,686	0,686	0,481
Biomass Energy	0,333	0,333	0,111	0,137	0,137	0,21
Biofuel Energy	0,333	0,333	0,111	0,137	0,137	0,21

In the last pairwise comparisons matrix, the alternative with the highest percentage weight in terms of service life criterion is Geothermal energy and the alternative with the lowest percentage weight is the Wind power.

The final stage is the values of these criteria and the values of the criteria of the alternatives were multiplied exactly and the criterion value of each alternative is found. The alternative with the highest value is the best alternative for the decision problem.

Table 36. Normalized Comparison matrix 9

COMPARISON OF ALTERNATIVES						
	Cost	**Efficiency**	**Reliability**	**Service life**	**Selection Scores**	**Selection**
Solar energy	0,163	0,464	0,072	0,049	0,258	1
Wind power	0,108	0,290	0,072	0,049	0,167	5
Geothermal energy	0,259	0,148	0,034	0,481	0,217	2
Biomass Energy	0,235	0,049	0,495	0,210	0,185	3
Biofuel Energy	0,235	0,049	0,327	0,210	0,173	4

The priority value of Solar energy is 0,258, the priority value of Wind power is 0,167, the priority value of Geothermal energy is 0,217, the priority value of Biomass Energy is 0,185, and the priority value of Biofuel Energy is 0,173. According to this result, Solar energy should be chosen as the energy type.

4.2.9 Determining the Irrigation Method to be Used in the Greenhouse

For the most appropriate Irrigation Method selection decision, interviews are held with expert agricultural engineers and the most appropriate criteria are determined in the light of evaluation elements. Then, the criteria are compared in order of importance in line with the importance scale developed by Saaty. Comparison matrices are created for the determined criteria as indicated in the table 38. Our criteria are Cost, Efficiency, Energy-saving and Lifetime. Minimizing the cost is a very important factor for the manufacturer. Efficiency should be at the maximum level. It should be aimed to get the highest efficiency from the product to be selected. Energy saving is an important criterion that affects both cost and efficiency criteria. It is very important for greenhouse cultivation. The producer wants to use the product he chooses in his greenhouse for a long time.

Table 37. Comparison matrix

COMPARISON MATRIX - (Decision Maker -1)				
DECISION CRITERIA	Cost	Efficiency	Energy-saving	Lifetime
Cost	1	3	1/7	5
Efficiency	1/3	1	1/5	7
Energy-saving	7	5	1	9
Lifetime	1/5	1/7	1/9	1
COMPARISON MATRIX - (Decision Maker -2)				
DECISION CRITERIA	Cost	Efficiency	Energy-saving	Lifetime
Cost	1	3	1/5	7
Efficiency	1/3	1	1/5	9
Energy-saving	5	5	1	9
Lifetime	1/7	1/9	1/9	1
COMPARISON MATRIX - (Decision Maker -3)				
DECISION CRITERIA	Cost	Efficiency	Energy-saving	Lifetime
Cost	1	3	1/9	5
Efficiency	1/3	1	1/5	5
Energy-saving	9	5	1	9
Lifetime	1/5	1/5	1/9	1

COMPARISON MATRIX				
DECISION CRITERIA	Cost	Efficiency	Energy-saving	Lifetime
Cost	1	3	1/7	5
Efficiency	1/3	1	1/5	7
Energy-saving	7	5	1	9
Lifetime	1/5	1/7	1/9	1
SUM	8,533	9,143	1,454	22,000

After the pairwise comparison matrix is constructed, the matrix normalization is performed. In the normalization process, all column values are divided by the sum of each matrix column. By using the normalized matrix, the average of each row value is taken and thus the eigenvector is found for each determined criterion.

Table 38. Comparison matrix 2

NORMALIZED COMPARISON MATRIX				
DECISION CRITERIA	**Cost**	**Efficiency**	**Energy-saving**	**Lifetime**
Cost	0,12	0,33	0,10	0,23
Efficiency	0,04	0,11	0,14	0,32
Energy-saving	0,82	0,55	0,69	0,41
Lifetime	0,02	0,02	0,08	0,05

After prioritization is made, it is measured whether the decision makers are consistent when making comparisons between the criteria. If the consistency ratio is less than 0.1, the matrix is considered to be consistent.

Table 39. Consistency Index

λ maks	4,931038001	**LARGEST EIGENVALUE**
CI	0,0310346	**CONSISTENCY INDEX**

After the CI is found, the consistency ratio is calculated. The consistency ratio is calculated as follows.

Table 40. Consistency Ratio

CR	0,034870337	**CONSISTENCY RATIO**

The result is expected to be less than 0.1. If it is lower than this rate, the result is consistent, if it is higher, the result is inconsistent. Our prioritization is consistent with the 0,034 ratio.

