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Risk Analysis Using Geographic Information Systems by Determining the Factors Affecting Yield in Plant Production: A case study from Ankara, Turkey

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ABSTRACT

Performing agricultural analysis is becoming much more effortless due to the rapid improvements in information technologies. Geographic Information Systems (GIS) provide more detailed data about climate, soil, topography, and irrigation values regarding agriculture; thus, allowing for performing detailed location analyses. These analyses cover agricultural investment maps, agricultural propriety areas, and plant pattern detections. The purpose of this study is to develop product-based agricultural risk analysis maps. Climate, soil, topography, and irrigation data are essential in the cultivation of agricultural products. With risk analysis, the risk values are determined for each risk factor. Applying the Analytical Hierarchy Process (AHP), which is one of the multi-criteria decision-making methods, the total risk value is calculated by prioritizing the risk factors. AHP is an efficient methodology developed to calculate scenario-based risk values by considering various possibilities.

In this study, a model is generated by studying apricot, sour cherry, and almond farming in Ankara. As a result of the development of a GIS model for Ankara, the total risk values were mapped as "high-risk areas", "medium-risk areas", "low-risk areas" and "strongly not recommended areas" according to the points they received spatially. When the maps were examined in detail; it was determined that apricot crops in Ankara province are more sensitive to climate, soil, and topography conditions than other products. Since apricot is affected by late spring frosts, it is recommended that risk factors can be reduced by taking climatic measures in areas where soil structure is suitable. It has been determined that the sour cherry crop is less sensitive to climatic and topographic conditions and is more affected by the risk factors from the soil layers; while the almond crop is more affected by the climatic conditions, though it is more tolerant to soil conditions. According to these results, apricot can be grown in large areas with medium and high-risk levels, and in limited areas with low-risk levels. Almond with a very high-risk level can be grown in large areas compared to apricot, and sour cherry can be grown in similar-sized areas with apricot, but with a lower risk level than apricot.

Keywords: Risk maps, Multi-Criteria decision Model (MCDM), Analytical hierarchy process (AHP), Fault tree analyses (FTA), Agricultural product risk maps

1. Introduction

The current world population of 7.6 billion is expected to reach 8.6 billion in 2030, 9.8 billion in 2050 and 11.2 billion in 2100, according to a United Nations last report. Numerous challenges linked to agricultural supply chains, as well as decreasing farmland, environmental problems, and the insufficient protection of natural resources have made it necessary to take urgent measures to meet the food needs of the increasing world population. Farming systems require an extensive and profound transformation from traditional practices to precision farming and to intelligent farming practices to cope with these challenges (FAO/WHO, 2018).

Approximately 13 billion hectares of the earth's surface is covered with land and 37% of this land (approximately 5 billion hectares) consists of agricultural land. Considering the distribution of the agricultural land according to its use; It is seen that field crops are grown in approximately 1.5 billion hectares of land, while perennial plants are also planted in 1.5 billion hectares. The remaining 2 billion hectares are utilized as meadows and pastures (Ministry Development of Turkey 2013).

The strategic importance of the protection and development of agricultural production, the continuity of nutrition, which is the basic need of human beings, the supply of food raw materials, and the sustainability of the agricultural sector has become even more evident during the COVID-19 process. The existing agricultural areas in the world are decreasing by 0.1% - 0.2% every 5 years. On the other hand, the world population has increased by 6.2% in the last 5 years (UN, 2013). Between 2001 and 2020, the total amount of land planted in Turkey decreased by 3 million 205 thousand hectares from 26 million 350 thousand hectares to 23 million 145 thousand hectares. The drop rate was 12 percent. In the same period, our population increased by 18 million 219 thousand and reached 83 million 385 thousand. The rate of increase was 28% (Turkish Statistical Institute 2021). It is estimated that the population of Turkey will reach 100 million in 2040. This shows that it will be more difficult to feed the increasing population with the decreasing agricultural lands (Kritikos 2017; Pablo et al. 2014).

In the current study, the reason why apricot, sour cherry, and almond were selected for creating a risk analysis map in Ankara was due to the fact that these crops are affected the most during early spring and late autumn frosts, and also that the damage caused by moisture and sunburn reduces the economic value of these products. These factors arising from the climate can be minimized via performing site selection analysis with GIS methods.

1.1. Risk analysis

In the current situation, the existence of a potential source that may cause deficiency or loss induces a risk. On the other hand, the presence of loss is not satisfactory in defining the risk situation encountered. At this point, there is vagueness as the loss has converted from potential to tangible loss. Therefore, the risk can be defined as a combination of any loss or omissions that may occur. Moreover, the vagueness of this possibility turns into an actual omission or loss. In brief, the risk is the probability of loss or deficiency and the degree of this deficiency. Risk is equal to the sum of incompleteness and uncertainty (Benner 1978). Another equation in this regard is the following formula, which includes the “result” and the "probability of occurrence"; Risk (R) is the multiplying of “product of severity” (S) and “probability” (P). As the formula indicates, the degree of risk revealed through result and probability values can have the equivalent value for various situations. Although the risk levels are similar; there are several techniques to reduce risk. In the first case, systems that may cause minor damage should be highlighted, considering the situations that will occur when the event occurs. Concerning the second case, the main objects generating the events should be ascertained and eliminated efficiently (Şenel & Şenel 2013; Çetinyokuş & Yeniay 2019).

1.2. Geographic information systems (GIS)

GIS has many different definitions due to its use in numerous disciplines. For instance, Geographic Information Systems (GIS) can be used as a landscape planning instrument for the landscape architect, a reserve calculation instrument for a mining engineer, or an instrument for calculating recall values for an agricultural engineer. GIS is defined as a system that is “designed to solve complex planning and management problems, which consists of hardware, software, and methods that cover the containment, management, processing, analysis, modeling, and display of data for a particular location” (Research In Urbanism Series Vol. 3, 2015). In addition, the agricultural meaning of GIS is a technology that facilitates the transition from existing methods to precision agriculture (Sharma et al. 2018).

In the current study, land propriety, land survey, selection, and risk assessment for agricultural products are discussed through GIS applications. GIS and Risk analysis are combined in the same model to determine location-based agricultural risks. This study has established a framework for crop harvesting in plant production where ecological risks can be predicted and preventive measures can be taken to minimize risks. That framework identifies extensive data analysis that plays an essential role in improving the quality of GIS implementation in agriculture and provides guidelines for researchers, practitioners, and policymakers to manage massive GIS data to successfully maintain enhanced agricultural productivity (Peggion et al. 2008).

