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OPTIMIZATION OF FERTILE LAND USAGE AND AGRICULTURAL PRODUCTION OF TURKEY

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OPTIMIZATION OF FERTILE LAND USAGE AND AGRICULTURAL PRODUCTION OF TURKEY

Abstract

Turkey has a large amount of land which is suitable for agriculture. On the other hand, agricultural activities gradually decrease every year. Moreover, the fertile lands are not used effectively. As a result, production of agricultural goods does not satisfy the domestic demand. Thus, Turkey is obliged to import lots of agricultural goods in the recent decade.

Turkey has to develop the agricultural potential and productivity and demand - supply stability as soon as possible. For this purpose, an optimization model has been developed to optimize the fertile land usage and agricultural production to satisfy the increasing agricultural demand of Turkey.

Residential settlements on fertile lands are another problem about the agricultural land usage of Turkey. The fertile lands are allowed for the construction of residential settlements and this causes the decrease of the fertile land area beside a lot of negative effects to the national economy and nature.

This study aims to find solutions to these problems with the help of an optimization model. Specifically, which parts of land has to be farmed, which products has to be cultivated, how much has to be cultivated, how much area has to be used for the cultivation of a specific product. Additionally, the model will yield the effect of loss of fertile land due to residential settlements on fertile lands.

Keywords: Agriculture, optimization, agricultural optimization, agricultural production, usage of fertile lands.

TÜRKİYE'NİN VERİMLİ TOPRAKLARININ KULLANIMININ VE TARIMSAL ÜRETİMİNİN OPTİMİZASYONU

Özet

Türkiye, tarım için uygun olan büyük bir araziye sahiptir fakat tarımsal faaliyetler yıldan yıla düşüş göstermektedir. Verimli araziler etkili bir şekilde kullanılmamakta ve azalmaktadır. Bunların sonucu olarak ve nüfus artışının da etkisi ile ülkedeki üretim miktarı iç talebi karşılayamaz hale gelmiş ve pek çok ürünün ithalatı söz konusu olmuştur.

Türkiye ivedilikle, tarımsal potansiyelini, üretkenliğini ve arz-talep dengelerini geliştirip, güçlendirmelidir. Bu amaçla bir optimizasyon modeli geliştirilmiştir. Model, verimli arazilerin kullanımını ve tarımsal üretimi optimize edip, üretim miktarını arttırarak, tarımsal talebin fazlasıyla karşılanmasını sağlamaya yardımcı olmaktadır.

Imara açılan verimli tarım toprakları ve hissedilen kuraklık ise ayrı bir tarımsal üretim sorunu olarak karşımıza çıkmaktadır. Bu durum hem verimli toprak alanlarının azalmasına neden olmakta hem de ulusal ekonomiye ve doğaya ciddi zarar vermektedir.

Bu çalışma, optimizasyon modeli ile tarımsal problemlere çözüm bulmayı amaçlamaktadır. özellikle hangi araziler ekilecek, hangi ürün ne kadar ekilecek, belirli bir ürün için ne kadar ekim alanı kullanılacak gibi problemlere model vasıtası ile çözüm aranacaktır.

Anahtar kelimeler: Tarım, optimizasyon, tarımsal optimizasyon, tarımsal üretim, verimli arazi kullanımı.

Acknowledgements

This study was supervised and mentored by respectable instructors of Industrial Engineering Department of Isık University.

To my dear family and friends…

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List of Abbreviations

LP	**L**inear **P**rogramming
DSS	**D**ecision **S**upport **S**ystem
vba	**V**isual **B**asic for **A**pplications
FAO	**F**ood and **A**griculture **O**rganization of the United Nations
TURKSTAT	**TURK**ish **STAT**istical Institute
IPAPSOM	**I**nterval- **P**robabilistic **A**gricultural **P**roduction **S**tructure **O**ptimization **M**odel

Chapter 1

Introduction

1.1 Brief History of Agriculture in Turkey

Agriculture in Turkey has been developed during from first years of the republic to nowadays. Agricultural production potential can still satisfy the domestic agricultural demand although the system has several impediments. The variety of agricultural products and their yields increase with the usage of technology. For instance; production of wheat increased 1574% and 2565% for cotton, 784% for sunflower and 8164% for potato (Dernek (2006) [1]). Similar increase rates are observed for livestock production. Moreover, with the mutual interactions, the industries which are dependent on the agriculture sector (such as food, leather, textile, machine and chemical) developed as well. The graphs of annual change in agricultural production are shown Figure (1.1).

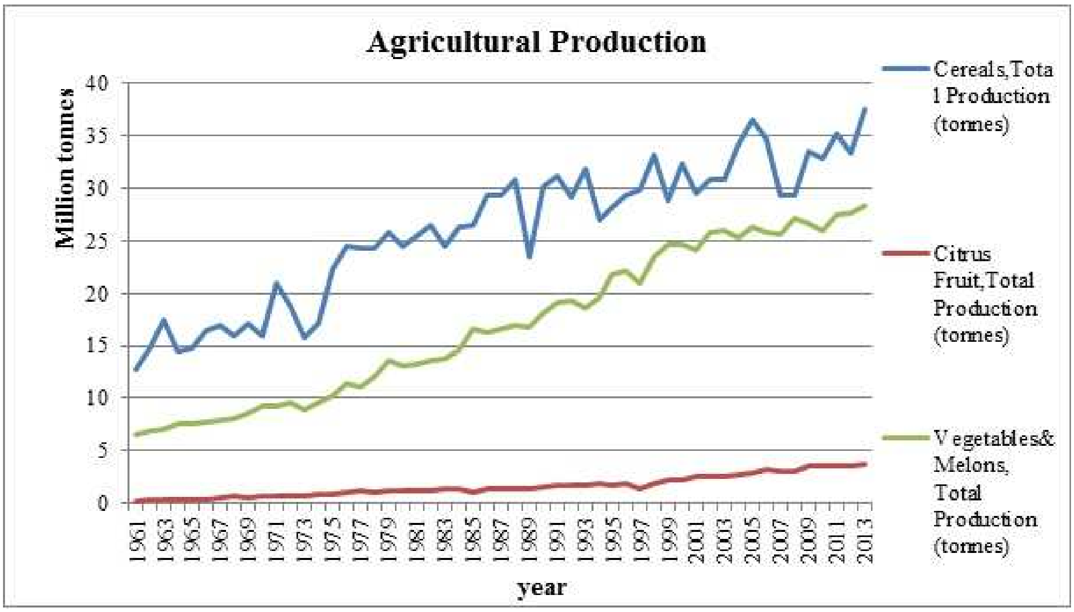

Figure 1.1: Annual change in agricultural production (FAO [2]).

However, these agricultural developments are not enough if it is compared to European Countries. Because of unrealized land reform, imbalanced land distribution, small-scale enterprisers which have poor yield, it was not possible to use advanced technology in agricultural production.

1.2 General Information

Turkey has a remarkable agricultural product range. Namely; rape, banana, kiwi, avocado, fig, orange, mandarin, lemon, grapefruit, bergamot, apple, pear, quince, loquat, medlar, nectarine, peach, plum, apricot, wild apricot, cherry, morello, cranberry, oleaster, jujube, strawberry, raspberry, blackberry, berry, pomegranate, persimmon, carob, bilberry, table olive, olive, almond, nut, walnut, chestnut, pistachio, tea, chili, aniseed, cumin, raziyane, coriander, nigella, thyme, ling, indoor ornamental plants, bulb, ornamental plants, scallion, onion, garlic, dried garlic, leek, carrot, swede, red beet, celery, turnip, radish, tomato, cucumber, gherkin, pepper, okra, eggplant, zucchini, pumpkin, peas, bean, pea, fava bean, cranberry bean, melon, watermelon, pepino, caulis, broccoli, cabbage, lettuce, artichoke, spinach, garden arch, purslane, tabooli, rocket, watercress, mint, dill, asparagus, mushroom, wheat, corn, rice plant, barley, rye, oat, millet, canary grass, triticale, sorghum, potato, broad bean, chickpea, horicot, red lentil, green lentil, vetch, greekclover, chickling, jeurselamartichoke, soya, peanut, sunflower, sesame, safflower, cole, cotton, hemp, hash, nicotina, white beet, viciasativa, clover, sainfoin seed, fodder beet, sage, lavender, melissa, stinger, rose, lupine, hop and etc. can be produced with fair yields in despite of not to use modern agricultural techniques effectively .

The graph of average yields (yields can change zone by zone) in 2014 of some products shown Figure (1.2)

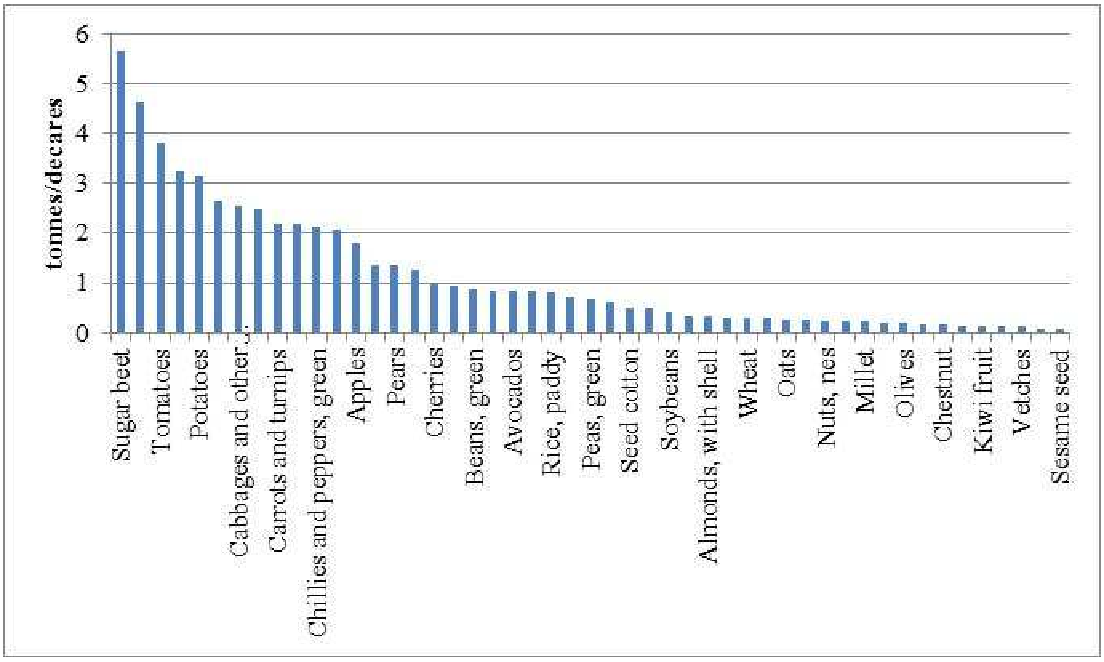

Figure 1.2: Yields of some products in 2014(FAO [3]).

Turkey besides its industrialization is an agricultural country and agricultural activities are performed in all of its regions. According to different geographical and land characteristics, 12 basic agricultural zones are identified. These zones are Mediterranean, Western Anatolia, Western Black sea, Western Marmara, Eastern Black sea, Eastern Marmara, Aegean, Southeastern Anatolia, Istanbul, Northeastern Anatolia, Central Anatolia, and Middle Eastern Anatolia. These zones

Figure 1.3: Agricultural regions of Turkey. (Wikipedia).

are predefined by TURKSTAT and also they are used as a set of regions in all optimization models.

The acreage of Turkey is 814,578,000 decares and there are 238,055,119 decares available fertile lands in 2013 according to TURKSTAT. In other words, nearly 30% of all lands are available for agricultural activities. The regional amounts of these lands shown in Figure (1.4)

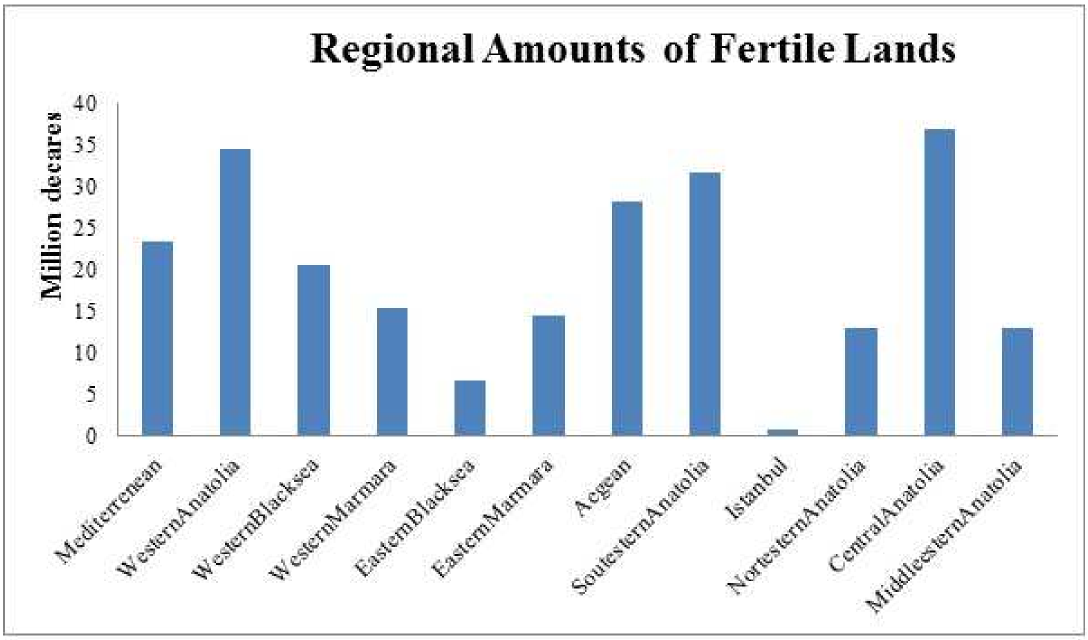

Figure 1.4: Amounts of fertile lands by regional in 2013 (TURKSTAT [4]).