Table 41. Comparsion Matrix

COMPARISON MATRIX								
DECISION CRITERIA	**Cost**	**Efficiency**	**Energy-saving**	**Lifetime**		**Eigenvector**		**Eigenvalue**
Cost	1	5	1/7	5		0,193		1,237
Efficiency	1/3	1	1/5	7	X	0,151	=	0,620
Energy-saving	7	5	1	9		0,616		3,082
Lifetime	1/5	1/7	1/9	1		0,040		0,169

The priority values are found to be 1,237 for the Cost criterion, 0,620 for the Efficiency criterion, 3,082 for the Energy-saving criterion and 0,169 for the Lifetime criterion. According to the comparison result, the criterion with the highest priority value is the Efficiency criterion; the lowest priority is the Lifetime criterion.

Table 42. Normalized Comparison Matrix1

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Cost**					
Alternatives	**Sprinkler İrrigation Method**	**Drip İrrigation Method**	**Fogging**	**Smart Irrigation System**	**Furrow Irrigation**	**Eigenvector**
Sprinkler İrrigation Method	0,074	0,317	0,018	0,088	0,185	0,136
Drip İrrigation Method	0,025	0,106	0,264	0,123	0,259	0,155
Fogging	0,369	0,035	0,088	0,088	0,259	0,168
Smart Irrigation System	0,517	0,528	0,617	0,614	0,259	0,507
Furrow Irrigation	0,015	0,015	0,013	0,088	0,037	0,033

In the pairwise comparison matrix given in the table 43, Smart Irrigation System has the highest percentage weight in terms of cost criteria, while Furrow Irrigation has the lowest percentage weight.

Table 43. Normalized Comparison Matrix2

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Efficiency**					
Alternatives	**Sprinkler İrrigation Method**	**Drip İrrigation Method**	**Fogging**	**Smart Irrigation System**	**Furrow Irrigation**	**Eigenvector**
Sprinkler İrrigation Method	0,055	0,023	0,024	0,032	0,241	0,075
Drip İrrigation Method	0,276	0,115	0,017	0,682	0,172	0,252
Fogging	0,276	0,802	0,118	0,032	0,241	0,294
Smart Irrigation System	0,386	0,038	0,825	0,227	0,310	0,357
Furrow Irrigation	0,008	0,023	0,017	0,025	0,034	0,021

In the comparison matrix in table 44, the alternative with the highest percentage weight in terms of Efficiency criteria is Smart Irrigation System, and the alternative with the lowest percentage weight is Furrow Irrigation.

Table 44. Normalized Comparison Matrix3

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Energy-saving**					
Alternatives	**Sprinkler İrrigation Method**	**Drip İrrigation Method**	**Fogging**	**Smart Irrigation System**	**Furrow Irrigation**	**Eigenvector**
Sprinkler İrrigation Method	0,055	0,015	0,107	0,032	0,200	0,082
Drip İrrigation Method	0,275	0,075	0,107	0,032	0,280	0,154
Fogging	0,275	0,375	0,533	0,669	0,280	0,426
Smart Irrigation System	0,385	0,525	0,178	0,223	0,200	0,302
Furrow Irrigation	0,011	0,011	0,076	0,045	0,040	0,036

In the comparison matrix in table 45, the alternative with the highest percentage weight in terms of energy saving criterion is Fogging and the alternative with the lowest percentage weight is the Furrow Irrigation.

Table 45. Normalized Comparison Matrix4

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Lifetime**					
Alternatives	**Sprinkler İrrigation Method**	**Drip İrrigation Method**	**Fogging**	**Smart Irrigation System**	**Furrow Irrigation**	**Eigenvector**
Sprinkler İrrigation Method	0,087	0,275	0,158	0,031	0,093	0,129
Drip İrrigation Method	0,017	0,055	0,263	0,018	0,093	0,089
Fogging	0,029	0,011	0,053	0,031	0,093	0,043
Smart Irrigation System	0,260	0,275	0,158	0,092	0,072	0,171
Furrow Irrigation	0,607	0,385	0,368	0,828	0,649	0,568

In the last pairwise comparisons matrix, the alternative with the highest percentage weight in terms of lifetime criterion is Furrow Irrigation and the alternative with the lowest percentage weight is Fogging.

The final stage is the values of these criteria and the values of the criteria of the alternatives were multiplied exactly and the criterion value of each alternative was found. The alternative with the highest value is the best alternative for the decision problem.

Table 46. Comparison Matrix4

	Cost	Efficiency	Energy-saving	Lifetime	Selection Scores	Selection
Sprinkler Irrigation Method	0,136	0,075	0,082	0,129	0,093	4
Drip Irrigation Method	0,155	0,252	0,154	0,089	0,166	3
Fogging	0,168	0,294	0,426	0,043	0,341	2
Smart Irrigation System	0,507	0,357	0,302	0,171	0,345	1
Furrow Irrigation	0,033	0,021	0,036	0,568	0,055	5

The priority value of Sprinkler Irrigation Method is 0,093, the priority value of Drip Irrigation Method is 0,166, the priority value of Fogging is 0,341, the priority value of Smart Irrigation System is 0,345, and the priority value of Furrow Irrigation is 0,055. According to this result, Smart Irrigation System should be chosen as the greenhouse type.