In similar studies, it has been observed that a limited number of agricultural risks are focused on a single GIS model. In addition, each of the risks creates the result with the same degree of importance. For example, it was seen that the frost risk, which significantly affects the yield, and the humidity risk, which affects the product quality, are calculated with the same degree of importance. In this study, due to Multi-Criteria Decision Model (MCDM) in Ankara, many agricultural risk layers and the sub-layers that make up these layers are scored according to the degree of importance with AHP and create a risk score from 0 to 25 (Nyeko 2012).

2. Material and Methods

2.1. Study area

In this study, Ankara is selected, since it is the capital city of Turkey and in the middle of it. Ankara has an area of 26,897 km² and its elevation above sea level is about 890 meters. Approximately 50% of the province's surface area formed in the plains is agricultural land, 28% is forest and heathland, 12% is meadow and pasture, and 10% is non-agricultural land (Ankara Governorship 2020; Turkish Statistical Institute 2020).

Kızılırmak River, one of the longest rivers in Turkey with a length of 1 355 kilometers, irrigates the east of the province, while the longest river with a length of 824 kilometers, irrigates the west of the Ankara province. Ankara stream, a branch of the Sakarya River, flows through the city center. Salt Lake is the second-largest lake in the country with 1 300 km², and with a salt rate of 32.4% it is the second saltiest lake in the world. In addition, the basin in which Salt Lake is located, is the largest closed basin in Turkey (Ankara Governorship 2020).

Ankara province has a variable geographical structure with Black Sea climate in the north, continental climate in the south and east, and temperate climate in the west. Due to these wide characteristics, the province of Ankara has been preferred in order to spread the test applicability of the current study throughout the country.

2.2. Data supply

Climate, soil, topography, and streambed maps provided by the General Directorate of State Hydraulic Works, General Directorate of Meteorology, as well as from the General Directorate of Abolished Land and Water datas (Table 1) were standardized. These data were transferred to the geographical database built-in with the ArcGIS 10.5 application and adapted to a single projection system.

The last published 30 years (1980-2010) of climatic data, collected from 228 stations in Turkey by the General Directorate of Meteorology, have been used. These data were classified monthly, and subsequently, the monthly mean values, minimum, as well as maximum values, were calculated. Consequently, data were converted to GIS format via co-kriging and inverse distance weighting (IDW) methods with the ArcGIS software, and surface spread was applied. In the process of spreading over the surface, considering the topography, values were divided into compartments with 20x20 meters size, and climate maps were generated in raster format.

Table 1- GIS Datasets

Climate Data	***Soil Data***
• Temperature ○ Average Temperature on a Monthly ○ Maximum Temperature on a Monthly ○ Minimum Temperature on a Monthly ○ Extreme Maximum Temperature on a Monthly ○ Extreme Minimum Temperature on a Monthly • Precipitation ○ Total Precipitation on a Monthly ○ Summer Months Total Precipitation ○ Total Annual Precipitation • Sunbathing ○ Total Sunbathing Times on a Monthly ○ Annual Total Sunbathing Time • Evaporation ○ Evaporation Values on a Monthly ○ Average Annual Evaporation Amount • Humidity ○ Average Humidity value on a Monthly ○ Spring Months Average Humidity value ○ Summer Months Average Humidity Value • Wind ○ Average Wind Speed on a Monthly • Soil Temperature, ***Water Data*** • Areas Irrigated by Surface and Groundwater Resources • Streams • Dams and Lakes • Sub-Basins Where Groundwater Is Insufficient	• Soil Depth ○ Lithosolic ○ Very Shallow (0-30cm) ○ Shallow (30-50cm) ○ Medium Deep (50-90cm) ○ Deep (90-150cm) ○ Very Deep (>150cm) • Soil Erosion ○ Wind Erosion ○ Rain Erosion • Land Use Capability ○ 1-8th Class Land • Available Land Use ○ Absolute Irrigated Farmland ○ Marginal Irrigated Agricultural Land ○ Absolute Dry Farmland ○ Marginal Dry Farmland ○ Planted Agricultural Land ○ Meadow and Pasture Areas ○ Wetlands ○ Forest Areas ○ More Fields • Drainage ***Topography*** Slope and Aspect maps are produced using the Turkish Digital Height Model (DHM) data at a resolution of 10 meters. • Height • Slope • Aspect

2.3. Statistical data

The province and district-based annual values of field, production, and yield where agricultural products are grown, offered by the Turkish Statistical Institute, were used. The average values of the last five years were calculated, and also the product-based county yield amount was calculated. Since it takes 3-5 years for fruit trees to reach economic value in perennial garden facilities, statistical data from the past 5 years have been used.

2.4. Method

Factors described graphically in the tree diagram and errors related to the used material can be attributed to human mistakes or different events that generate unintended outcomes. The Failed Tree Analyses (FTA) method can be qualitatively used to identify the reasons and events that lead to an error and can be used quantitatively, to calculate the probability of recurrence of the main reason as well. In the design stage of a system, The FTA method is also used to calculate potential losses and collect from different design options and predict the significance of potential losses during the operation phase (Limnios 1993).

Based on deductive logic, the factors that may cause an undesirable situation are determined and analyzed. The severity of the risk arising from undesirable conditions is calculated by the FTA method. Risk factors are organized, defined, and presented on a tree diagram with a logical system. Undesirable peak events should be detected and any factor considered in this event should be analyzed. The model setup is started by using the total risk value of a selected fruit product. Consequently, sub-risks such as climate, soil, topography, and water restrictions that lead to total risk are determined. Factors that lead to sub-risks are selected based on a product and inscribed as layers. The FTA method used in complex systems focuses only on the risk of a single product (Çınar & Karacabey 2004).

2.5. Agricultural risk analysis

Various risks that farmers experience in developing countries are listed under two main headings; ecological risks which arise from the uncertainty of production amount related to climatic factors in current agricultural activities; and economic risks which arise from potential fluctuations in cost and sales. In recent years, risks such as increasingly large disasters, droughts, floods, frost, hail damages, shifting of seasons, erosion, new types of diseases, and pests are collected under the heading of ecological risks. In a recent study, researchers estimate that 23% of the field products have been lost due to adverse weather conditions. This percentage is remarkable in garden plants (Islam et al. 2018).