The percentage distribution chart of fertile lands of regions (Figure (1.5)) gives more observable picture.

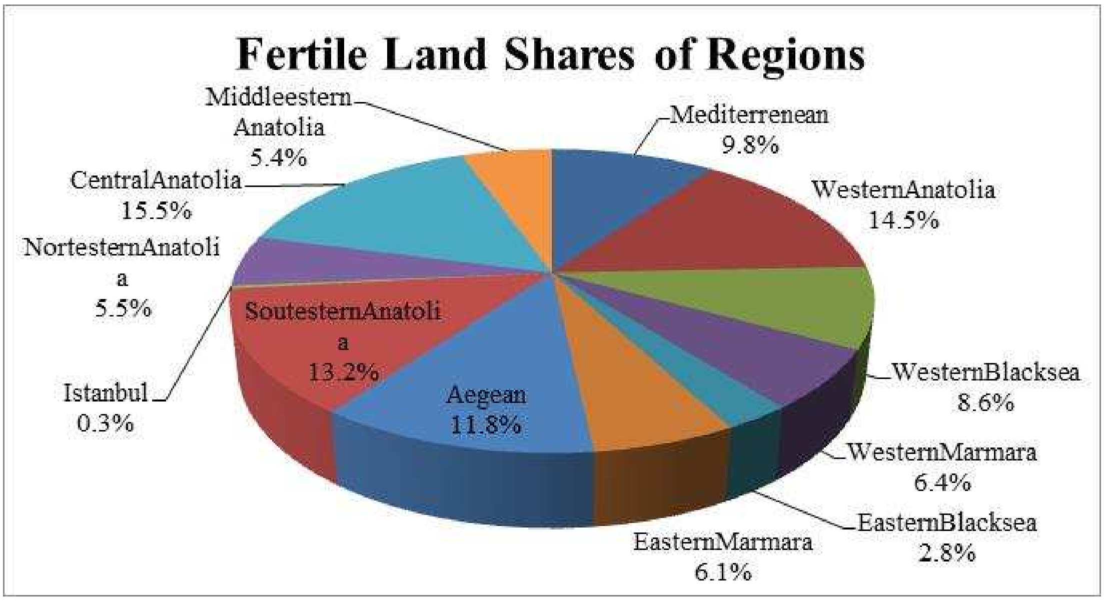

Figure 1.5: Percentage distribution of fertile lands in 2013 (TURKSTAT [4]).

Since zone characteristics are different, every product cannot be planted in every zone. Moreover, their yields can change zone by zone, so product range of every zone varies out of the amount of zone's fertile lands. The regions which have a large amount of fertile lands makes it possible to plant a few crops such as; Middleeastern Anatolia and Central Anatolia. Table (1.1) contains the amounts of fertile lands, the number of highest yield products and the number of non-growable products of each agricultural zone in 2013.

REGION	AMOUNT OF FERTILE LANDS (decares)	NUMBER OF HIGHEST YIELD PRODUCTS	NUMBER OF NON-GROWABLE PRODUCTS
Mediterrenean	23,385,270	31	13
WesternAnatolia	34,500,466	25	38
WesternBlacksea	20,506,420	10	37
WesternMarmara	15,262,906	10	29
EasternBlacksea	6,757,423	10	55
EasternMarmara	14,501,178	9	28
Aegean	28,094,540	11	14
SoutesternAnatolia	31,525,928	6	54
Istanbul	708,986	15	61
NortesternAnatolia	12,976,835	3	64
CentralAnatolia	36,864,042	3	58
MiddleesternAnatolia	12,971,127	3	55

Table 1.1: Product range of regions(TURKSTAT [4]).

Chapter 2

Problem Definition

Turkey has a growing population (Figure (2.1)), so the consumption of agricultural products increases every year, in spite of that the efficiency of agricultural activities are not improving as it expected to be. As a result, poor production performance does not satisfy increasing consumption. Moreover, agricultural import expenditures and export revenues prove this. The following graphs (Figures (2.2) and (2.3)) represent the import and export values of all cereals and the cereal that has the biggest share in all of them namely wheat. Moreover, the most important observation on these graphs the imports had increased for last 5 years.

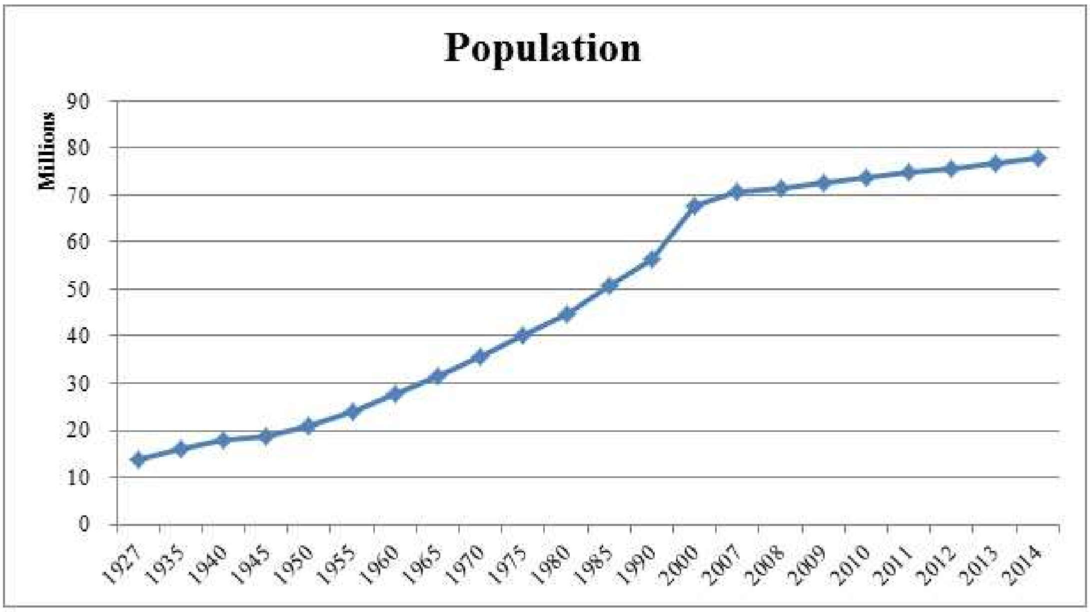

Figure 2.1: Population of Turkey(FAO [2]).

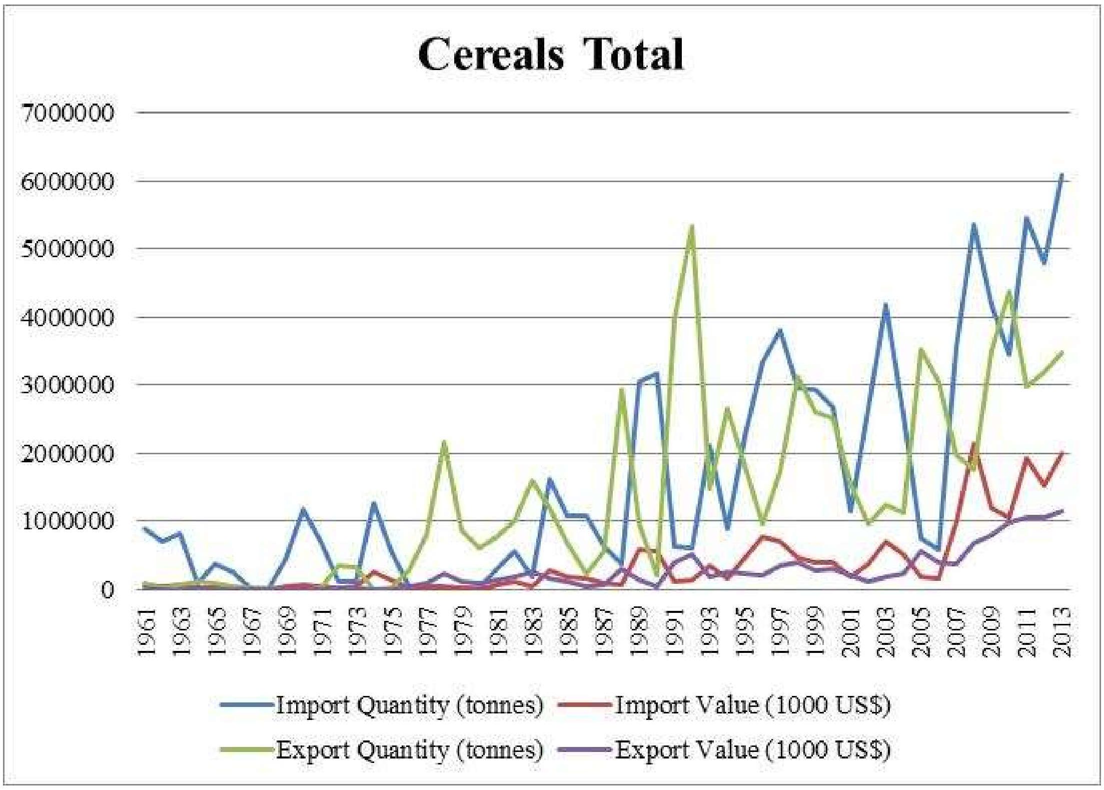

Figure 2.2: Annual Import and export data of total of cereals (FAO [2]).

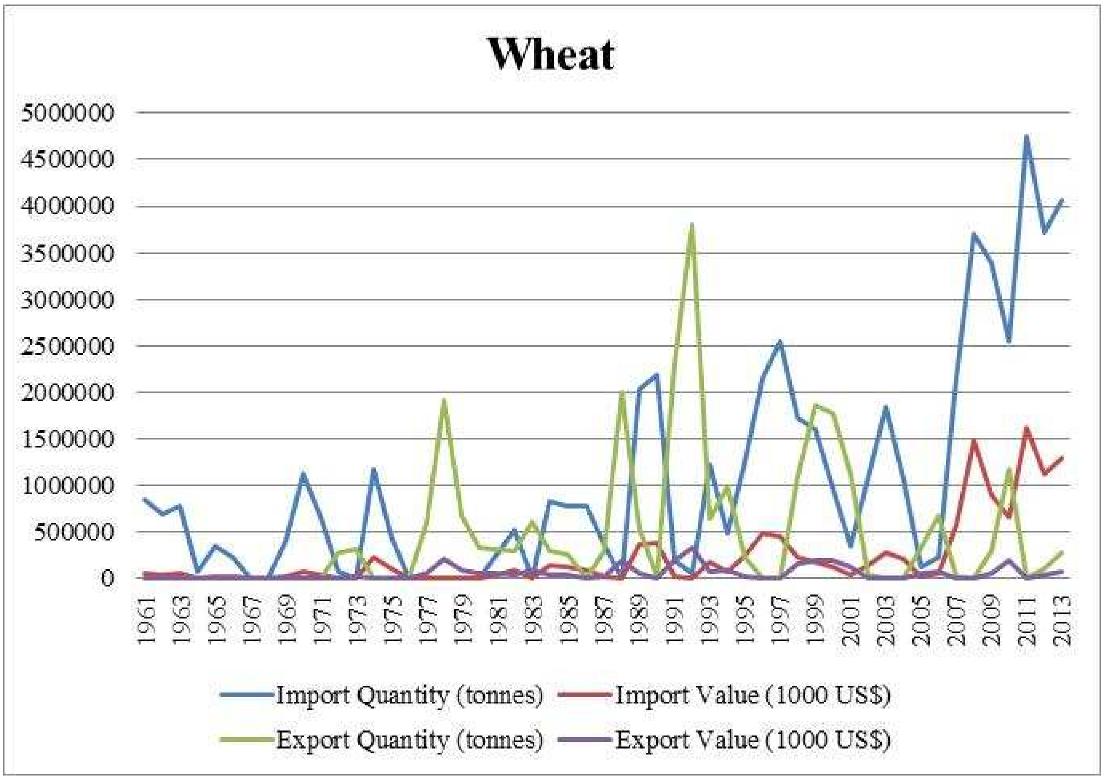

Figure 2.3: Annual Import and export data of wheat (FAO [2]).