4.2.10 Determining the Agriculture 4.0 Component to be Used in the Greenhouse

For the most appropriate agriculture 4.0 component selection decision, interviews are held with 3 expert agricultural engineers and the most appropriate criteria are determined in the light of evaluation elements. Then, the criteria are compared in order of importance in line with the importance scale developed by Saaty. By taking the geometric mean of the answers given by the experts, comparison matrices ae created for the determined criteria as indicated in the table 47.

Table 47. Comparison Matrix 5

COMPARISON MATRIX - (Decision Maker -1)				
DECISION CRITERIA	Cost	Efficiency	Energy-saving	Lifetime
Cost	1	1/7	1/5	5
Efficiency	7	1	7	9
Energy-saving	5	1/7	1	5
Lifetime	1/5	1/9	1/5	1
COMPARISON MATRIX - (Decision Maker -2)				
DECISION CRITERIA	Cost	Efficiency	Energy-saving	Lifetime
Cost	1	3	1/7	7
Efficiency	1/3	1	7	9
Energy-saving	7	1/7	1	7
Lifetime	1/7	1/9	1/7	1
COMPARISON MATRIX - (Decision Maker -3)				
DECISION CRITERIA	Cost	Efficiency	Energy-saving	Lifetime
Cost	1	3	1/9	5
Efficiency	1/3	1	7	9
Energy-saving	9	1/7	1	9
Lifetime	1/5	1/9	1/9	1

COMPARISON MATRIX				
DECISION CRITERIA	Cost	Efficiency	Energy-saving	Lifetime
Cost	1	3	1/7	5
Efficiency	1/3	1	1/5	7
Energy-saving	7	5	1	9
Lifetime	1/5	1/7	1/9	1
SUM	8,533	9,143	1,454	22,000

After the pairwise comparison matrix is constructed, the matrix normalization is performed. In the normalization process, all column values are divided by the sum of each matrix column. By using the normalized matrix, the average of each row value is taken and thus the eigenvector is found for each determined criterion.

Table 48. Normalized Comparison Matrix 5

NORMALIZED COMPARISON MATRIX				
DECISION CRITERIA	Cost	Efficiency	Energy-saving	Lifetime
Cost	0,12	0,33	0,10	0,23
Efficiency	0,04	0,11	0,14	0,32
Energy-saving	0,82	0,55	0,69	0,41
Lifetime	0,02	0,02	0,08	0,05

After prioritization was made, it is measured whether the decision makers are consistent when making comparisons between the criteria.

If the consistency ratio is less than 0.1, the matrix is considered to be consistent.

Table 49. Consistency Index 5

λ maks	4,931038001	**LARGEST EIGENVALUE**
CI	0,0310346	**CONSISTENCY INDEX**

After the CI is found, the consistency ratio was calculated. The consistency ratio is calculated as follows.

Table 50. Consistency Ratio 5

CR	0,006293726	**CONSISTENCY RATIO**

The result is expected to be less than 0.1. If it is lower than this rate, the result is consistent, if it is higher, the result is inconsistent. Our prioritization is consistent with the 0,00629 ratio.

Table 51. Comparison matrix 5

COMPARISON MATRIX								
DECISION CRITERIA	Cost	Efficiency	Energy-saving	Lifetime		Eigenvector		Eigenvalue
Cost	1	1	1/7	5		0,193		0,633
Efficiency	1/3	1	1/5	7	X	0,151	=	0,620
Energy-saving	7	5	1	9		0,616		3,082
Lifetime	1/5	1/7	1/9	1		0,040		0,169

The priority values are found to be 0,633 for the Cost criterion, 0,620 for the Efficiency criterion, 3,082 for the energy-saving criterion and 0,169 for the lifetime criterion. According to the comparison result, the criterion with the highest priority value is the energy-saving criterion, the criterion with the lowest priority is the lifetime criterion.

Table 52. Normalized Comparison matrix 5

NORMALIZED COMPARISON MATRIX					Eigenvector
DECISION CRITERIA	**Cost**	**Efficiency**	**Energy-saving**	**Lifetime**	
Cost	0,12	0,33	0,10	0,23	0,193
Efficiency	0,04	0,11	0,14	0,32	0,151
Energy-saving	0,82	0,55	0,69	0,41	0,616
Lifetime	0,02	0,02	0,08	0,05	0,040

In the pairwise comparison matrix given in the table 53, Agrobot has the highest percentage weight in terms of Cost criteria, while Naio Technology has the lowest percentage weight.