2.6. Step model establishment

Analytical Hierarchy Process (AHP) model is developed in the GIS environment under the capabilities of the ArcGIS software. The “weighted overlay analysis” tool, the equivalent of the AHP method in ArcGIS software, is used. During the calculation of the risk factors of the substrates constituting the distinctive climate risk factor, it was accepted that the main climate risk factor is the highest risk factor, since it would contain the highest risk in terms of plant growth. At this stage, the “fuzzy overlay analysis” tool in the ArcGIS software was used.

In that model, with the road map in figure 1, values lead to risk during the plant's growth in the climate, soil, topography, and water presence layers, and the risk probabilities are inscribed in the Figure 2. Consequently, optimum values, i.e., the lowest risk values, promote selected plant growth according to the risk matrix that has scored the lowest. In contrast, high-risk values for the plant's growing conditions are scored as the highest according to the risk matrix.

In addition, thanks to the “weighted overlap analysis tool”, the risk scores from the layers can be re-scored hierarchically by assigning values between climate, soil, hill, and irrigation layers according to their importance (Tuncay & Demirel 2017).

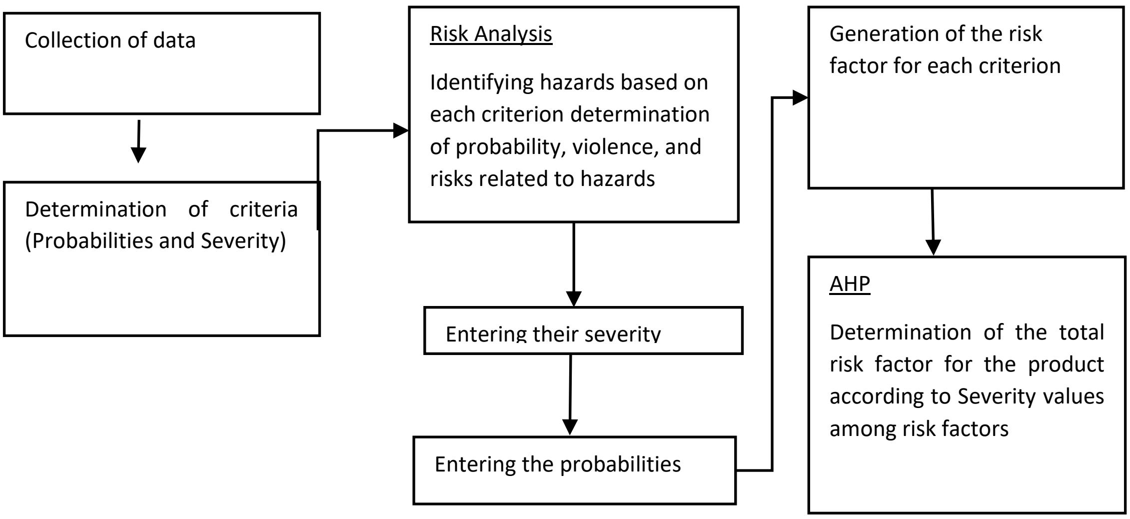

Figure 1- GIS/AHP Model Flow Chart

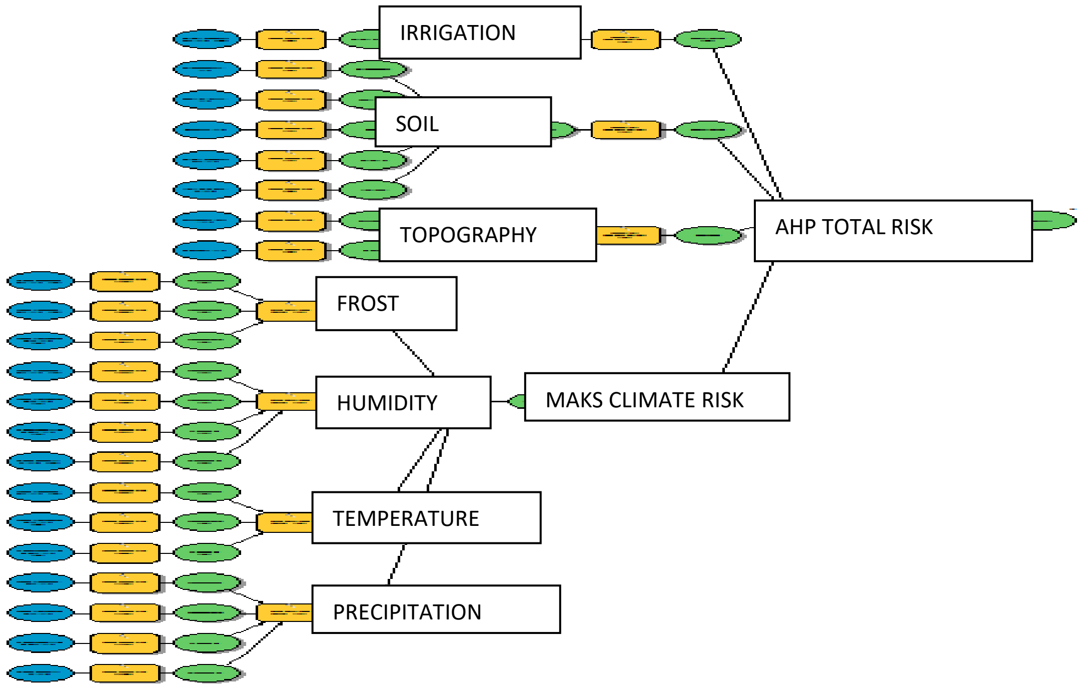

Figure 2- GIS Model (Error Tree, FMEA System hierarchical structure)

2.7. Step; GIS/AHP scoring

All of the data required on the cultivation of agricultural products were collected from crop specialists (Researchers working on crop improvement in Agricultural Research Institutes) and from published scientific studies. Data have been entered into the GIS/AHP Model by following the steps below (Çobanoğlu et al. 2007; Öztekin et al. 2008; Gür et al. 2011; Eroğlu & Mısırlı 2012; Göçmez & Seferoğlu 2014).