Additionally, despite the fact that the necessity of food increases with growing population, the amount of fertile lands decreases every year. Natural disasters are one of the reasons of this such as, erosion, flood disaster, climate changes, and depleted clean water recourses. Furthermore, there are some agricultural disasters which arise from human-related reasons. For instance, hydroelectric power plants damage fertile lands and also a natural habitat for a long run. A residential settlement on fertile lands and wrong irrigation are the other reasons. Figure (2.4) shows the significant amount of lost fertile lands:

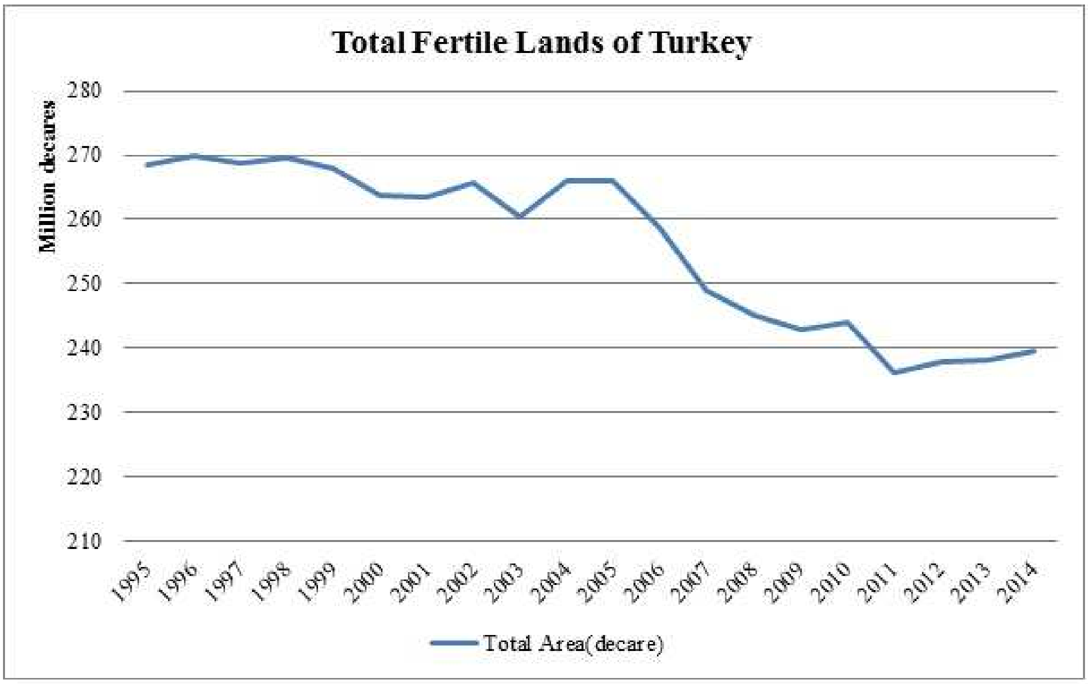

Figure 2.4: Annual change in fertile lands (TURKSTAT [4]).

Insufficient planning of Ministry of Agriculture causes the production surplus on some products or scarcity on some other products every year. As a result, some products are not harvested; they are left on cropland, vice versa some products are imported while they can be produced. We tried to solve insufficient central organization of agricultural production problem with the help of optimization models. These models will fix some agricultural problems but not all of them. Inefficient and unavailable stocking availabilities is another cause of not harvesting the crops.

	2013 Netherlands	2013 Turkey
Total Harvested Area (ha)	2,202,141.00	54,747,488.00
Import Value (1000 US$)	58,500,833.00	13,331,040.00
Export Value (1000 US$)	90,945,022.00	16,556,030.00
Total Population - Both sexes (1000)	16,809.16	76,223.64
Rural population (1000)	1,798.00	20,704.00
Urban population (1000)	14,961.12	54,229.07
Cereals,Total - Yield (Hg/Ha)	86,301.00	32,567.00
Coarse Grain, Total - Yield (Hg/Ha)	82,953.00	39,837.00
Fibre Crops Primary - Yield (Hg/Ha)	67,962.00	18,463.00
Fruit excl Melons,Total - Yield (Hg/Ha)	337,267.00	133,375.00
Oilcrops Primary - Yield (Hg/Ha)	8,327.00	6,324.00
Pulses,Total - Yield (Hg/Ha)	34,411.00	14,099.00
Roots and Tubers,Total - Yield (Hg/Ha)	422,075.00	314,435.00
Vegetables Primary - Yield (Hg/Ha)	571,499.00	253,045.00
Vegetables&Melons, Total - Yield (Hg/Ha)	571,499.00	253,045.00

Table 2.1: The agricultural comparison of Turkey and Netherlands(FAO [3]).

As is seen from Table (2.1), Turkey had had so bad agricultural profile compared to Netherlands. Turkey had harvested area nearly 25 times more than Netherlands, but agricultural export value of Netherlands had been nearly 6 times more than Turkey's agricultural export value. It is not true that this situation just depends on difference in populations of these two country. Yields of Netherlands are very higher than yields of Turkey. Of course it is not possible to solve the agricultural problems of Turkey by just comparing the parameters of these two countries. The models will just reorganize production with existing yields and other parameters and try to increase agricultural efficiency of Turkey.

Chapter 3

Literature Review

Agricultural production planning problem has been examined in operations research, agricultural economics and operation management literatures. For instance, Lu at al. (2013) [5] had been developed an optimization model called interval - probabilistic agricultural production structure optimization model (IPAPSOM). The IPAPSOM considers food security policies, increasing rural household's income, resource preservation, eco-environment conservation, risk of violating. Additionally, it works in multi-period planning horizon. It had been applied to a real case of long-term agricultural production structure optimization in Dancheng Country in Province of Central China. IPAPSOM contains multiple agricultural industry types and it has multiple objectives and multiple objective technologies. It has also complex, uncertain and dynamic characteristics. Even if IPAPSOM has more or less similar aims with our models but it holds different considerations and characteristics from ours'. Detailed information is given about our models in Chapter 4. The another interval - probabilistic programming study had been developed by Lu at al. (2015) [6]. It works under uncertainties like Lu at al. (2013) [5].

There is an implementation of farm planning in Model Building in Mathematical Programming (1999)[7] and it based on Swart at al. (1975)[8]. It is a multi-period model and considers to make maximum profit in five year. There are determined constant total farm lands and grain and sugar beets are grown on these farm lands to feed dairy cows. The aims of the model are to make decisions how much lands to use growing grain and sugar beets, how much grain and sugar beets to buy or to sell and how many heifers to sell in each year. Our models works for one single year and it is the most basic difference from this model. Moreover, it works for farm land in other words for a small share of land, our models work for all country.

Ahmet at al. (2015) [9] considers to develop quantity of agricultural production in a province of Pakistan called Punjab. They had worked a multi-objective optimization model which includes agriculture, forestry, animal husbandry and fishery sectors to maximize total income. The model consists ecological and environmental and industry relation constraints as well as resource and demand constraints. Haddad at al. (2012) [10] had been studied on another agricultural production optimization for Jordan Valley which specified financial risk of water.

A study (Heady at al. (1964) [11]) which consists a linear programming had aimed to determine regional production patterns for specified farm commoditions in the United States. It had worked on 122 agricultural regions and tried to determine which field in these regions that crops be produced and to find out total acreage required to produce crops basically. Moreover an early study (Heady at al. (1959) [12]) of reginal programming in United States exists to have same basic aims with Heady at al. (1964) [11]. Furthermore, a multi-period mixed integer programming model had been created Glen (1996) [13] for development of livestock specialized deer farming in the UK.

Chapter 4

The Optimization Models

4.1 Model 1: LP Approach 1

The first model organizes cultivable lands in all regions in Turkey such that which agricultural product has to be produced, of what amount of area, in which region so that the production amounts of products would be increased and high level of domestic and export demands could be satisfied. Furthermore, the model decreases import amounts of products. Details of the model are given following parts:

4.1.1 Sets of model 1:

I: set of products.

J: set of regions be appropriate for agricultural production.

4.1.2 Parameters of model 1:

p_i: Unit domestic price of product i (\$/ton)

e_i: Unit export price of product i (\$/ton)

d_i: Domestic demand of product i for the specific year (ton)

o_i: Export demand of product i for the specific year (ton)

c_i: Unit cost of unsold product i (\$/ton)

K_j: Amount of fertile land in region j (decare)

r_j: Opportunity cost of unused fertile agricultural area in region j (\$/decare)

$cost_{ij}$: Unit cost of planting product i in region j (\$/decare)

v_{ij}: Productivity level of product i in region j (ton/decare)

$impCost_i$: Unit cost of imported product i (\$/ton)

oh_i: On hand inventory of product i (ton)

4.1.3 Decision variables of model 1:

x_i: Amount of production of product i for domestic consumption for the specific year (ton)

y_i: Amount of production to export of product i for the specific year (ton)

ka_{ij}: Amount of needed area in region j to produce product i (decare)

T_i: Total amount of production of product i for the specific year (ton)

$import_i$: Amount of import of product i for the specific year (ton)

$impx_i$: Amount of imported product i which is consumed in domestic market (ton)

$impy_i$: Amount of imported product i which for export (ton)

ohx_i: Amount of on-hand inventory product i which is consumed in domestic market (ton)

ohy_i: Amount of on-hand inventory of product i to export (ton)

4.1.4 Model 1:

$$
\begin{aligned}
\max_{profit} \quad & \textstyle\sum_{\forall i \in I}(p_i * (x_i + impx_i + ohx_i)) \\
& + \textstyle\sum_{\forall i \in I}(e_i * (y_i + impy_i + ohy_i)) \\
& - \textstyle\sum_{\forall i \in I}[c_i * (T_i - x_i - y_i)] \\
& - \textstyle\sum_{\forall i \in I}\sum_{\forall j \in J}(cost_{ij} * ka_{ij}) \\
& - \textstyle\sum_{\forall j \in J}[r_j * (K_j - \sum_{\forall i \in I} ka_{ij})] \\
& - \textstyle\sum_{\forall i \in I}(impCost_i * import_i)
\end{aligned}
$$

$$
\begin{array}{lrcll}
\text{s.t.} & x_i + y_i & \leq & T_i & \forall i \in I \\
& x_i + impx_i + ohx_i & = & d_i & \forall i \in I \\
& y_i + impy_i + ohy_i & \leq & o_i & \forall i \in I \\
& ohx_i + ohy_i & = & oh_i & \forall i \in I \\
& impx_i + impy_i & = & import_i & \forall i \in I \\
& \sum_{\forall j \in J}(v_{ij} * ka_{ij}) & = & T_i & \forall i \in I \\
& \sum_{\forall i \in I} ka_{ij} & \leq & K_j & \forall j \in J \\
& x_i, y_i & \geq & 0 & \forall i \in I \\
& import_i, impx_i, impy_i & \geq & 0 & \forall i \in I \\
& ohx_i, ohy_i & \geq & 0 & \forall i \in I \\
& ka_{ij} & \geq & 0 & \forall i \in I, \forall j \in J
\end{array} \tag{4.1}
$$

4.1.5 Description of model 1:

4.1.5.1 Objective function of model 1:

The revenue according to domestic consumption:

$$\sum_{\forall i \in I}(p_i * (x_i + impx_i + ohx_i)) \tag{4.2}$$

The domestic market demand is satisfied by the sum of domestic production, import and on hand inventory usage for domestic consumption. The sum of the product of price and the domestic consumption gives us the revenue.

The revenue of export:

$$\sum_{\forall i \in I} (e_i * (y_i + impy_i + ohy_i)) \tag{4.3}$$

Overseas demand is satisfied likewise domestic market demand.

Unsold cost:

$$\sum_{\forall i \in I} [c_i * (T_i - x_i - y_i)] \tag{4.4}$$

For a product, if the sum of production for domestic consumption and production for export is not equal to (lower than) total production, there are the unconsumed amount of that product. Additionally, unsold costs of products were defined as parameter according to these unconsumed products. If a product is perishable like tabooli, its unsold cost is equal production cost; otherwise, (like wheat) unsold cost is equal holding cost.

Production cost:

$$\sum_{\forall i \in I} \sum_{\forall j \in J} (cost_{ij} * ka_{ij}) \tag{4.5}$$

There is a unit production cost to produce a product on a region and a decision variable which is the amount of land used to produce a product. The sum product of this two gives total production cost.

Opportunity cost:

$$\sum_{\forall j \in J} [r_j * (K_j - \sum_{\forall i \in I} ka_{ij})] \tag{4.6}$$

The unused fertile lands cause economic loss. In other words, some products can be planted on uncropped lands and earned income. So, the unit opportunity cost was determined for each region as the average price of all appropriate products which can be planted a region. The sum product of uncropped area and unit opportunity cost gives total opportunity cost.

Import Cost:

$$\sum_{\forall i \in I} (impCost_i * import_i) \tag{4.7}$$

The sum product of unit import cost and amount of import of each products gives total import cost.