Table 53. Normalized Comparison matrix 6

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Cost**					
Alternatives	**Cleaning robots**	**RoBoPlant**	**Ecorobotix**	**Agrobot**	**Naio Technology**	**Eigenvector**
Cleaning robots	0,074	0,296	0,021	0,088	0,185	0,133
RoBoPlant	0,025	0,099	0,107	0,123	0,259	0,122
Ecorobotix	0,369	0,099	0,107	0,088	0,259	0,184
Agrobot	0,517	0,493	0,749	0,614	0,259	0,527
Naio Technology	0,015	0,014	0,015	0,088	0,037	0,034

In the comparison matrix in table 54, the alternative with the highest percentage weight in terms of efficiency criteria is Agrobot, and the agriculture 4.0 component with the lowest percentage weight is Naio Technology robots.

Table 54. Normalized Comparison matrix 7

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Efficiency**					
Alternatives	**Cleaning robots**	**RoBoPlant**	**Ecorobotix**	**Agrobot**	**Naio Technology**	**Eigenvector**
Cleaning robots	0,055	0,097	0,018	0,032	0,241	0,089
RoBoPlant	0,276	0,484	0,264	0,682	0,172	0,376
Ecorobotix	0,276	0,161	0,088	0,032	0,241	0,16
Agrobot	0,386	0,161	0,617	0,227	0,31	0,34
Naio Technology	0,008	0,097	0,013	0,025	0,034	0,035

In the comparison matrix in table 55,, the alternative Ecorobotix has the highest percentage weight in terms of Energy-saving criterion and the alternative with the lowest percentage weight is the Naio technology.

Table 55. Normalized Comparison matrix 8

NORMALIZED COMPARISON MATRIX						
Decision Criterion	**Energy-saving**					
Alternatives	**Cleaning robots**	**RoBoPlant**	**Ecorobotix**	**Agrobot**	**Naio Technology**	**Eigenvector**
Cleaning robots	0,055	0,015	0,107	0,032	0,2	0,082
RoBoPlant	0,275	0,075	0,107	0,032	0,28	0,154
Ecorobotix	0,275	0,375	0,533	0,669	0,28	0,426
Agrobot	0,385	0,525	0,178	0,223	0,2	0,302
Naio Technology	0,011	0,011	0,076	0,045	0,04	0,036

In the last pairwise comparisons matrix, the alternative Naio Technology has the highest percentage weight in terms of lifetime criterion and the Ecorobotix has the lowest percentage weight.

Table 56. Normalized Comparison matrix 9

NORMALIZED COMPARISON MATRIX						
Decision Criterion	Lifetime					
Alternatives	Cleaning robots	RoBoPlant	Ecorobotix	Agrobot	Naio Technology	Eigenvector
Cleaning robots	0,087	0,275	0,158	0,031	0,093	0,129
RoBoPlant	0,017	0,055	0,263	0,018	0,093	0,089
Ecorobotix	0,029	0,011	0,053	0,031	0,093	0,043
Agrobot	0,26	0,275	0,158	0,092	0,072	0,171
Naio Technology	0,607	0,385	0,368	0,828	0,649	0,568

The final stage is the values of these criteria and the values of the criteria of the alternatives were multiplied exactly and the criterion value of each alternative was found. The alternative with the highest value is the best alternative for the decision problem.

Table 57. Normalized Comparison matrix 9

COMPARISON OF ALTERNATIVES						
	Cost	Efficiency	Energy-saving	Lifetime	Selection Scores	Selection
Cleaning robots	0,133	0,089	0,082	0,129	0,581	4
RoBoPlant	0,122	0,376	0,154	0,089	1,617	2
Ecorobotix	0,184	0,160	0,426	0,043	1,528	3
Agrobot	0,527	0,340	0,302	0,171	2,166	1
Naio Technology	0,034	0,035	0,036	0,568	0,310	5

As seen in table 56, the priority value of Cleaning robots is 0,581, the priority value of RoBoPlant is 1,617, the priority value of Ecorobotix is 1,528, the priority value of Agrobot is 2,166, and the priority value of Naio Technology is 0,310. According to this result, Agrobot should be chosen as the agriculture 4.0 component.

5. FINDINGS AND DISCUSSION

Strawberry cultivation will be carried out in our designed smart greenhouse. Strawberry belongs to the group of berry fruits. Strawberry fruits are used extensively in the production of jams, marmalades and fruit juices, as well as for fresh consumption. The Mediterranean Region has an important place in early strawberry cultivation. It acquires products in November, December, and January and sells them at high prices. For this reason, it is necessary to use cover systems to grow crops in these months.

Figure 10. Strawberry Greenhouse

The TR62 Region is under the influence of the Mediterranean climate. In the regions where the Mediterranean climate is effective, the summers are hot and dry, and the winters are warm and rainy. Considering the climatic values, it is necessary to heat, ventilate and cool the greenhouses in certain periods.

In our greenhouses, the amount of heat to be given to the interior with underfloor heating will be determined by constantly measuring the outside air temperature with special thermometers. The desired absolute temperature in the greenhouse will be easily reached with the under-gluter heating system. Underfloor heating systems are among the best heating systems that can be chosen instead of other methods due to their affordable prices, easy maintenance, energy saving, and high efficiency. We preferred underfloor heating because it has these advantages.