1. Entering the probabilities
2. Entering its severity
3. Generation of risk matrix
4. Determining risks
5. Prioritization of risks with AHP
6. Determination of total risk

In the light of this information, risk severity for each layer that is essential for the selected product's growth is filled in Table 2 with the "reclassification" tool on GIS.

Table 2- Severity Rating of AHP

Risk Matrix Severity	*Degree*	*Description*
Very light	1	Product/yield loss less than 10%
Light	2	Up to 10% product/yield loss
Moderate	3	10%-30% product/yield loss
Serious	4	30%-50% product/yield loss
Very serious	5	Product yield loss more than 50%

For instance, for the apricot crop, when the April minimum temperature value is at -10 ºC, frostbite intensity is "5" as "very high", while at 1 ºC, the frostbite intensity is "3" as "moderate", and at +6 ºC, frostbite intensity is "1" as "very low."

For example, for Apricot, the minimum temperature value for April is “5” at -10 °C, while the severity of frost is “very severe”, and at -3 °C the severity of frost is “3”, and finally at +3 °C, the severity of frost is considered as light at “3”. In addition, apricot cultivation is definitely not recommended at locations where the average temperature layer shows temperatures below -10 °C. Considering this situation, when the risk severity exceeds the "irrecoverable" level, with the "no data" command entered into the model, the information that an apricot crop is not recommended for this region is processed regardless of other conditions (Chen et al. 2009).

Table 3- Severity Rating (Example: Average Temperature Layer)

Average Temperature Layer	*State of Violence*	*Severity ating*	*Description*
+6,+10 C	Very light	1	Product/yield loss less than 10%
+3,+5C	Light	2	Up to 10% product/yield loss
-2,+2 C	Moderate	3	10%-30% product/yield loss
-5,-3 C	Serious	4	30%-50% product/yield loss
-10,-6 C	Very serious	5	Product yield loss more than 50%
> -10 C	Definitely	No data	No products can be grown

Each layer essential for the selected plant growth has been inputted with probability values such as the values given above.

Risk probability values such as the risk severity values given in Table 3 were entered for all layers that are important for the growth of the selected plant. After the risk severity values were entered into the GIS model, the "probability" values were filled as shown in Table 4. Here, the aim is to enter the information about how likely the risk severity layer is to realize the severity. This process is formed with the "Weighted Overlay Analyses" tool in GIS (Öztekin et al. 2008; Mokarram & Aminzadeh 2010; Mokarram & Hojati 2016)

Table 4- Degree of Probability

Risk Matrix Probability	*Degree*	*Description*
Very small	1	No more than once in 30 years
Small	2	2-5 times in 30 years
Moderate	3	Seen 6-10 times in 30 years
High	4	11-15 sightings in 30 years
Too high	5	Seen more than 15 times in 30 years

For instance, in Table 3, April frostbite severity values are noted for the apricot crop. Supposing that value for February, March, and May is "5" as "too high." Hence, in April, frost probability is higher than the rest of the year due to the flowering of apricot trees. The average temperature layer data of March, May, and February can be entered into the model as "3" "moderate", "2" "small", and "1" "very small" respectively (İbrahim & Pırlak 2011).

Table 5- Degree of Probability

Mounts	*Probability*	*Degree of Probability*	*Description*
February	Very small	1	No more than once in 30 years
Mart	Moderate	3	Seen 6-10 times in 30 years
April	Too high	5	Seen more than 15 times in 30 years
May	Small	2	2-5 times in 30 years

2.8. Risk Matrix

Risk= Severity x Probability; Using the probability values in Tables 5 - 7 risk matrix was created with this formula.

According to the scores after the values entered;

- Green Areas: Low-risk from 1 to 6 (inclusive) (1 pointless risk)
- Yellow Areas: Medium risk from 6 to 12 (inclusive)
- Red Areas: High risk from 12 and 25 (inclusive) (25 non-tolerable risks)

Table 6- Risk Matrix

RISK MATRIX	***Violence***				
Probability	***1 (Very Light)***	***2 (Light)***	***3 (Moderate)***	***4 (Serious)***	***5 (Very Serious)***
1 (Very small)	**1** Meanless	**2** Low	**3** Low	**4** Low	**5** Low
2 (Small)	**2** Low	**4** Low	**6** Low	**8** Medium	**10** Medium
3 (Moderate)	**3** Low	**6** Low	**9** Medium	**12** Medium	**15** High
4 (High)	**4** Low	**8** Medium	**12** Medium	**16** High	**20** High
5 (Too high)	**5** Low	**10** Medium	**15** High	**20** High	**25** Irrecoverable

The GIS model places the probability values entered for layers locational into each grid as values. A selected point in Ankara is the average temperature layer (-1 °C) in April. Hence, the severity of apricot trees damaged by frostbite is a moderate "3". The average temperature value of the same point is (-5 °C) in March, and the average temperature value is (+3 °C) in May. Therefore, the average temperature value, in other words, the frostbite severity of March and May, is 5 and 1 °C, respectively. However, considering the periods when apricot trees bloom at the selected region, in April when flowering is the highest, the probability of frostbiting is serious "5", and the probability of frostbiting in March and May is "3" and "1", respectively, since the flowering of trees is low in the months of March and May (Öztekin et al. 2008; İbrahim & Pırlak 2011).

Table 7- Risk Factor

For a selected point	*Temperature*	*State of Severity*	*Severity Rating*	*Probabilities*	*Degree of Probability*	*RISK Status*	*RISK Severity*	*Frost Risk Factor*
Average temperature value for March	-5 C	Moderate	4	High	3	Moderate	4x3 **12**	**Maximum risk severity = 15**
Average temperature value for April	-1 C	Very serious	3	High	5	High	3x5 **15**	
Average temperature value for May	+6 C	Light	1	Very Small	2	Low	1x2 **2**	

Table 7 has the frostbite risk factor for the region selected for the apricot crop. Factors essential in agricultural productivity which may include risks for products in their lack or excess can be calculated separately for the following factors; risk factors; climate (frost, humidity, temperature, precipitation, sunshine, wind), soil, topography, and water presence (drought).