4.1.5.2 Constraints of model 1:

$$x_i + y_i \leq T_i \quad \forall i \in I \tag{4.8}$$

The sum of domestic and export sales of a product which was produced domestically must be lower than the total amount of domestic production (equation 4.8).

$$x_i + impx_i + ohx_i = d_i \quad \forall i \in I \tag{4.9}$$

There are three ways to satisfy the domestic demand as follows, domestic production, import, and stocks. Domestic demand has to be satisfied (equation 4.9).

$$y_i + impy_i + ohy_i \leq o_i \quad \forall i \in I \tag{4.10}$$

Likewise domestic demand, there are also three ways to satisfy the overseas demand. Note that, the imported products can be exported. Overseas demand has not to be satisfied completely (equation 4.10).

$$ohx_i + ohy_i = oh_i \quad \forall i \in I \tag{4.11}$$

Products in inventory can be consumed in the domestic market or exported. However, they must be exactly consumed (equation 4.11).

$$impx_i + impy_i = import_i \quad \forall i \in I \tag{4.12}$$

Imported products can be consumed in the domestic market or exported. The amount of import a product is as needed (equation 4.12).

$$\sum_{\forall j \in J} (v_{ij} * ka_{ij}) = T_i \quad \forall i \in I \tag{4.13}$$

Each area has a measured productivity for each product. So, the sum of product of productivity and amount of area is equal to total amount of production (equation 4.13).

$$\sum_{\forall i \in I} ka_{ij} \leq K_j = T_i \quad \forall j \in J \tag{4.14}$$

The amount of fertile lands of each area was measured. The sum of used area for production can not to be higher than the amount of fertile lands (equation 4.14).

$$x_i, y_i, ka_{ij}, import_i, impx_i, impy_i, ohx_i, ohy_i \geq 0 \quad \forall i \in I, \forall j \in J \tag{4.15}$$

All variables must be positive (equation 4.15).

4.2 Model 2: LP Approach 2

Agricultural cultivable lands can be organized by the first model but there is an important handicap of it. The assumption of the first model was that every product can be cultivated on every part of regions according to their yields. However, the farmers have divided their lands to several portions to produce several products and it makes no sense to produce cereals on orchards at the cost of cutting fruit trees. So product groups (cereals, fruits, vegetables and ornament plants) were defined and upper limits of these were added in the model. Moreover, there are uncultivated lands (fallowed areas) in every region so these lands might be considered. Thus, the model could reflect real life better.

4.2.1 Sets of model 2:

I: set of products.

J: set of regions be appropriate for agricultural production.

M: set of product groups.

4.2.2 Parameters of model 2:

p_i: Unit domestic price of product i ($/ton)

e_i: Unit export price of product i ($/ton)

d_i: Domestic demand of product i for the specific year (ton)

o_i: Export demand of product i for the specific year (ton)

c_i: Unit cost of unsold product i ($/ton)

K_j: Amount of fertile land in region j (decare)

r_j: Opportunity cost of unused fertile agricultural area in region j ($/decare)

$cost_{ij}$: Unit cost of planting product i in region j ($/decare)

v_{ij}: Productivity level of product i in region j (ton/decare)

$impCost_i$: Unit cost of imported product i ($/ton)

oh_i: On hand inventory of product i (ton)

b_{mj}: Usable amount of area j to produce product group m

4.2.3 Decision variables of model 2:

x_i: Amount of production of product i for domestic consumption for the specific year (ton)

y_i: Amount of production to export of product i for the specific year (ton)

ka_{ij}: Amount of needed area in region j to produce product i (decare)

T_i: Total amount of production of product i for the specific year (ton)

$import_i$: Amount of import of product i for the specific year (ton)

$impx_i$: Amount of imported product i which is consumed in domestic market (ton)

$impy_i$: Amount of imported product i which for export (ton)

ohx_i: Amount of on-hand inventory product i which is consumed in domestic market (ton)

ohy_i: Amount of on-hand inventory of product i to export (ton)

4.2.4 Model 2:

$$
\begin{aligned}
\max_{profit} \quad & \textstyle\sum_{\forall i \in I}(p_i * (x_i + impx_i + ohx_i)) \\
& + \textstyle\sum_{\forall i \in I}(e_i * (y_i + impy_i + ohy_i)) \\
& - \textstyle\sum_{\forall i \in I}[c_i * (T_i - x_i - y_i)] \\
& - \textstyle\sum_{\forall i \in I}\sum_{\forall j \in J}(cost_{ij} * ka_{ij}) \\
& - \textstyle\sum_{\forall j \in J}[r_j * (K_j - \sum_{\forall i \in I} ka_{ij})] \\
& - \textstyle\sum_{\forall i \in I}(impCost_i * import_i)
\end{aligned}
$$

$$
\begin{array}{lrcll}
\text{s.t.} & x_i + y_i & \leq & T_i & \forall i \in I \\
& x_i + impx_i + ohx_i & = & d_i & \forall i \in I \\
& y_i + impy_i + ohy_i & \leq & o_i & \forall i \in I \\
& ohx_i + ohy_i & = & oh_i & \forall i \in I \\
& impx_i + impy_i & = & import_i & \forall i \in I \\
& \sum_{\forall j \in J}(v_{ij} * ka_{ij}) & = & T_i & \forall i \in I \\
& \sum_{\forall i \in I} ka_{ij} & \leq & K_j - b_{FallowArea,j} & \forall j \in J \\
& \sum_{i \in m = Cereals} ka_{ij} & \leq & b_{Cereals,j} & \forall j \in J \\
& \sum_{i \in m = Vegetables} ka_{ij} & \leq & b_{Vegetables,j} & \forall j \in J \\
& \sum_{i \in m = Fruits} ka_{ij} & \leq & b_{Fruits,j} & \forall j \in J \\
& \sum_{i \in m = OrnamentPlants} ka_{ij} & \leq & b_{OrnamentPlants,j} & \forall j \in J \\
& x_i, y_i & \geq & 0 & \forall i \in I \\
& import_i, impx_i, impy_i & \geq & 0 & \forall i \in I \\
& ohx_i, ohy_i & \geq & 0 & \forall i \in I \\
& ka_{ij} & \geq & 0 & \forall i \in I, \forall j \in J
\end{array}
\tag{4.16}
$$

4.2.5 Description of model 2:

4.2.5.1 Objective function of model 2:

The revenue according to domestic consumption:

$$\sum_{\forall i \in I} (p_i * (x_i + impx_i + ohx_i)) \tag{4.17}$$

The domestic market demand is satisfied by the sum of domestic production, import and on hand inventory usage for domestic consumption. The sum of the product of price and the domestic consumption gives us the revenue.

The revenue of export:

$$\sum_{\forall i \in I} (e_i * (y_i + impy_i + ohy_i)) \tag{4.18}$$

Overseas demand is satisfied likewise domestic market demand.

Unsold cost:

$$\sum_{\forall i \in I} [c_i * (T_i - x_i - y_i)] \tag{4.19}$$

For a product, if the sum of production for domestic consumption and production for export is not equal to (lower than) total production, there are the unconsumed amount of that product. Additionally, unsold cost of a product is defined as a parameter according to these unconsumed products. If a product is perishable like tabooli, its unsold cost is equal production cost; otherwise, (like wheat) unsold cost is equal holding cost.

Production cost:

$$\sum_{\forall i \in I} \sum_{\forall j \in J} (cost_{ij} * ka_{ij}) \tag{4.20}$$

There is a unit production cost to produce a product on a region and a decision variable which is the amount of land used to produce a product. The sum product of this two gives total production cost.

Opportunity cost:

$$\sum_{\forall j \in J} [r_j * (K_j - \sum_{\forall i \in I} ka_{ij})] \tag{4.21}$$

The unused fertile lands cause economic loss. In other words, some products can be planted on uncropped lands and earned income. So, the unit opportunity cost was determined for each region as the average price of all appropriate products which can be planted a region. The sum product of uncropped area and unit opportunity cost gives total opportunity cost.

Import Cost:

$$\sum_{\forall i \in I} (impCost_i * import_i) \tag{4.22}$$

The sum product of unit import cost and amount of import of each item gives total import cost.

4.2.5.2 Constraints of model 2:

$$x_i + y_i \leq T_i \quad \forall i \in I \tag{4.23}$$

The sum of domestic and export sales of a product which was produced domestically must be lower than the total amount of domestic production (equation 4.23).

$$x_i + impx_i + ohx_i = d_i \quad \forall i \in I \tag{4.24}$$

There are three ways to satisfy the domestic demand as follows, domestic production, import, and stocks. Domestic demand has to be satisfied (equation 4.24).

$$y_i + impy_i + ohy_i \leq o_i \quad \forall i \in I \tag{4.25}$$

Likewise domestic demand, there are also three ways to satisfy the overseas demand. Note that, the imported products can be exported. Overseas demand has not to be satisfied completely (equation 4.25).

$$ohx_i + ohy_i = oh_i \quad \forall i \in I \tag{4.26}$$

Products in inventory can be consumed in the domestic market or exported. However, they must be exactly consumed (equation 4.26).

$$impx_i + impy_i = import_i \quad \forall i \in I \tag{4.27}$$

Imported products can be consumed in the domestic market or exported. The amount of import a product is as needed (equation 4.27).

$$\sum_{\forall j \in J} (v_{ij} * ka_{ij}) = T_i \quad \forall i \in I \tag{4.28}$$

Each area has a measured productivity for each product. So, the sum product of productivity and amount of area is equal to total amount of production (equation 4.28).

$$
\begin{aligned}
\sum_{\forall i \in I} ka_{ij} &\leq K_j - b_{FallowArea,j} && \forall j \in J \\
\sum_{i \in m=Cereals} ka_{ij} &\leq b_{Cereals,j} && \forall j \in J \\
\sum_{i \in m=Vegetables} ka_{ij} &\leq b_{Vegetables,j} && \forall j \in J \\
\sum_{i \in m=Fruits} ka_{ij} &\leq b_{Fruits,j} && \forall j \in J \\
\sum_{i \in m=OrnamentPlants} ka_{ij} &\leq b_{OrnamentPlants,j} && \forall j \in J
\end{aligned}
\tag{4.29}
$$

The amount of fertile lands of each area was measured and these areas are separated according to the plantation of product groups. The sum of used area for production of all products can not to be higher than the amount of fertile lands in a region and followed areas cannot be used. Moreover, there are upper bounds of land which can be used for the production of all product groups for each region (equation 4.29).

$$
x_i, y_i, ka_{ij}, import_i, impx_i, impy_i, ohx_i, ohy_i \geq 0 \quad \forall i \in I, \forall j \in J \tag{4.30}
$$

All variables must be positive (equation 4.30).

4.3 Model 3: LP Approach 3

The second model can reflect a real life well but there is another handicap occurred. Uncultivated lands or fallowed areas caused a big economic problem (More details will be given following parts). Fallowed areas occur when a rest necessity of some parts of cultivated lands. In other words, when the same product is cultivated on a land to consecutive years, its yield can reduce. On the other hand, some other products can be cultivated on this land next year. The third model defines the products that can be cultivated in this land next year according to their yields. Thus fallowed areas were used in the third model.

4.3.1 Sets of model 3:

I: set of products.

J: set of regions be appropriate for agricultural production.

M: set of product groups.

4.3.2 Parameters of model 3:

p_i: Unit domestic price of product i ($/ton)

e_i: Unit export price of product i ($/ton)

d_i: Domestic demand of product i for the specific year (ton)

o_i: Export demand of product i for the specific year (ton)

c_i: Unit cost of unsold product i ($/ton)

K_j: Amount of fertile land in region j (decare)

r_j: Opportunity cost of unused fertile agricultural area in region j ($/decare)

$cost_{ij}$: Unit cost of planting product i in region j ($/decare)

v_{ij}: Productivity level of product i in region j (ton/decare)

$impCost_i$: Unit cost of imported product i ($/ton)

oh_i: On hand inventory of product i (ton)

b_{mj}: Usable amount of area j to produce product group m

4.3.3 Decision variables of model 3:

x_i: Amount of production of product i for domestic consumption for the specific year (ton)

y_i: Amount of production to export of product i for the specific year (ton)

ka_{ij}: Amount of needed area in region j to produce product i (decare)

T_i: Total amount of production of product i for the specific year (ton)

$import_i$: Amount of import of product i for the specific year (ton)

$impx_i$: Amount of imported product i which is consumed in domestic market (ton)

$impy_i$: Amount of imported product i which for export (ton)

ohx_i: Amount of on-hand inventory product i which is consumed in domestic market (ton)

ohy_i: Amount of on-hand inventory of product i to export (ton)

4.3.4 Model 3:

$$
\begin{aligned}
\max_{profit} \quad & \textstyle\sum_{\forall i \in I}(p_i * (x_i + impx_i + ohx_i)) \\
& + \textstyle\sum_{\forall i \in I}(e_i * (y_i + impy_i + ohy_i)) \\
& - \textstyle\sum_{\forall i \in I}[c_i * (T_i - x_i - y_i)] \\
& - \textstyle\sum_{\forall i \in I}\sum_{\forall j \in J}(cost_{ij} * ka_{ij}) \\
& - \textstyle\sum_{\forall j \in J}[r_j * (K_j - \sum_{\forall i \in I} ka_{ij})] \\
& - \textstyle\sum_{\forall i \in I}(impCost_i * import_i)
\end{aligned}
$$

$$
\begin{array}{lrcll}
\text{s.t.} & x_i + y_i & \leq & T_i & \forall i \in I \\
& x_i + impx_i + ohx_i & = & d_i & \forall i \in I \\
& y_i + impy_i + ohy_i & \leq & o_i & \forall i \in I \\
& ohx_i + ohy_i & = & oh_i & \forall i \in I \\
& impx_i + impy_i & = & import_i & \forall i \in I \\
& \sum_{\forall j \in J}(v_{ij} * ka_{ij}) & = & T_i & \forall i \in I \\
& \sum_{\forall i \in I} ka_{ij} & \leq & K_j & \forall j \in J \\
& \sum_{i \in m = Cereals} ka_{ij} & \leq & b_{Cereals,j} + b_{FallowArea,j} & \forall j \in J \\
& \sum_{i \in m = Vegetables} ka_{ij} & \leq & b_{Vegetables,j} + b_{FallowArea,j} & \forall j \in J \\
& \sum_{i \in m = Fruits} ka_{ij} & \leq & b_{Fruits,j} + b_{FallowArea,j} & \forall j \in J \\
& \sum_{i \in m = OrnamentPlants} ka_{ij} & \leq & b_{OrnamentPlants,j} + b_{FallowArea,j} & \forall j \in J \\
& x_i, y_i & \geq & 0 & \forall i \in I \\
& import_i, impx_i, impy_i & \geq & 0 & \forall i \in I \\
& ohx_i, ohy_i & \geq & 0 & \forall i \in I \\
& ka_{ij} & \geq & 0 & \forall i \in I, \forall j \in J
\end{array} \tag{4.31}
$$

4.3.5 Description of model 3:

4.3.5.1 Objective function of model 3:

The revenue according to domestic consumption:

$$\sum_{\forall i \in I} (p_i * (x_i + impx_i + ohx_i)) \tag{4.32}$$

The domestic market demand is satisfied by the sum of domestic production, import and on hand inventory usage for domestic consumption. The sum of the product of price and the domestic consumption gives us the revenue.