While greenhouses are heated in cold seasons, they also need to be cooled in hot seasons. High heat accumulation in the greenhouse in cold and cool seasons can be prevented by ventilation. After a short heating period in our city, the air temperature increases. During this period, the greenhouse temperature may harm plant growth. Especially in greenhouses grown in summer, with the effect of sunlight, the temperature inside the greenhouse becomes 5-10°C higher than the outside temperature. This also causes the assimilation in plants to decrease and stop. In other words, the substance gained by the plant by assimilation is less than it loses by respiration. The assimilation (photosynthesis) in plants increases from 0°C to 20°C. In greenhouses, cooling can be done as long as it is economical.

Figure 11. Greenhouse Heating System

Cellulosic pads will be used while cooling our greenhouse. Cellulosic pads are mounted on the northern walls of the greenhouse. Thanks to the water circulation circulating inside and the humidity created by the exhaust fans, cooling up to 10 degrees is provided inside the greenhouse. It is simply cellulosic paper impregnated with chemicals that provide wettability and strength. Its wavy and cross-channel structure expands the surface area, facilitating the contact of air with water and providing minimum air resistance.

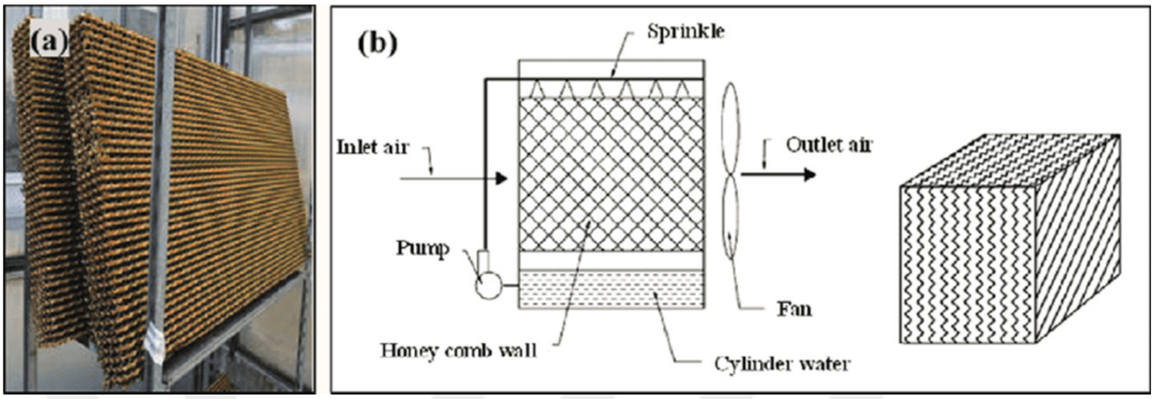

Figure 12. Cellulosic pads

The energy to be used for heating and cooling will be met from solar energy and natural gas.Specially designed solar panels will be placed on the roof of the greenhouse. The special 2 mm thick thin glass module has been our reason for preference due to its lightness and both moisture and nitrogen proofing. Half-spaces where the panels will be placed ensure a good light transmission in the greenhouse. It will be placed on the illuminated side walls and two large edges with manual or automatic openings to integrate the light diffusion inside.Greenhouse Solar Energy Systems are the most suitable solutions to benefit from “green” energy production and to provide the most suitable environment for crops.

Figure 13. Solar Energy Panel

Soilless agriculture will be done in our designed greenhouse. In soilless culture, the salinity, mineral substance density, air and water in the root of the plant are adjusted more evenly. In soilless agriculture, nutrients are used more effectively. Soilless agriculture is very suitable for greenhouse automation. With the automation to be made, labor savings will be achieved. If the plant gets sick in soilless agriculture, the disease of the plant can be controlled without the need for pesticides. In soilless agriculture, there are no diseases and weeds that can come from the soil. Since it is possible to grow plants more frequently in line with the suitability of soilless agricultural environmental conditions, if the light is sufficient, the product to be obtained per unit area will be more. Strawberry harvest grown with this method increases 5 times more than in soil farming.

Figure 14. Kokopit and coconut shells

In the old-type greenhouses, 9 seedlings are planted per unit area. In our smart greenhouse, 25 seedlings will be planted per unit area in the layered soilless production. Layered production chutes will be used. Kokopit and coconut shells will be used as the growing medium in soilless production in the greenhouse. Production bags with a length of one meter have a volume of 15 liters of Cocopeat. These production environments can be used for two or three years.