Therefore, Table 8 is filled for each risk factor, and "importance assessment" is carried out using AHP through those risk factors. Scoring is determined among the risk factors with the support of Table 8, which was generated during the AHP. This is conducted with the "Weighted Overlay" analysis tool on GIS (Ünüvar & Pırlak 2016).

Table 8- AHP Severity Values

Value	*Definition*	*Description*
1	Equally important	Equally important in two options
3	Little important.	Where one criterion is slightly superior to another
5	Too important.	One criterion is considered superior to another
7	Too important.	One criterion is considered quite superior to another
9	Extremely important	One criterion is superior to another.
2, 4, 6, 8	Intermediate values	Specify intermediate values between two consecutive evaluations

After determining criteria and sub-criteria, using the Super Decision software, the interactions between the criteria can be analyzed, and the criteria affecting each other can be determined. The network structure in Figure 3 is established by generating inter-criteria connections, internal and external dependencies, and feedback with the program's help (Rabia & Terribile 2013).

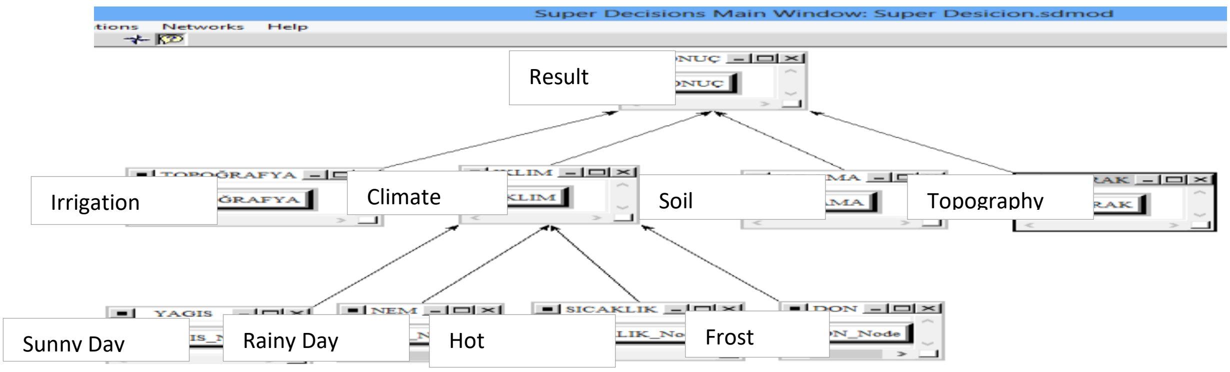

Figure 3- Super Decision Program Interface

Cross-layer "severity scores" (Figure 4) were calculated by entering the critical values of the AHP method to the Super Decision software (Figure 3). Score values can be entered directly into the GIS Model (Altay & Keskin 2018; Paulraj & Easwaran 2008).

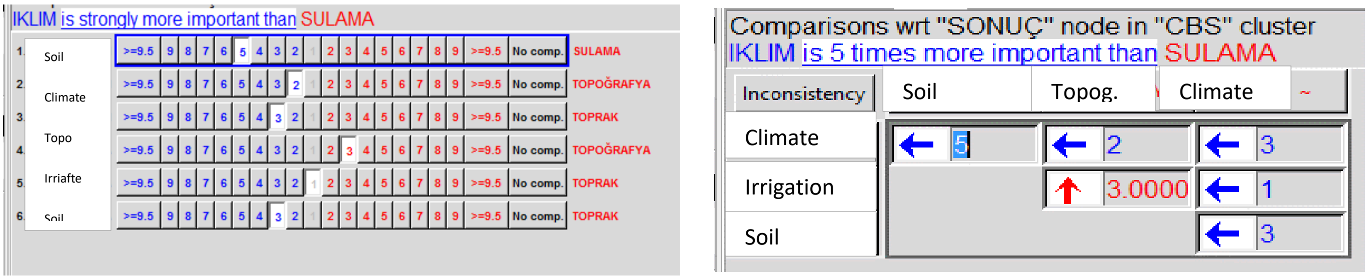

Figure 4- Entering data into the Super Decision Program

For the apricot crop selected as a model, the "supremacy" importance scores of the risk factors that were formed after all the layers under the climate, soil, topography, and irrigation layer groups were entered using Table 9. The sum of the importance values to be given to the risk factor groups should be equal to “1” (Van Chuong 2008).

Table 9- Total Risk Prioritization

Risk Factors			*Severity Weight*	*Total Risk*
Irrigation			0.10303	**Climate + Soil + Topography + Irrigation**
Soil			0.11887	
Topography			0.29271	
	Layers	**Climate Max Risk**		
Climate	Frost Humidity Temperature Precipitation	Max (Frost, Humidity, Temperature, Precipitation)	0.48090	

2.9. Step; running the model

All the steps and formulas described above to calculate total risk are processed into the GIS model developed on ArcGIS Desktop software and the values entered are run on the tools shown in Figure 2 and rendered into the pop-up windows. The blue oval shapes shown in figure 2 represent the layers entered into the model. Checkboxes colored yellow are the toolboxes that are processed. Green oval shapes, on the other hand, express the newly formed layers after the procedure. In the model, the layers that are decisive in the growing of apricot crops are primarily chosen. These layers are divided into groups as climate, soil, topography, and irrigation. The climate is divided into subgroups as frost, temperature, precipitation, and humidity. Risk probabilities and risk severity values in each sub-group are entered as described in this article's setting-up-the-model section. Scores from sub-groups are calculated with the formula “X=Max ∑Probability x Severity”. Since there are four subgroups of this factor in calculating the risk factor value of the climate group, each risk factor is calculated separately, and the maximum climate risk layer is created by selecting the maximum risk that matches with each point with the “fuzzy overlay analysis” tool.

In calculating soil, topography, and irrigation risk factors, probability and severity values in the sub-layers are entered. Risk factors for groups are calculated by multiplying the probability and severity values, which have been entered. The maximum climate risk layer described in the previous step is used for the climate.

After this stage, risk factors ranging from zero to 25 are obtained in each group. To prioritize climate, soil, topography, and irrigation with AHP, the "AHP Importance Values" shown in Table 9 are entered into the “weighted overlay analysis” tool. Since the sum of the values entered in AHP is equal to 100% of the values entered, the final values can be the “total risk” values between 0 and 25.