The revenue of export:

$$\sum_{\forall i \in I} (e_i * (y_i + impy_i + ohy_i)) \tag{4.33}$$

Overseas demand is satisfied likewise domestic market demand.

Unsold cost:

$$\sum_{\forall i \in I} [c_i * (T_i - x_i - y_i)] \tag{4.34}$$

For a product, if the sum of production for domestic consumption and production for export is not equal to (lower than) total production, there are the unconsumed amount of that product. Additionally, unsold cost of a product is defined as a parameter according to these unconsumed products. If a product is perishable like tabooli, its unsold cost is equal production cost; otherwise, (like wheat) unsold cost is equal holding cost.

Production cost:

$$\sum_{\forall i \in I} \sum_{\forall j \in J} (cost_{ij} * ka_{ij}) \tag{4.35}$$

There is a unit production cost to produce a product on a region and a decision variable which is the amount of land used to produce a product. The sum product of this two gives total production cost.

Opportunity cost:

$$\sum_{\forall j \in J} [r_j * (K_j - \sum_{\forall i \in I} ka_{ij})] \tag{4.36}$$

The unused fertile lands cause economic loss. In other words, some products can be planted on uncropped lands and earned income. So, the unit opportunity cost was determined for each region as the average price of all appropriate products which can be planted a region. The sum product of uncropped area and unit opportunity cost gives total opportunity cost.

Import Cost:

$$\sum_{\forall i \in I} (impCost_i * import_i) \tag{4.37}$$

The sum product of unit import cost and amount of import of each item gives total import cost.

4.3.5.2 Constraints of model 3:

$$x_i + y_i \leq T_i \quad \forall i \in I \tag{4.38}$$

The sum of domestic and export sales of a product which was produced domestically must be lower than the total amount of domestic production (equation 4.38).

$$x_i + impx_i + ohx_i = d_i \quad \forall i \in I \tag{4.39}$$

There are three ways to satisfy the domestic demand as follows, domestic production, import, and stocks. Domestic demand has to be satisfied (equation 4.39).

$$y_i + impy_i + ohy_i \leq o_i \quad \forall i \in I \tag{4.40}$$

Likewise domestic demand, there are also three ways to satisfy the overseas demand. Note that, the imported products can be exported. Overseas demand has not to be satisfied completely (equation 4.40).

$$ohx_i + ohy_i = oh_i \quad \forall i \in I \tag{4.41}$$

Products in inventory can be consumed in the domestic market or exported. However, they must be exactly consumed (equation 4.41).

$$impx_i + impy_i = import_i \quad \forall i \in I \tag{4.42}$$

Imported products can be consumed in the domestic market or exported. The amount of import a product is as needed (equation 4.42).

$$\sum_{\forall j \in J} (v_{ij} * ka_{ij}) = T_i \quad \forall i \in I \tag{4.43}$$

Each area has a measured productivity for each product. So, the sum product of productivity and amount of area is equal to total amount of production (equation 4.43).

$$\begin{aligned}
\sum_{\forall i \in I} ka_{ij} &\leq K_j && \forall j \in J \\
\sum_{i \in m=Cereals} ka_{ij} &\leq b_{Cereals,j} + b_{FallowArea,j} && \forall j \in J \\
\sum_{i \in m=Vegetables} ka_{ij} &\leq b_{Vegetables,j} + b_{FallowArea,j} && \forall j \in J \qquad (4.44)\\
\sum_{i \in m=Fruits} ka_{ij} &\leq b_{Fruits,j} + b_{FallowArea,j} && \forall j \in J \\
\sum_{i \in m=OrnamentPlants} ka_{ij} &\leq b_{OrnamentPlants,j} + b_{FallowArea,j} && \forall j \in J
\end{aligned}$$

The amount of fertile lands of each area was measured also these areas are separated according to the plantation of product groups. The sum of used area for production of all products can not to be higher than the amount of fertile lands in a region. Moreover, there are upper bounds of land which can be used for the production of all product groups for each region. When it is necessary, fallowed areas can be used for the production of any product in each region. The yields of products are determinative for usages of fallowed areas (equation 4.44).

$$x_i, y_i, ka_{ij}, import_i, impx_i, impy_i, ohx_i, ohy_i \geq 0 \quad \forall i \in I, \forall j \in J \qquad (4.45)$$

All variables must be positive (equation 4.45).

4.4 Model 4: LP Approach 4

An additional constraint was added in the fourth model to protect fruit orchards. Previously designed models it was possible to crop products which were used to crop by other product groups on fruit orchards instead of fruits. So lower bounds of fruit orchards areas were added.

4.4.1 Sets of model 4:

I: set of products.

J: set of regions be appropriate for agricultural production.

M: set of product groups.

4.4.2 Parameters of model 4:

p_i: Unit domestic price of product i ($/ton)

e_i: Unit export price of product i ($/ton)

d_i: Domestic demand of product i for the specific year (ton)

o_i: Export demand of product i for the specific year (ton)

c_i: Unit cost of unsold product i ($/ton)

K_j: Amount of fertile land in region j (decare)

r_j: Opportunity cost of unused fertile agricultural area in region j ($/decare)

$cost_{ij}$: Unit cost of planting product i in region j ($/decare)

v_{ij}: Productivity level of product i in region j (ton/decare)

$impCost_i$: Unit cost of imported product i ($/ton)

oh_i: On hand inventory of product i (ton)

b_{mj}: Usable amount of area j to produce product group m

LB_{ij}: Lower bound of area in region j to produce product i

4.4.3 Decision variables of model 4:

x_i: Amount of production of product i for domestic consumption for the specific year (ton)

y_i: Amount of production to export of product i for the specific year (ton)

ka_{ij}: Amount of needed area in region j to produce product i (decare)

T_i: Total amount of production of product i for the specific year (ton)

$import_i$: Amount of import of product i for the specific year (ton)

$impx_i$: Amount of imported product i which is consumed in domestic market (ton)

$impy_i$: Amount of imported product i which for export (ton)

ohx_i: Amount of on-hand inventory product i which is consumed in domestic market (ton)

ohy_i: Amount of on-hand inventory of product i to export (ton)

4.4.4 Model 4:

$$
\begin{aligned}
\max_{profit} \quad & \textstyle\sum_{\forall i \in I}(p_i * (x_i + impx_i + ohx_i)) \\
& + \textstyle\sum_{\forall i \in I}(e_i * (y_i + impy_i + ohy_i)) \\
& - \textstyle\sum_{\forall i \in I}[c_i * (T_i - x_i - y_i)] \\
& - \textstyle\sum_{\forall i \in I}\sum_{\forall j \in J}(cost_{ij} * ka_{ij}) \\
& - \textstyle\sum_{\forall j \in J}[r_j * (K_j - \sum_{\forall i \in I} ka_{ij})] \\
& - \textstyle\sum_{\forall i \in I}(impCost_i * import_i)
\end{aligned}
$$

$$
\begin{aligned}
\text{s.t.} \quad x_i + y_i &\leq T_i && \forall i \in I \\
x_i + impx_i + ohx_i &= d_i && \forall i \in I \\
y_i + impy_i + ohy_i &\leq o_i && \forall i \in I \\
ohx_i + ohy_i &= oh_i && \forall i \in I \\
impx_i + impy_i &= import_i && \forall i \in I \\
\sum_{\forall j \in J}(v_{ij} * ka_{ij}) &= T_i && \forall i \in I \\
\sum_{\forall i \in I} ka_{ij} &\leq K_j && \forall j \in J \\
ka_{ij} &\geq LB_{ij} && \forall i \in I, \forall j \in J \\
\sum_{i \in m = Cereals} ka_{ij} &\leq b_{Cereals,j} + b_{FallowArea,j} && \forall j \in J \\
\sum_{i \in m = Vegetables} ka_{ij} &\leq b_{Vegetables,j} + b_{FallowArea,j} && \forall j \in J \\
\sum_{i \in m = Fruits} ka_{ij} &\leq b_{Fruits,j} + b_{FallowArea,j} && \forall j \in J \\
\sum_{i \in m = OrnamentPlants} ka_{ij} &\leq b_{OrnamentPlants,j} + b_{FallowArea,j} && \forall j \in J \\
x_i, y_i &\geq 0 && \forall i \in I \\
import_i, impx_i, impy_i &\geq 0 && \forall i \in I \\
ohx_i, ohy_i &\geq 0 && \forall i \in I \\
ka_{ij} &\geq 0 && \forall i \in I, \forall j \in J
\end{aligned}
\tag{4.46}
$$

4.4.5 Description of model 4:

4.4.5.1 Objective function of model 4:

The revenue according to domestic consumption:

$$\sum_{\forall i \in I}(p_i * (x_i + impx_i + ohx_i)) \tag{4.47}$$

The domestic market demand is satisfied by the sum of domestic production, import and on hand inventory usage for domestic consumption. The sum of the product of price and the domestic consumption gives us the revenue.

The revenue of export:

$$\sum_{\forall i \in I}(e_i * (y_i + impy_i + ohy_i)) \tag{4.48}$$

Overseas demand is satisfied likewise domestic market demand.

Unsold cost:

$$\sum_{\forall i \in I}[c_i * (T_i - x_i - y_i)] \tag{4.49}$$

For a product, if the sum of production for domestic consumption and production for export is not equal to (lower than) total production, there are unconsumed amount of that product. Additionally, unsold cost of a product is defined as a parameter according to these unconsumed products. If a product is perishable like lettuce, its unsold cost is equal production cost; otherwise, (like wheat) unsold cost is equal holding cost.

Production cost:

$$\sum_{\forall i \in I}\sum_{\forall j \in J}(cost_{ij} * ka_{ij}) \tag{4.50}$$

There is a unit production cost to produce a product on a region and a decision variable which is the amount of land used to produce a product. The sum product of this two gives total production cost.

Opportunity cost:

$$\sum_{\forall j \in J} [r_j * (K_j - \sum_{\forall i \in I} ka_{ij})] \tag{4.51}$$

The unused fertile lands cause economic loss. On the other hand, some products can be planted on uncropped lands and earned income. So, the unit opportunity cost was determined for each region as the average price of all appropriate products which can be planted on that region. The sum product of uncropped area and unit opportunity cost gives total opportunity cost.

Import Cost:

$$\sum_{\forall i \in I} (impCost_i * import_i) \tag{4.52}$$

The sum product of unit import cost and amount of import of each item gives total import cost.