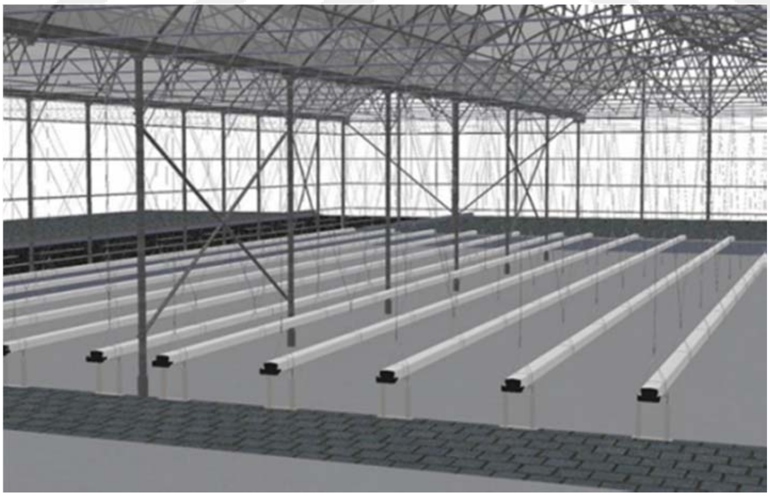

Figure 15. Greenhouse without soil

Plant production in greenhouses in hot and temperate climates is constantly threatened by viruses carried by insects and pests. Pests and insects entering the greenhouse infect the plant with phytopathogenic organisms. Keeping the insects and pests that harm the plants out of the greenhouse with insect nets is important in terms of control. Physical control against pests and pests has gained importance due to the chemical pesticides that are not allowed to be used and the resistance of the pests to the pesticides. Insect nets should be installed carefully without leaving any gaps in the door entrances and ventilation openings in the greenhouse.

Irrigation has great significance for plant production, since the water required for plant growth in greenhouses is given artificially. The average water requirement in greenhouses can be taken as 5 l/m2 plant area per day or 0.15 m3 /m2 per month for summer months. The annual requirement is 0.8-2.0 m3 /m2. A fully grown crop in a greenhouse needs 120 m3 of water per hectare per day, including drainage water.

Intelligent irrigation systems are systems developed to irrigate irrigation areas in the most effective way, to give water as much as the plant needs, and to obtain maximum efficiency from water and production. These irrigation systems will be used in our greenhouse. With the smart irrigation system, smart valve control will meet the measurements of the land and plant condition with the sensor. ensuring maximum utilization of resources.

With smart irrigation systems, less resources, more efficiency, feed the plant, not the soil. That makes a lot of difference! . Because when you deliver water and nutrients directly to the roots, you lower your costs. More importantly, your plant will be healthier and you will increase your yield.