An example of manual calculation for a selected point is made below. in the apricot example described above, "frost risk factor" scored "15" at a chosen point. again, the calculation process is continued assuming its score is "10" from the risk factors "humidity," "temperature," and "precipitation." When calculating the climate risk factor, prioritization scores are given among the sub-groups as shown in Table 9 total risk calculation.

Climate Risk Factor$=$ Maksimum[Frost Risk, Humidity Risk, Precipitation Risk, Temperature Risk]
Climate Risk Factor (Calculation with Virtual Values)$=$ Maksimum$[15, 10, 10, 10] = 15$

When the treating was performed, the "climate risk factor" scored 15. Considering the risk matrix, the climate risk factor of the chosen point is the "high risk" level for the apricot crop.

Once again, the process was continued assuming that the soil risk factor from the same point scored "8" and the topography risk factor scored as "12" and the irrigation risk factor scored as "18". Table 9: In calculating the total risk, AHP and "importance values" scores for climate, soil, topography, and irrigation are multiplied.

$$\textbf{Total risk} = \text{Climate x } 0.48090 + \text{Soil x } 0.11887 + \text{Topography x } 0.29271 + \text{Irrigation x } 0.10303$$
$$\textbf{Total risk} = 15 \text{ x } 0.48 + 8 \text{ x } 0.12 + 12 \text{ x } 0.30 + 18 \text{ x } 0.10 = 12.54$$

The total risk value calculated for apricot farming at the chosen point after the previously explained procedure is "moderate," according to Table 6 risk matrix. Assume that the total risk score calculated for the chosen point is decision 1. Since AHP allows calculations exerted in consideration of several possibilities, a new total risk score has been calculated by assuming that the importance of the climate risk factor weight is reduced at the same point. This reduction is due to the conservative effect of measures such as a temporary greenhouse plant, running a fan on icy cold days, creating smoke by burning hay, and tying mesh against hail risk.

In order to check the model result, calculations will also be made manually for 3 different points, which are currently apricot, cherry and almond orchards. In this way, it will be possible to compare the score status of the risk maps in the lands that can grow high-yield crops.

2.10. Creating risk maps

The climate (Figure 5), soil (Figure 6), topography (Figure 7) and irrigation (Figure 8) sub-risk layers created as a result of running the GIS model are shown on the maps. While the risk value is low in the north of Ankara in the climate risk map, the situation is calculated as the opposite in the topography risk map. The soil risk map shows a complex distribution. Fixed risk has been determined in non-irrigated lands. (El-Sheikh et al. 2010)

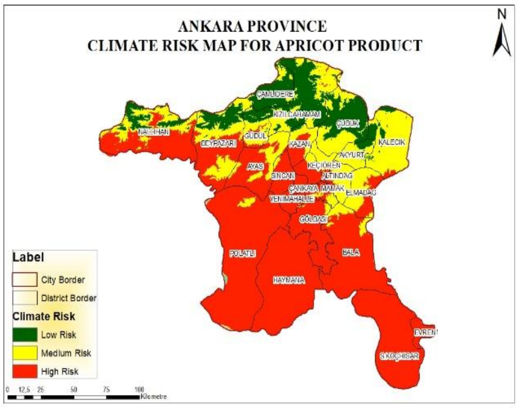

Figure 5- Climate Risk Map

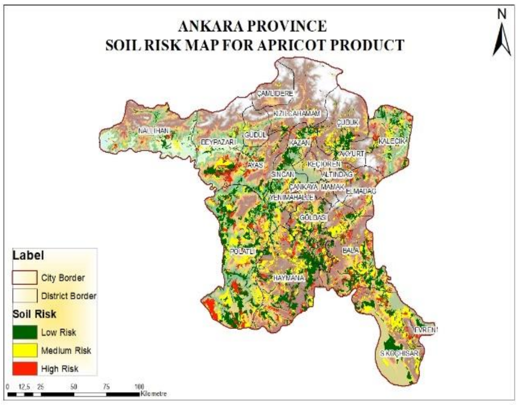

Figure 6- Soil Risk Map

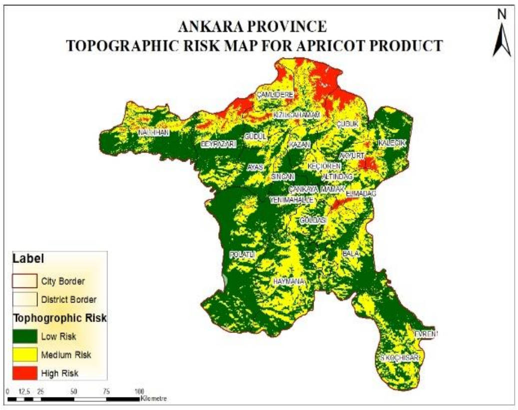

Figure 7- Topography Risk Map

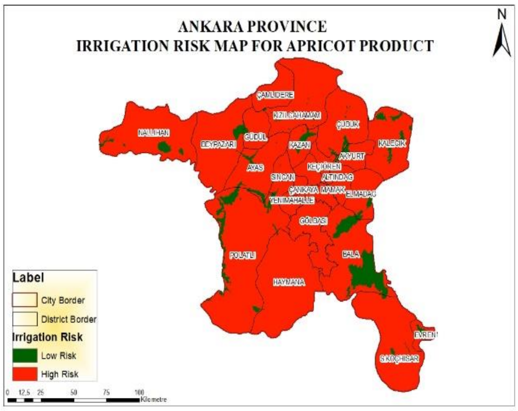

Figure 8- Irrigation Risk Map

Total Risk Map

The total risk map of apricot created by the combination of the sub-risk layers, are shown Figure 9.