4.4.5.2 Constraints of model 4:

$$x_i + y_i \leq T_i \quad \forall i \in I \tag{4.53}$$

The sum of domestic and export sales of a product which was produced domestically must be lower than the total amount of domestic production (equation 4.53).

$$x_i + impx_i + ohx_i = d_i \quad \forall i \in I \tag{4.54}$$

There are three ways to satisfy the domestic demand as follows, domestic production, import, and stocks. Domestic demand has to be satisfied (equation 4.54).

$$y_i + impy_i + ohy_i \leq o_i \quad \forall i \in I \tag{4.55}$$

Likewise domestic demand, there are also three ways to satisfy the overseas demand. Note that, the imported products can be exported. Overseas demand has not to be satisfied completely (equation 4.55).

$$ohx_i + ohy_i = oh_i \quad \forall i \in I \tag{4.56}$$

Products in inventory can be consumed in the domestic market or exported. However, they must be exactly consumed (equation 4.56).

$$impx_i + impy_i = import_i \quad \forall i \in I \tag{4.57}$$

Imported products can be consumed in the domestic market or exported. The amount of import a product is as needed (equation 4.57).

$$\sum_{\forall j \in J} (v_{ij} * ka_{ij}) = T_i \quad \forall i \in I \tag{4.58}$$

Each area has a measured productivity for each product. So, the sum product of productivity and amount of area is equal to total amount of production (equation 4.58).

$$\begin{aligned}
\sum_{\forall i \in I} ka_{ij} &\leq K_j && \forall j \in J \\
ka_{ij} &\geq LB_{ij} && \forall i \in I, \forall j \in J \\
\sum_{i \in m = Cereals} ka_{ij} &\leq b_{Cereals,j} + b_{FallowArea,j} && \forall j \in J \\
\sum_{i \in m = Vegetables} ka_{ij} &\leq b_{Vegetables,j} + b_{FallowArea,j} && \forall j \in J \\
\sum_{i \in m = Fruits} ka_{ij} &\leq b_{Fruits,j} + b_{FallowArea,j} && \forall j \in J \\
\sum_{i \in m = OrnamentPlants} ka_{ij} &\leq b_{OrnamentPlants,j} + b_{FallowArea,j} && \forall j \in J
\end{aligned} \tag{4.59}$$

The amount of fertile lands of each area was measured also these areas are separated according to the plantation of product groups. The sum of used area for production of all products can not to be higher than the amount of fertile lands in a region. Moreover, there are upper bounds of land which can be used for the production of all product groups for each region. When it is necessary, fallowed areas can be used for the production of any product in each region. The values of products' yields are determinative to be used fallowed area. Furthermore, area lower bounds can be specified for production of any product in a region. This constraint was created for especially products grew on a tree (equation 4.59).

$$x_i, y_i, ka_{ij}, import_i, impx_i, impy_i, ohx_i, ohy_i \geq 0 \quad \forall i \in I, \forall j \in J \tag{4.60}$$

All variables must be positive (equation 4.60).

4.5 The Comparison of the Models

To optimize agricultural lands of Turkey, 4 LP models were designed. Even if, each model resemble with each other, their features and outputs differ. These differences are shown Table (4.1)

–	**Criterias**	**model1**	**model2**	**model3**	**model4**
features	1. Lower bounds of areas for individual products	–	–	–	✓
	2. Upper bounds of areas for product groups	–	✓	✓	✓
	3. Usage of fallowed areas	✓	–	✓	✓
	4. Exact satisfaction of domestic demand	✓	✓	✓	✓
	5. Exact satisfaction of export demand	–	–	–	–
	6. Tendency of production instead of import	✓	✓	✓	✓
	7. The highest applicability	–	–	–	✓
outputs	8. Maximum import	–	✓	–	–
	9. Minimum import	✓	–	–	–
	10. Maximum export	✓	–	–	–
	11. Minimum export	–	✓	–	–
	12. Maximum profit	✓	–	–	–
	13. Minimum profit	–	✓	–	–

Table 4.1: The differences of the models.

All of the models can be applied to different conditions. For example, model 1 must be applied on a country or region which had very few agricultural activities before because model 1 has few area constraints and it defines regional area usages to produce products more freely (detailed information were given in previous sections). Model 2 gives solution, if fallowed areas does not need to be used in a country. Model 3 reorganize usage of fallowed areas. As for model 4 works highly based on existing agricultural system of a country. So, model 4 is more favorable for Turkey.

Chapter 5

Data Collection

Turkey has a big potential of product variety in the field of agriculture. Since designed optimization models work on all regions of Turkey, all products which can be grown were tried to include in all models. Consequently, 136 base products were chosen and it is considered that these products reflect product variety with a high degree. Moreover, these products were classified under 4 product groups. The list of base products and product groups is shown in Table (5.1)

As mentioned in a previous chapter, there are 12 agricultural regions in Turkey according to TURKSTAT. These regions were used in models likewise.

One of the basic aim of each of the model is to maximize the agricultural profitability related to the total production at an agricultural year. The model needs real-like estimated parameters to be successful. Moreover, the parameters estimation of incipient season is toilsome, time-consuming and multidisciplinary job. To check applicability of the models and to gain time, real data of 2013 was used as parameters of models. Some establishments and their web sites were helpful to obtain data. TURKSTAT, FAO, TARSIM are some of them.

In addition, parameter of opportunity cost of uncropped lands (opportunity cost of unused lands explained in previous parts.) was calculated as follows:

Cereals	**Vegetables**	**Fruits**	**OrnamentPlants**
wheat	scallion	grape	indorornamentalplants
corn	onion	banana	bulb
riceplant	garlic	kiwi	ornamentalplants
barley	driedgarlic	avocado	
rye	leek	Fig	
oat	carrot	orange	
millet	swede	mandarin	
carnarygrass	redbeet	lemon	
tricale	celery	grapefruit	
sorghum	turnip	bergamot	
potato	radish	apple	
broadbean	tomato	pear	
chickpea	cucumber	quince	
horicot	gherkin	loquat	
redlentil	pepper	medlar	
greenlentil	okra	nectarine	
vetch	eggplant	peach	
greekclover	zucchini	plum	
chickling	pumpkin	apricot	
jeurselamartichoke	pease	wildapricot	
soya	bean	cherry	
peanut	pea	morello	
sunflover	favabean	cranberry	
sesame	cranberrybean	oleaster	
safflover	melon	jujube	
cole	watermelon	strawberry	
cotton	Pepino	raspberry	
hemp	cauli	blackberry	
hash	broccoli	berry	
nicotina	cabbage	pomegranate	
whitebeet	lettuce	persimmon	
viciasativa	artichoke	carob	
clover	spinach	bilberry	
sainfoinseed	gardenoarch	table olive	
fodderbeet	purslane	olive	
sage	tabooli	almond	
lavender	rocket	nut	
melissa	watercress	walnut	
stinger	mint	chestnut	
rose	dill	pistachio	
lupine	asparagus	Tea	
hop	mushroom	chili	
		aniseed	
		cumin	
		raziyane	
		coriander	
		nigella	
		thyme	
		ling	

Table 5.1: List of base products and product groups.

Opportunity Cost of Uncropped Land in a Region($\$/decare$) =
$average$[Unit Price of product that can be cropped in related region($\$/ton$)
* Productivity($ton/decare$)]

On hand inventories of all products were taken to be zero because not enough information is available about inventory levels in stocks.

The models outputs may give some results such that the production is more than the consumption in that case production surplus of some products may occur. There are three types of cost of production surplus according to product types. These types are shown as follows:

- **Cost of perishable products:** average unit production cost of products
- **Holding cost:** unit cost of products which hold in cold room
- **No cost:** these products have long shelf life

The unit import prices of products in 2013 were used in models as unit import costs, but prices of some products could not be obtained, so big numbers were taken as unit import costs of such products, so that the models do not import these products.

The upper bounds of product groups' areas and fallowed areas were determined according to cultivated areas in 2013.

Some values in some parameters could not be found, so these values were estimated, if possible.

Chapter 6

Data Analysis and Results

6.1 Models Solving and DSS (Decision Support System)

The models were solved by a mathematical problem solver program called GAMS. Although data can be written in this program, it is not quite easy to write large amount of data in it. So, we used excel to load data into gams. Moreover, a DSS based on excel vba was designed to make these jobs easy. Thanks to DSS, sets and parameters sheets are formed automatically. DSS also enables to run model and to reach results easily. In other words, users do not need to labor with engineering jobs, it is enough that they press buttons and fill parameter tables. The figure (6.1) shows user interface of DSS:

Figure 6.1: Figure of DSS interface.

6.2 Results

Same data was used for each model and detailed information about data was given in previous chapter. Each model was run and outcomes were obtained successfully. As expected, some outcomes of models were different and some of them is the same. These outcomes will examined in detail in this section.

6.2.1 Production

The purposes of the models are increasing agricultural profit based on production. So amounts of total productions of some important products (also see Appendix

A.1 for production levels for all products) will be examined in detail. Table of this outcome is shown below (Table (6.1))

	Model 1	**Model 2**	**Model 3**	**Model 4**
grape	3196576	3196576	3196576	**3220458**
banana	419638	419638	419638	419638
fig	95448	95448	95448	**274028**
orange	1692133	1692133	1692133	1692133
mandarin	944165	944165	944165	**1026411**
lemon	671524	671524	671524	**720199**
apple	2404349	2404349	2404349	**2845188**
pear	432092	432092	432092	**446630**
quince	131666	131666	131666	**136275**
peach	615259	615259	615259	615259
plum	259294	259294	259294	**295459**
apricot	368510	368510	368510	**766271**
cherry	460436	460436	460436	460436
pomegranate	227389	227389	227389	**379379**
table olive	546056	546056	546056	546056
olive	1343221	1343221	1343221	1343221
almond	98204	98204	98204	98204
nut	204400	204400	204400	**550524**
walnut	227384	227384	227384	227384
chestnut	55965	55965	55965	55965
pistachio	84977	84977	84977	88272
tea	1009686	1009686	1009686	**1180010**
chili	71376	71376	71376	71376
onion	1671192	1671192	1671192	1671192
garlic	81253	81253	81253	81253
dried garlic	93125	93125	93125	93125

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Table 6.1 – *Continued from previous page*

	Model 1	**Model 2**	**Model 3**	**Model 4**
carrot	504741	504741	504741	504741
tomato	10793223	10793223	10793223	10793223
pepper	2088902	2088902	2088902	2088902
eggplant	811580	811580	811580	811580
watermelon	3801380	3801380	3801380	3801380
lettuce	455345	455345	455345	455345
wheat	41198520	**30304039**	41198520	41198520
corn	6649887	6649887	6649887	6649887
rice plant	766157	766157	766157	766157
barley	7467482	7467482	7467482	7467482
millet	15981	**0**	15981	15981
carnary grass	3031	**0**	3031	3031
potato	3937892	3937892	3937892	3937892
chickpea	542236	542236	542236	542236
red lentil	524999	524999	524999	524999
green lentil	150121	**0**	150121	150121
soya	1817894	1817894	1817894	1817894
cotton	1266280	1266280	1266280	1266280
white beet	16488591	16488591	16488591	16488591

TABLE 6.1: Amount of production of some products for each model (ton).

As is seen from Table (6.1), production amounts of lots of the products are same for each model. Hereinbefore, all models have same base structure but they separated with additional constraints. So, many of products were produced as much as demands in all models. On the other hand, some production levels in model 4 are bigger compared to the other models'. The reason for this is area lower bounds constraint in model 4. Thanks to defined area lower bound of some product, productions of these products exceeded their demands. Likewise, model 2 gave

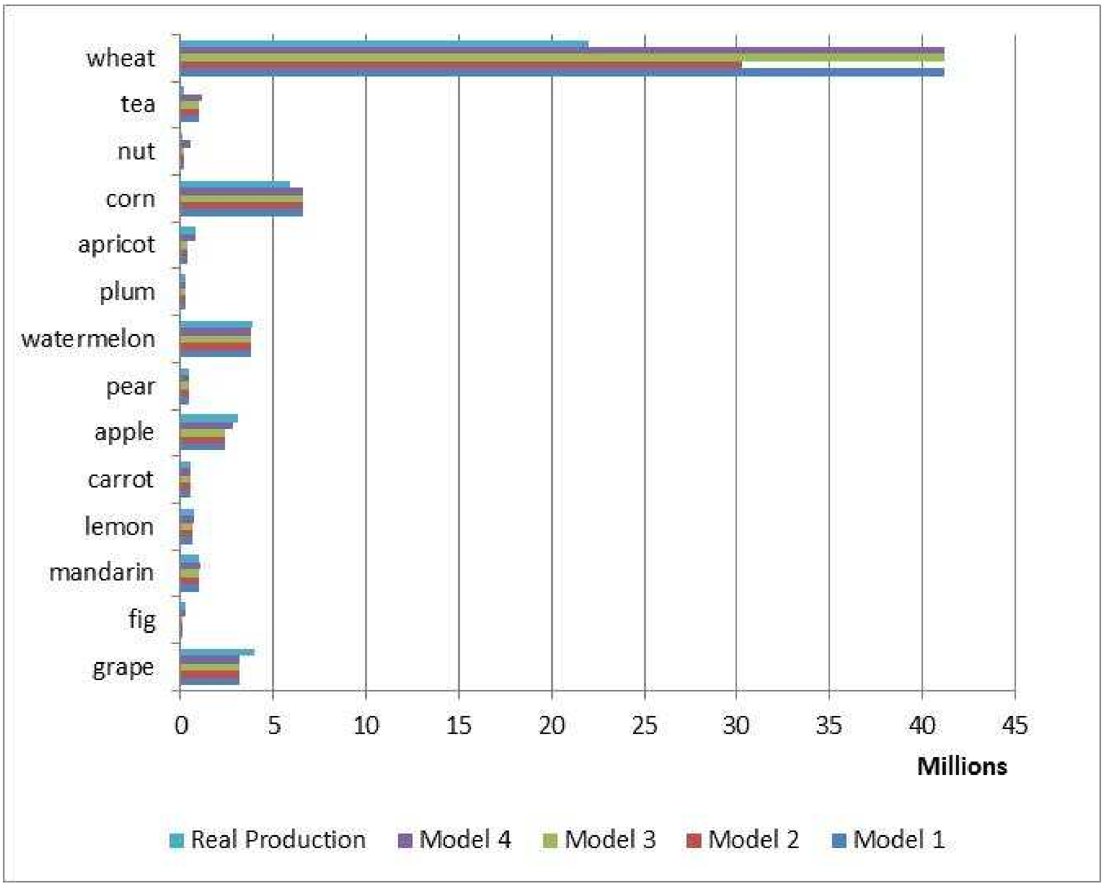

Figure 6.2: The comparison of model and real productions (ton).