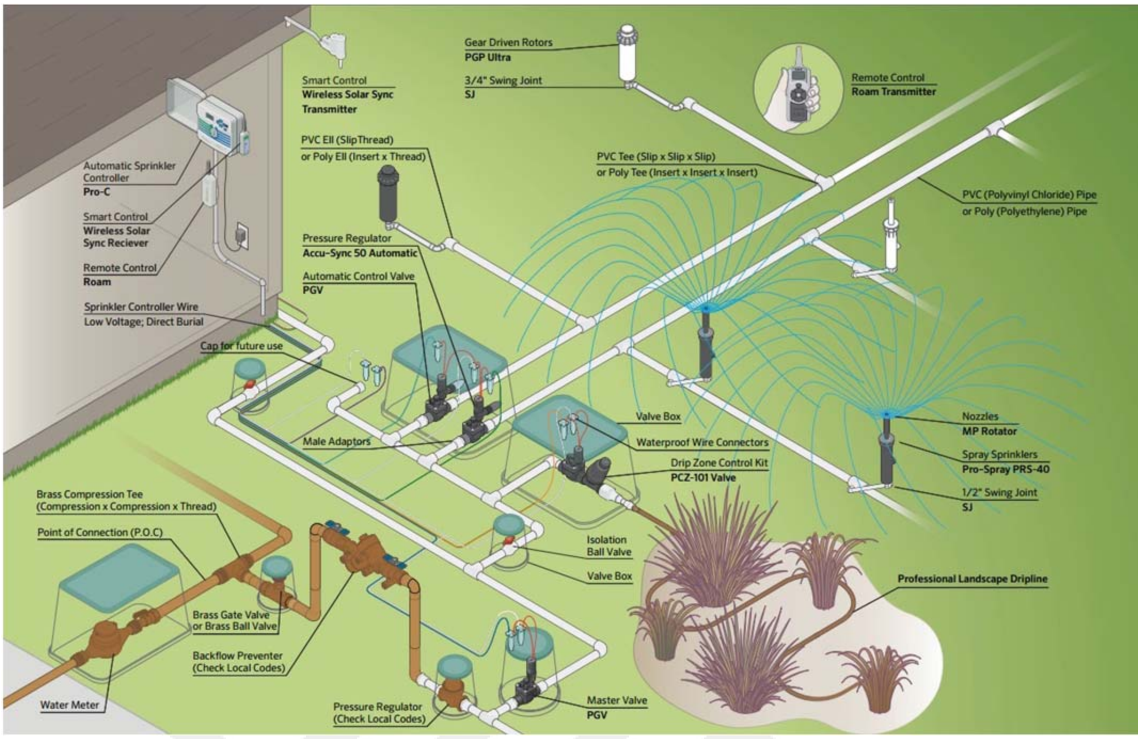

Figure 16. Smart irrigation method

Rainwater harvesting from sustainable agricultural practices will be used in our greenhouse to provide water savings.Rain water will be collected in steel water tanks with the roof gutters and discharge pipes to be mounted on the greenhouse upper construction. Thanks to this application, water consumption is prevented and it contributes to the economy. The average annual rainfall of the Mediterranean region is 666.5 mm, and the annual water capacity that can be collected is 47.988 tons. This is a very serious saving rate.

Figure 17. Steel water tanks

Irrigation and fertilization will be controlled in acres in the greenhouse. Irrigation and fertilization control unit will be able to control EC and PH. The software will be in Turkish. If desired, there will be a Turkish/English option. There will be 3 fertilizer channels and 1 acid channel. The system will be monitored and controlled over the Internet.

Figure 18. The Air Conditioning system

The Air Conditioning Control Unit will be integrated into the greenhouse. With the help of the climate computer to be installed in the greenhouse, in addition to the control of heating, ventilation, circulation fan, fogging and heat curtain, the measurement of the sensors connected to the meteorology station (indoor and outdoor humidity and temperature sensor, rain and wind sensor) will be recorded.

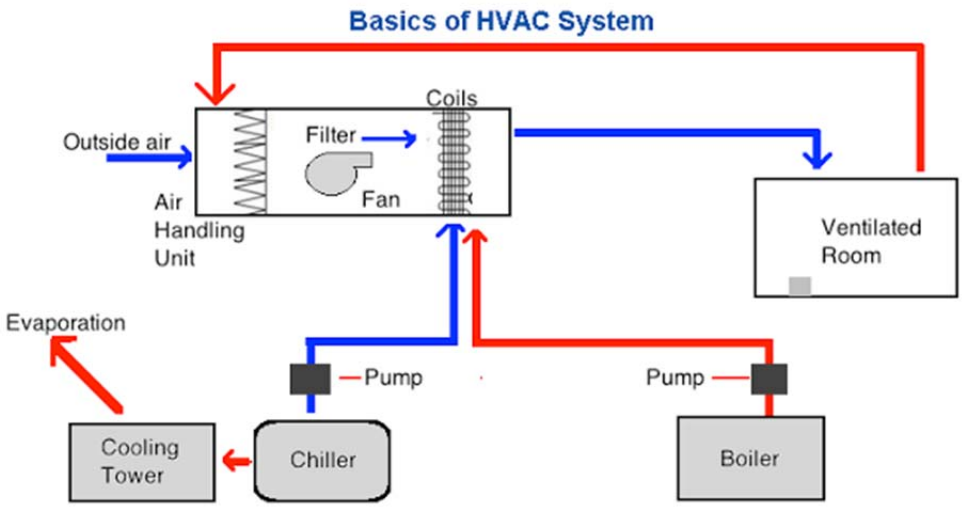

Figure 19. HVAC system

While harvesting strawberries in our greenhouse, an intelligent robot called agrobot e series will be used. This robot is a robot designed according to advanced artificial intelligence principles. The robot, which includes an advanced AI (Artificial Intelligence) system, can determine whether the strawberries are ripe and collect them. While doing this, it stands out as a plus feature that it does not harm the plant. Wireless communication is also available. The robot navigates between the shelves where strawberries grow hanging. Its algorithm, created by combining computer vision and machine learning techniques, scans each strawberry one by one. The robot identifies the ripest and best berries, extends its arm, and picks up and stores them without damaging the plant. The collecting tip of the robot is produced from a three-dimensional printer with a flexible material.

Figure 20. Agrobot

If a strawberry is not ready to be picked, the robot records its position and status and puts it on the list to come back later. It also arranges the strawberries it collects into boxes on the top according to their redness level. Considering all these advantages, this robot will be used in our greenhouse.

Figure 21. Strawberries Robot

Specialized cleaning robots will be used to cleanthe windows of the ceiling of the greenhouse and the solar energies positioned in the ceiling area. These robots, which can operate with remote control, move quickly and are light. They clean without scratching the glass.