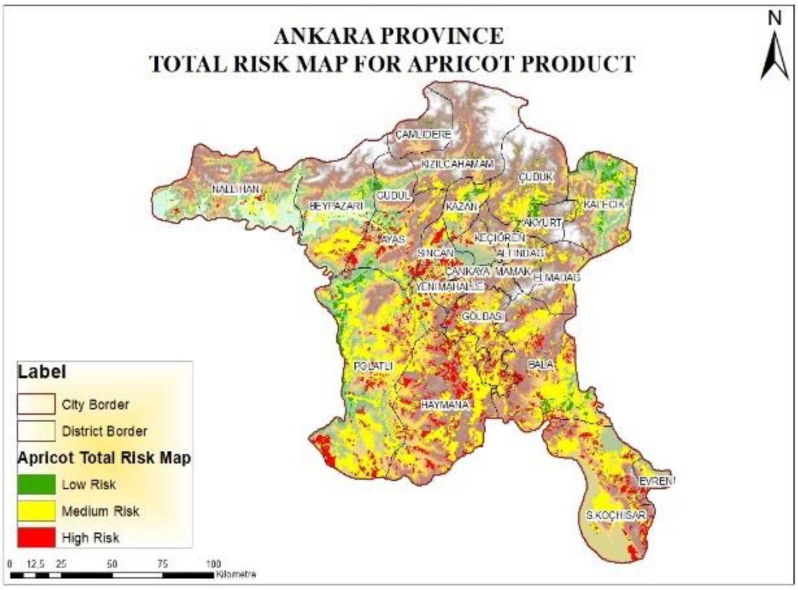

Figure 9- Apricot Risk Map in Ankara Province

Table 10- Turkish Statistical Institute 2020 Plant Production Statistics

Provincial Name	*County Name*	*Product Name*	*Planted Area (da)*	*Number of Trees*	*Production (Tons)*	*Average Yield Per Tree (kg)*
Ankara	Evren	Apricot	0	1140	68	60
Ankara	Kalecik	Apricot	499	21550	690	32
Ankara	Beypazarı	Apricot	0	1000	30	30
Ankara	Güdül	Apricot	170	6500	195	30
Ankara	Kahramankazan	Apricot	23	1800	54	30
Ankara	Keçiören	Apricot	7	535	16	30
Ankara	Yenimahalle	Apricot	0	250	7	28
Ankara	Çankaya	Apricot	15	2700	70	26
Ankara	Polatlı	Apricot	878	24400	561	23
Ankara	Çubuk	Apricot	340	5435	125	23
Ankara	Şereflikoçhisar	Apricot	0	2000	40	20
Ankara	Etimesgut	Apricot	18	215	4	19
Ankara	Haymana	Apricot	295	12550	213	17
Ankara	Ayaş	Apricot	65	9400	141	15
Ankara	Nallıhan	Apricot	5	6550	98	15
Ankara	Pursaklar	Apricot	20	400	6	15
Ankara	Sincan	Apricot	122	5270	79	15
Ankara	Mamak	Apricot	40	1290	18	14
Ankara	Gölbaşı	Apricot	1550	21792	283	13
Ankara	Elmadağ	Apricot	43	5250	63	12
Ankara	Altındağ	Apricot	24	469	4	9
Ankara	Akyurt	Apricot	49	2120	11	5
Ankara	Bala	Apricot	27	750	1	1
Total/Average			**4 190**	**133 366**	**2 777**	**21**

According to the Turkish Statistical Institute apricot maximum yield in Turkey is 95 kg, the average yield is 47 kg in 2020. When Table 10 is examined, it is understood that the average yield for the apricot crop is below the country average in all except Evren district of Ankara province. There is no closed garden in Evren district either. It is seen that the yield is quite low in the high-risk red areas on the map, while the yield is relatively high in the low-risk green areas. High and medium risk areas make up the bulk of the map.

Since it is possible to develop risk maps of different products with the same model, risk maps are generated for the sour cherry and almond crops. Probability and severity values entered into the model are predetermined for the product, and two new maps are generated.

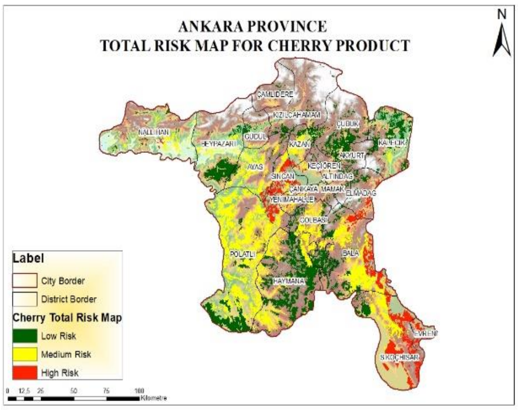

Figure 10- Sour Cherry Risk Map in Ankara Province

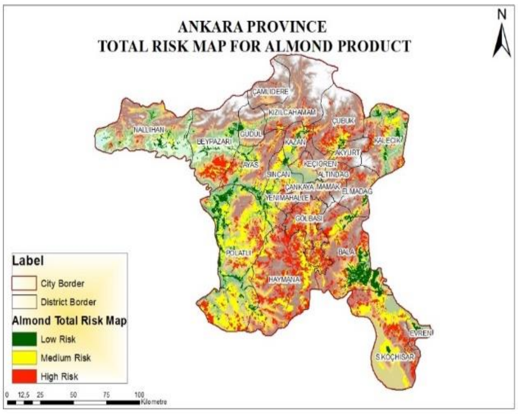

Figure 11- Almond Risk Map in Ankara Province

Table 11- Turkish Statistical Institute 2020 Plant Production Statistics

Provincial Name	*County Name*	*Product Name*	*Planted Area (da)*	*Number of Trees*	*Production (Tons)*	*Average Yield Per Tree (kg)*
Ankara	Evren	S. Cherry	20	1.270	76	60
Ankara	Akyurt	S. Cherry	88	2.720	136	50
Ankara	Güdül	S. Cherry	800	14.500	725	50
Ankara	Sincan	S. Cherry	265	6.530	327	50
Ankara	Şereflikoçhisar	S. Cherry	0	1.500	75	50
Ankara	Polatlı	S. Cherry	276	10.240	410	40
Ankara	Çankaya	S. Cherry	3	2.050	72	35
Ankara	Yenimahalle	S. Cherry	0	150	5	33
Ankara	Ayaş	S. Cherry	1.900	55.200	1.766	32
Ankara	Kalecik	S. Cherry	300	13.400	415	31
Ankara	Keçiören	S. Cherry	18	258	8	31
Ankara	Elmadağ	S. Cherry	136	7.350	221	30
Ankara	Kahramankazan	S. Cherry	67	6.040	181	30
Ankara	Çubuk	S. Cherry	1.230	19.661	590	30
Ankara	Etimesgut	S. Cherry	14	750	22	29
Ankara	Çamlıdere	S. Cherry	58	1.100	26	24
Ankara	Kızılcahamam	S. Cherry	40	6.500	143	22
Ankara	Beypazarı	S. Cherry	203	14.020	280	20
Ankara	Haymana	S. Cherry	76	2.730	54	20
Ankara	Pursaklar	S. Cherry	45	1.300	26	20
Ankara	Altındağ	S. Cherry	18	429	8	19
Ankara	Mamak	S. Cherry	8	440	8	18
Ankara	Gölbaşı	S. Cherry	520	10.824	162	15
Ankara	Nallıhan	S. Cherry	74	11.600	174	15
Ankara	Bala	S. Cherry	28	825	8	10
Total/Average			**6 187**	**191 387**	**5 918**	**31**