lower production levels of some products than the others. Fallowed areas were not used in this model and remaining available lands were not sufficient. Graphical display of models and real production levels comparison for some products are shown Figure (6.2):

Turkey has a big population and big amount of produced product are spent for consumption. Table (6.2) shows consumptions amounts of some most produced products (also see Appendix A.2 for all products). Since demands were constant, amounts of consumptions were same for all models except model 2. Production of model 2 could not satisfy demand because of unused fallowed areas. In addition, demands of some products could not be satisfied by domestic production of any model. Because import costs of those products are smaller than production cost of them. So, these products were imported. (This issue was examined in Chapter 7)

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Demand**
grape	2993290	2993290	2993290	2993290	2993290
banana	419638	419638	419638	419638	419638
fig	19180	19180	19180	19180	19180
orange	1411564	1411564	1411564	1411564	1411564
mandarin	413200	413200	413200	413200	413200
lemon	261721	261721	261721	261721	261721
apple	2278667	2278667	2278667	2278667	2278667
pear	419507	419507	419507	419507	419507
quince	118566	118566	118566	118566	118566
peach	580259	580259	580259	580259	580259
plum	233494	233494	233494	233494	233494
apricot	210620	210620	210620	210620	210620
cherry	406969	406969	406969	406969	406969
pomegranate	227389	227389	227389	227389	227389
table olive	545995	545995	545995	545995	545995
olive	1273990	1273990	1273990	1273990	1273990
almond	89102	89102	89102	89102	89102
nut	92822	92822	92822	92822	92822
walnut	223357	223357	223357	223357	223357
chestnut	50799	50799	50799	50799	50799
pistachio	81029	81029	81029	81029	81029
tea	1004833	1004833	1004833	1004833	1004833
chili	1376	1376	1376	1376	1376
onion	1513156	1513156	1513156	1513156	1513156
garlic	81227	81227	81227	81227	81227
dried garlic	93125	93125	93125	93125	93125
carrot	504741	504741	504741	504741	504741
tomato	10187265	10187265	10187265	10187265	10187265
gherkin	50000	50000	50000	50000	50000
pepper	2020095	2020095	2020095	2020095	2020095
eggplant	798175	798175	798175	798175	798175
melon	**0**	**0**	**0**	**0**	**1655639**
watermelon	3778453	3778453	3778453	3778453	3778453
cabbage	**0**	**0**	**0**	**0**	**709498**

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Table 6.2 – *Continued from previous page*

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Domestic Demand**
lettuce	454610	454610	454610	454610	454610
artichoke	**0**	**0**	**0**	**0**	**37452**
wheat	40923388	30304038.7	40923388	40923388	40923388
corn	6649887	6649887	6649887	6649887	6649887
riceplant	667701	667701	667701	667701	667701
barley	7366711	7366711	7366711	7366711	7366711
millet	**15906**	**0**	**15906**	**15906**	**15906**
carnarygrass	**2485**	**0**	**2485**	**2485**	**2485**
potato	3843396	3843396	3843396	3843396	3843396
horicot	**0**	**0**	**0**	**0**	**245636**
red lentil	426293	426293	426293	426293	426293
green lentil	51415	0	51415	51415	51415
soya	1804798	1804798	1804798	1804798	1804798
peanut	40000	40000	40000	40000	40000
sunflover	**0**	**0**	**0**	**0**	**2558108**
cotton	1262167	1262167	1262167	1262167	1262167
white beet	16488590	16488590	16488590	16488590	16488590

Table 6.2: Table of production for consumption of some products (ton).

Domestic demands of nearly all of products were satisfied by production of models. For previously explained reasons, demand satisfaction of model 2 was lowest.

However, export demand satisfactions of products by production were lower than domestic demand satisfactions. There are not any exact export demand satisfactions constraints in any models so there are not penalty for unsatisfied export demands. The lowest satisfaction was occurred by model 2 again (You can reach the detailed table of export demand satisfaction by production in Appendix A.3).

We could not reach the correct domestic and export demands of indoor ornamental plants, bulbs and ornamental plants from any data source. So, approximate values were used for them.

6.2.2 Import

In real life, Turkey imports a lot of agricultural product in large quantities. On the other hand, models decrease imports compared to real import levels. Decreasing import amounts show that models work well. Even so, optimization models could not finish import completely because production costs are bigger than import costs for some products (also see Chapter 7 for the examinations of effects of high production costs). Table of products' import amounts is shown below (Table (6.3)):

	Model 1	**Model 2**	**Model 3**	**Model 4**
melon	1660788	1660788	1660788	1660788
cabbage	713002	713002	713002	713002
artichoke	37453	37453	37453	37453
horicot	247016	247016	247016	247016
sunflover	2598256	2598256	2598256	2598256
carnarygrass		3031		
wheat		10619349		
greenlentil		150121		
millet		15981		

Table 6.3: Table of total imports of products (ton).

Models produced same import values for some products due to same reasons with same production levels of some products. In addition, model 2 gave more import than others because model 2 use less fertile lands because of unused fallowed areas.

As mentioned before, imported products is not used for only consumption, they also used for export. If import for export is profitable for any product, models let to occur this. Table 6.4 indicates total imports and tables of import for consumption and import for export are shown below (Tables (6.4)) and (6.5))):

	Model 1	**Model 2**	**Model 3**	**Model 4**
melon	1655639	1655639	1655639	1655639
cabbage	709498	709498	709498	709498
artichoke	37452	37452	37452	37452
horicot	245636	245636	245636	245636
sunflover	2558108	2558108	2558108	2558108
carnarygrass		2485		
wheat		10619349		
greenlentil		51415		
millet		15906		

Table 6.4: Table of import for consumption (ton).

	Model 1	**Model 2**	**Model 3**	**Model 4**
melon	5149	5149	5149	5149
cabbage	3504	3504	3504	3504
artichoke	1	1	1	1
horicot	1380	1380	1380	1380
sunflover	40148	40148	40148	40148
millet		75		
greenlentil		98706		
carnarygrass		546		

Table 6.5: Table of Import for export (ton).

Most of the imports which models produce were used for consumption and there were trades of goods in small quantities. An imported product which has unit import cost less than unit export price can be exported. In addition, there may be two reason to import products. One of them is less fertile lands and the other

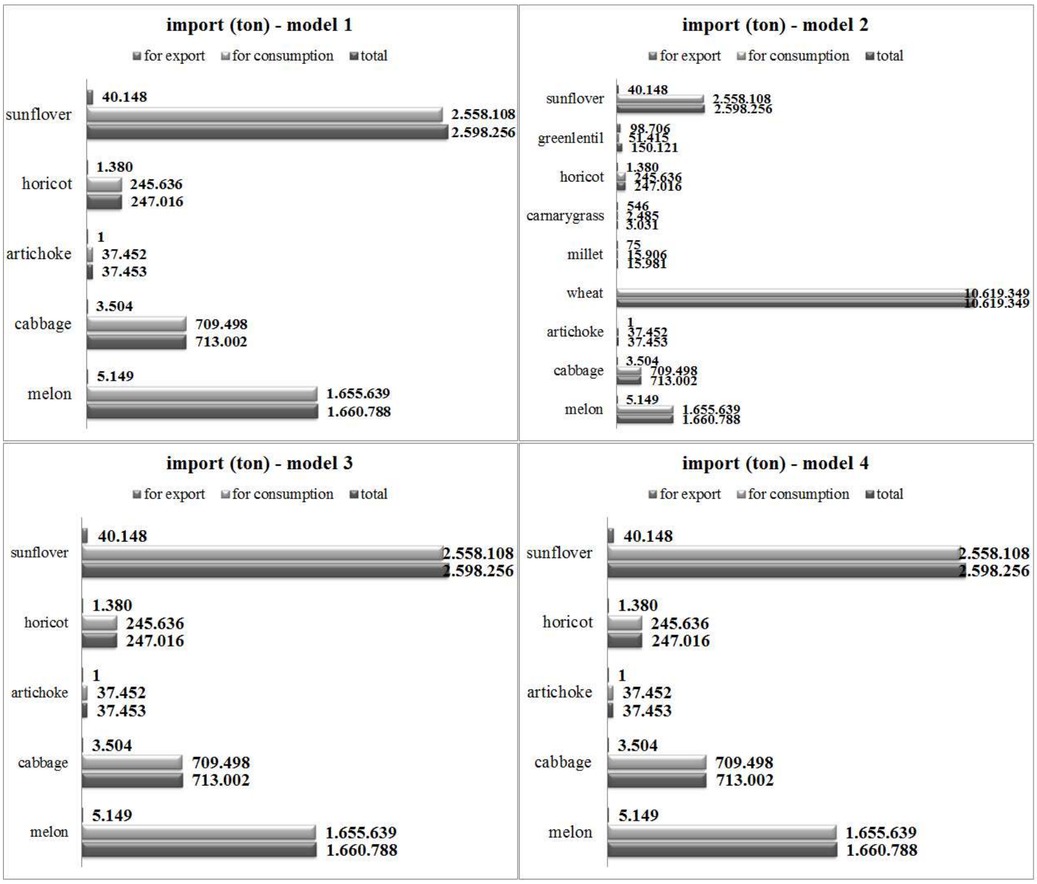

Figure 6.3: Import results of models (ton).

one is high production costs. Reasons of import will be examined in Chapter 7 (also see Section 7.1).

Graphical display of import results of models is shown in Figure 6.3.

The total values of imported product that given by model 1, model 3 and model 4 were approximately 2 billion dollars and model 2 gave approximately 5.5 billion dollars total import value. In fact, Turkey's total agricultural products import value was approximately 13 billion dollars in 2013. It is clear that models decreased total import value of agricultural products.

6.2.3 Area Usage

The most important job of the models is to define that how much land in a region that has to be used to plant a product. All of the other outputs which were mentioned previously such as production, export, import depend on this output called area usage.

Firstly, area usage will be examined on Mediterranean Region for all models comparatively. Mediterranean Region is one of the 12 agricultural regions and it has biggest product range. Table (6.6) shows area usages of it.

MEDITERRANEAN	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
grape		1,402,898	1,614,703	700,000	789,899
banana	90,949	90,949	90,949	90,949	46,700
kiwi		43,029		600	589
avocado				1,900	1,899
fig				12,000	12,016
orange	516,524			449,933	442,091
mandarin				290,000	293,943
lemon		250,102	82,279	245,000	246,433
grapefruit	50,563			60,000	62,156
bergamot	532	532	532	532	472
apple		755,314	948,619	480,000	494,036
pear		224,114		42,000	42,366
quince				8,000	8,017
loquat				11,000	11,338
nectarine				18,000	18,098
peach			396,430	71,000	71,495
plum				62,000	62,085
apricot		344,724	344,724	200,000	206,268
cherry		376,219			121,562
jujube	347	347	347	347	241

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Table 6.6 – *Continued from previous page*

MEDITERRANEAN	Model 1	Model 2	Model 3	Model 4	Real Area Usage
strawberry	104,806			104,806	58,919
blackberry	91	91	91	91	195
pomegranate				115,000	115,865
carob	5,191		5,191	5,191	5,119
table olive		1,060,711		470,000	471,938
olive				900,000	904,778
almond		203,743		46,000	46,898
nut	336,184			600	688
walnut				60,000	60,463
pistachio				73,000	73,861
chili		35,143	35,143		17,955
raziyane	26,917	26,917	26,917	26,917	13,800
ornamentalplants		496			1,414
scallion			68,471		18,997
onion			472,984		130,619
leek	55,813	55,813		55,813	18,954
celery	4	4	4	4	140
turnip			118,987		779
radish	20,906	20,906		20,906	47,511
tomato		698,923	1,542,054	1,589,651	431,364
cucumber	337,781				95,712
pepper	547,263	118,346		105,021	164,491
okra		14,285		15,892	10,935
eggplant	167,821	167,821			75,713
zucchini	71,556	71,556		71,556	36,524
pumpkin	136,411				2,461
pease			76,286		27,134
bean	434,261	434,261	434,261		95,043
favabean			46,897		23,864
watermelon	688,781				249,959
Pepino	0.1	0.1	0.1	0.1	10

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Table 6.6 – *Continued from previous page*

MEDITERRANEAN	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
cauli		33,652		33,652	17,177
broccoli		43,986		43,986	9,092
spinach			175,479		26,075
rocket	96	96	96	96	1,100
watercress	6	6	6	6	1,729
mushroom	1,311	1,311	1,311	1,311	
wheat	19,678,471	15,279,356	16,838,122	16,838,122	7,825,090
millet	46,322				470
sorghum	1,976				150
broadbean	64,361	64,361	64,361	64,361	2,653
lavender	20	20	20	20	650
rose	7	7	7	7	23,496

Table 6.6: Table of area usage of Mediterranean Region (decare).