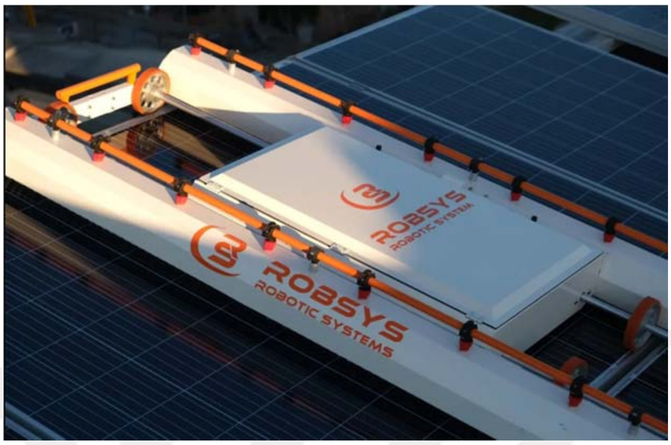

Figure 22. Window Robot

SWOT analysis of the TR62 region(Adana) in terms of smart greenhouse cultivation is done. The strengths and weaknesses of the TR62 Region(Adana) in terms of smart greenhouse cultivation are given below.

Strengths

1. Climate,
2. The region is one of Turkey's most important agricultural centers,
3. Presence of land, rail, air and seaway networks,
4. Geographical location, proximity to the Middle East countries and the existence of logistics advantages in agriculture-based exports,
5. The region plays an important role in the foreign trade of fresh fruits and vegetables on the scale of Turkey,
6. Carrying out R&D studies related to agriculture in Regional Universities,
7. Agricultural production data average being above Turkey average,
8. Consumption power of the domestic market.

Weaknesses

1. Using traditional methods in agricultural activities,
2. The use of agricultural technology creates large costs for small-scale producers,
3. Lack of agricultural education,
4. Low organizational awareness of producers,
5. Insufficient production infrastructure.

Opportunities

1. Increasing interest in technology
2. Having agricultural areas suitable for greenhouse cultivation and planning organized greenhouse zones,
3. The potential to use renewable energy sources in greenhouse heating,
4. Using the waste heat to be obtained from existing and newly established thermal power plants in greenhouses,
5. Adana is within the scope of Agriculture and Rural Development Support Institution,
6. Having a young and dynamic population,
7. Consumption power of the domestic market and surrounding provinces,
8. Proximity to markets where foreign consumption is concentrated (Russia, Middle East).

Threats

1. Keeping the young population away from the agriculture sector
2. Increase in input costs
3. Natural disasters such as droughts and floods
4. Disregard for technological methods
5. Decline in employment of agricultural workers with the reduction of manpower-based work

6. CONCLUSION, SUGGESTION AND EVALUATIONS

Agriculture in the world is in constant development. Adaptation to technological developments with unmanned aerial vehicles and satellite technologies, the use of sensors and agricultural machinery, and the management of cultural processes, and wireless data transfer will initially bring many costs. The contribution of Agriculture 4.0 to the increase in productivity, the decrease in the costs in all activities, the increase in the income obtained from the sector by increasing the quality, and the reduction of the economic losses due to the negative effects of climate change make the initial costs insignificant. Agriculture 4.0 will help make the producer's job easier.

In addition to agricultural production and arable agricultural lands, our country, which is in a suitable ecological position, uses its resources effectively so that it can compete in the same lane with the countries that have a say in the field of agricultural production. As well as making progress in the technological field and integrating the technologies it has made into agricultural production in the shortest possible time for the sustainability of the production in question must be provided in time.

In our study, firstly, information about the situation of the term Smart Agriculture in the world and in Turkey is given. A survey of 100 people was conducted to measure the awareness of the term Agriculture 4.0 in Turkey. When the survey questions are analyzed, it is seen that people who know actually about some components of agriculture 4.0 do not know that these components are within the scope of agriculture 4.0. Smart agriculture is seen as a key to the future of agriculture. the concept of smart agriculture or Agriculture 4.0 is considered an unusual concept in Turkey. Research institutes, ministries, universities, public institutions and private companies should work in cooperation on the dissemination of Agriculture 4.0, announcing examples and dissemination of applications. Support should be increased by starting to be implemented in pilot regions, applications should be increased and successful projects should be announced. After the work is done, its sustainability should be ensured and monitored.

If energy consumption in the world continues in this way, it is estimated that half of the fossil fuel resources will be consumed in the coming years. Fossil resources are used not only as fuel but also in many areas of the chemical industry, especially in medicine. With this aspect, it is important to protect it at least to reduce its consumption. As a result of the burning of fossil fuels such as coal or oil, CO2 is always formed. Compared to other greenhouse gases, carbon dioxide has the greatest effect on the deterioration of natural temperature balances, causing Global Warming. To protect the balance of nature, while designing our greenhouse, it is planned to provide its energy with solar energy, which is a renewable energy type. At the same time, rainwater will be collected by the greenhouse rain gutters, and used in greenhouse irrigation and water waste will be avoided. In this direction, for the smart greenhouse designed in our study, greenhouse type, greenhouse cover, irrigation type of the greenhouse, and energy alternatives are selected using the AHP method in order to find the optimum components. Smart agriculture components have been selected to be suitable for the planned plant type that will be grown in the greenhouse. Since incorporations and investments in the agricultural sector are increasing day by day, we believe that the number of smart greenhouse projects in the future will increase, and our work will be a source for the projects to be done.

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