According to the Turkish Statistical Institute, sour cherry maximum yield in Turkey is 83 kg, the average yield is 33 kg in 2020. The current product statistics of the sour cherry crop in Table 11 are examined, it is understood that it is similar to the map created as a result of the model in Figure 10. It is seen that the risk is low in the flat areas located in the north and west of Ankara. It is observed that the risk increases in mountainous areas.

Table 12- Turkish Statistical Institute 2020 Plant Production Statistics

Provincial Name	*County Name*	*Product Name*	*Planted Area (da)*	*Number of Trees*	*Production (Tons)*	*Average Yield Per Tree (kg)*
Ankara	Evren	Almond	585	16000	560	35
Ankara	Akyurt	Almond	150	1550	47	30
Ankara	Polatlı	Almond	1.438	35800	1074	30
Ankara	Beypazarı	Almond	66	4188	105	25
Ankara	Sincan	Almond	200	1880	47	25
Ankara	Çankaya	Almond	3	925	23	25
Ankara	Çubuk	Almond	350	5595	140	25
Ankara	Etimesgut	Almond	8	200	4	20
Ankara	Güdül	Almond	70	4250	85	20
Ankara	Haymana	Almond	488	3200	65	20
Ankara	Kahramankazan	Almond	58	1959	39	20
Ankara	Kalecik	Almond	6003	16459	331	20
Ankara	Pursaklar	Almond	45	1300	25	19
Ankara	Ayaş	Almond	130	4400	79	18
Ankara	Nallıhan	Almond	330	6500	98	15
Ankara	Keçiören	Almond	2	70	1	14
Ankara	Şereflikoçhisar	Almond	600	11100	144	13
Ankara	Gölbaşı	Almond	955	18984	190	10
Ankara	Mamak	Almond	150	5874	47	8
Ankara	Altındağ	Almond	6	560	4	7
Ankara	Bala	Almond	1840	21275	106	5
Ankara	Elmadağ	Almond	590	15600	78	5
Ankara	Yenimahalle	Almond	42	1500	8	5
Total/Average			**14 109**	**179 169**	**3 300**	**18**

According to the Turkish Statistical Institute, almond maximum yield in Turkey is 70 kg, the average yield is 15 kg for 2020. When Table 12 and Figure 11 are interpreted together, it is considered that almond crops settle with less risk in mountainous areas. From the risk maps obtained as a result of the analysis made on the GIS, the areas where the crop can be grown are calculated in table 13.

Table 13- Crops area calculation

Product Name	***Low Risk Area (Da)***	***Medium Risk Area (Da)***	***High Risk Area (Da)***	***Total Areas (Da)***
Apricot	572 290	5 496 557	1 574 379	7 643 227
Sour Cherry	3 031 271	3 498 374	1 083 955	7 613 601
Almond	1 210 614	3 447 835	2 946 215	7 604 215

According to these results, all crops have a similar total growing area even if they have different risk factors. However, the sour cherry crop has more low-risk growing areas than the others, and the apricot crop has more medium risk growing areas, while the almond crop has few ‘low risk’ growing areas, with mostly 'moderate risk' and 'high risk' growing areas.

3. Conclusions

The fact that agriculture is indispensable not only for Turkey, but also for all the countries in the world during the pandemic, has made it necessary to continue with agriculture more consciously after scientific analysis. The study aims to develop a methodology to provide farmers with the highest profit from their fields with the lowest risk. As a result of entering the correct data, crop risk analysis can be performed with the developed method in this study, for millions of geographic points within a few minutes.

The risks that led to yield loss in fruit growing are pretty high. The probability of those risks remains seasonal and decreases and increases in severity as the plants grow, bloom, and bear fruits. In addition, the effect of each risk factor on yield/crop loss is different from each other. A model is developed to generate product-based risk analysis maps with the analytical hierarchy method, a multi-criteria decision-making method, risk matrix, and fault tree analysis over GIS, by considering the cumulative information specific to agriculture.

In this study, apricot, sour cherry, and almond farming in Ankara were chosen as a model. Risk maps were prepared separately for the climate, soil, topography, and irrigation factors. Total risk maps for apricot, sour cherry, and almond crops were created in general, with all the layers taken together. The reason for those ascertained risks can be easily accessed, retrospectively, with the fault tree analysis. Risk values of 3 different points chosen in Ankara, which were entered into the GIS model were compared, and the accuracy was confirmed with manual calculations. In this manner, this analysis can be performed for millions of points on the GIS, in the time allotted for manual risk analysis calculation for each point.

When the risk maps and sub-layers are examined in detail, it was determined that the apricot tree is more susceptible to soil and topography conditions and is highly affected by risk factors from soil and topography layers. Hence, it was concluded that the total risk factors for apricot can be mitigated with improvements that can be performed in terms of soil and topography. It was also determined that the almond crop is more susceptible to climatic conditions and is highly affected by the risk factors that arise from the climatic layers. Thus, finally it was concluded that the sour cherry crop is less affected by the climate, soil, and the topography risk layers as compared to apricot and almond, and it has a high yield with less risk in irrigated areas.

Considering the climate, soil, topography, and irrigation data throughout Turkey, this study can be implemented for all plant products with known ecological demands using this developed model. After the products have been examined, a methodology study can be conducted to find answers to the questions as to which crops can grow more riskily in various regions, and which of these risks are caused by climate, soil, topography, and irrigation resources, and finally what precautions can be taken against them.

In this study, it was concluded that with the risk analysis methodology developed on GIS, the sour cherry crop can be grown in Ankara with lesser risk as compared to the other products examined.

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