As is seen from Table (6.6), the models produced different amounts of used areas to produce most of the products. Additionally, amounts of used areas produced by models were generally different from real area usages. But some results of model 4 were close with real area usages. The reason of this, the lower bounds of area usages of some products (especially orchards) in model 4 were taken close to real area usage in 2013.

Area usages tables of models with comparison of real area usages for all regions were added in Appendix B. The interpretation of these tables are similar with area usage table of Mediterranean Region.

Secondly, we will examine area usages on all regions for some products and these products are wheat, tomato, tea, table olive and olive.

WHEAT	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Mediterranean	19.678.471	15.279.356	16.838.122	16.838.122
Western Anatolia	32.121.085	20.552.975	32.687.462	32.687.462
Western Blacksea	18.568.157			
Western Marmara	4.261.492	12.544.868	12.942.044	12.942.044
Eastern Blacksea				
Eastern Marmara		8.400.281	10.990.355	10.990.355
Aegean	24.282.213	6.592.826	14.531.558	14.531.558
Southeastern Anatolia	4.038.445	23.434.371	25.638.105	25.638.105
Istanbul		643.418		
Northeastern Anatolia		6.882.763	1.745.431	1.745.431
Central Anatolia	36.114.163	2.497.991	19.046.664	19.046.664
Middleestern Anatolia	9.535.559			
sum=	148.599.587	96.828.850	134.419.740	134.419.740

Table 6.7: Table of area usages in all regions to produce wheat(decare)

As is seen from Table (6.7), any model did not offer to produce wheat in Eastern Blacksea Region because of production cost and yield of wheat in this region. Furthermore, model 3 and model 4 gave some area usages results for wheat because both models have same product group upper bounds constraints and lower bound constraints in model 4 are available for only fruits. Model 2 had given significant wheat import due to explained reasons in previous section, so this model used fewest area to produce wheat.

TABLEOLIVE and OLIVE	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Mediterranean		1.060.711		1.370.000
Western Anatolia		1.019.771	596.657	18.000
Western Blacksea				384.366
Western Marmara	2.957.391			1.509.385
Eastern Blacksea	1.221.602			36.734
Eastern Marmara	635.948	825.738		540.097
Aegean		7.106.989	7.702.990	4.000.000
Southeastern Anatolia			3.868.054	1.557.719
Istanbul				
Northeastern Anatolia				
Central Anatolia				
Middleestern Anatolia				
sum=	4.814.940	10.013.210	12.167.702	9.416.301

Table 6.8: Table of area usages in all regions to produce table olive and olive(decare)

The total area usages for table olive and olive production in all region are shown in Table (6.8). The upper bound areas for table olive and olive in regions were available in model 4, so this model used more number of region to produce this product. Moreover, Istanbul, Northeastern Anatolia, Central Anatolia and Middleestern Anatolia were not used by any models to produce this product because of yields of them in these regions.

TOMATO	Model 1	Model 2	Model 3	Model 4
Mediterranean		698.923	1.542.054	1.589.651
Western Anatolia				
Western Blacksea		889.468		
Western Marmara				
Eastern Blacksea				
Eastern Marmara	1.709.411			36.644
Aegean		271.266		
Southeastern Anatolia				
Istanbul				
Northeastern Anatolia				
Central Anatolia				
Middleestern Anatolia		220.941	504.502	294.087
sum=	1.709.411	2.080.597	2.046.556	1.920.382

Table 6.9: Table of area usages in all regions to produce tomato(decare)

As is seen from Table (6.9), model 1 offer to use only Eastern Marmara Region to produce tomato, because this model used areas in regions more freely compared to other models. Moreover other models used areas of limited number of regions to produce this product because of yield and production cost of it in non-offered regions.

TEA	Model 1	Model 2	Model 3	Model 4
Eastern Blacksea	653.942	653.942	653.942	764.255

Table 6.10: Table of area usages in all regions to produce tea(decare)

Table (6.10) shows that tea can be produce in only Eastern Blacksea Region according to all models and this situation reflects the actual state. Moreover, model 4 used more area from others to produce tea because of lower bound of tea areas in this region. Model 1, model 2 and model 3 used area to produce tea as much as demand satisfaction.

Area usages based on regions and area usages based on products were examined. Now, area usages of models for product groups will be examined comparatively.

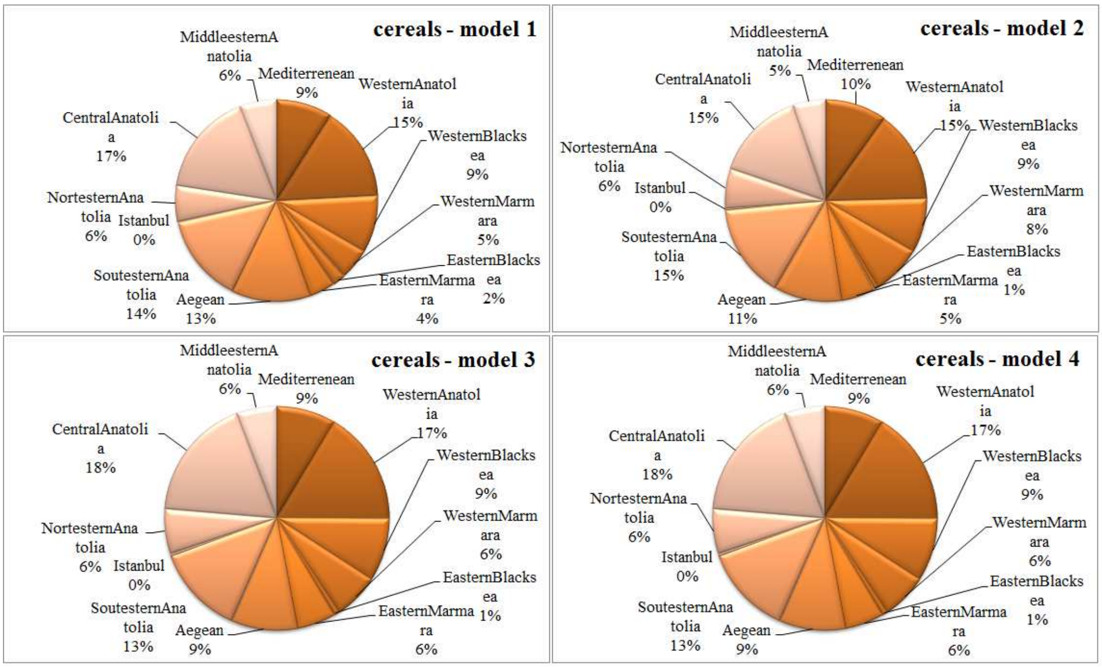

Figure 6.4: Area usages of models for each region to produce cereals

Central Anatolia was offered mostly by models to produce cereals (Figure 6.4)and Western Anatolia and Southeastern Anatolia followed Central Anatolia. These three regions lands are more appropriate to cereals production than the other regions and yields of cereals in these regions are generally higher compared to other regions. Moreover, models gave some close regional amounts to produce cereals because all of them used same parameters and they have same base structure. On the other hand, they gave some different regional amounts because developer constraints were added incrementally.

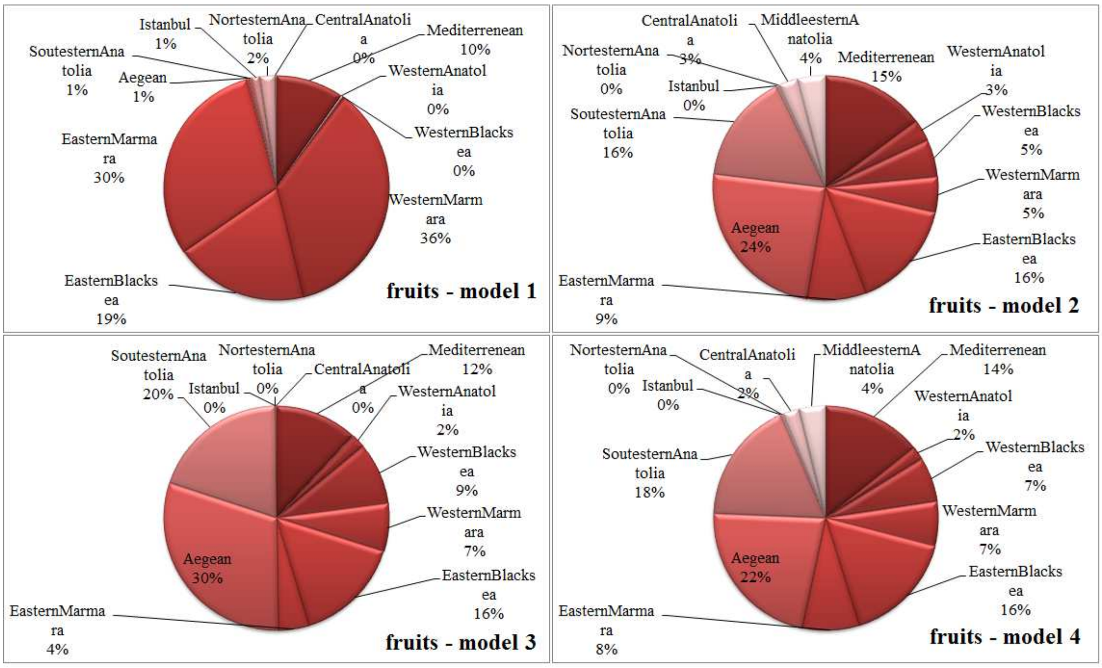

Figure 6.5: Area usages of models for each region to produce fruits

The model 1 gave optimal area usages to produced fruits (Figure 6.5) just based on yield parameters and it gave highest net profit. However when constraints of upper bounds of product groups stepped in model 2, model 3 and model 4 and constraints of lower bounds of products stepped in model 4, optimal area usages changed offered by models and also net profits decreased.

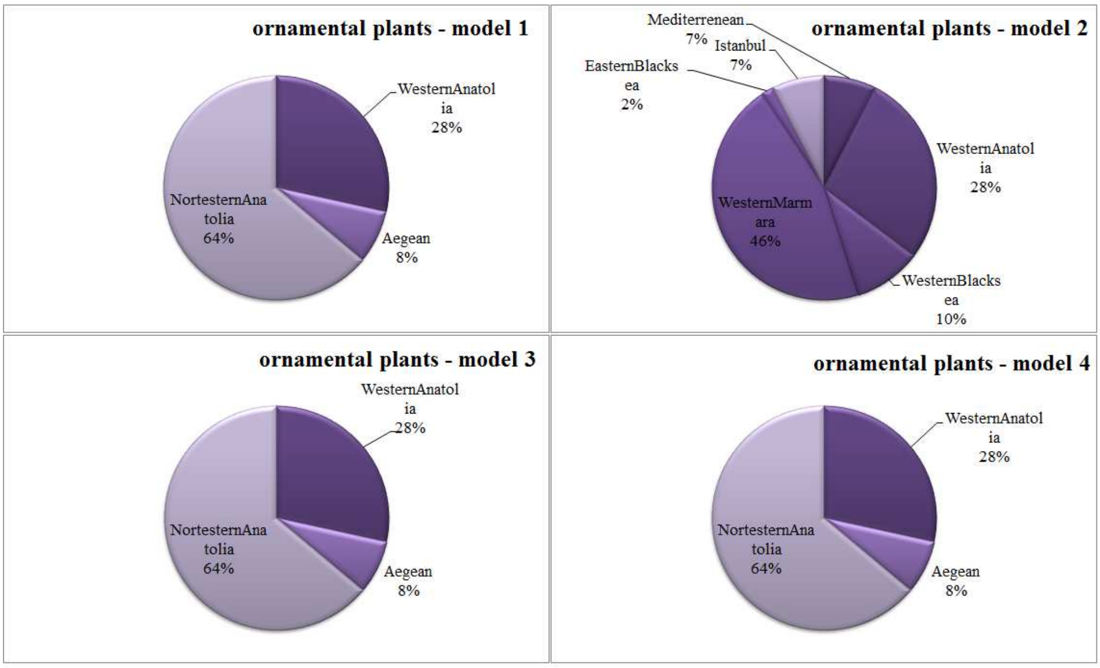

Figure 6.6: Area usages of models for each region to produce ornamental plants

There was an extraordinary situation occurred that area usages to produce ornamental plants (Figure 6.6). Model 1, model 3 and model 4 offered nearly same area usages. The reasons of this, ornamental plants can not be cultivated every region (or their yields are very low in some regions) and ornamental plants production based on their demands requires to be a trace of area usage. Since model 2 could not use all of the fertile lands (because of fallowed areas), its area usages to produce ornamental plants were different from others.

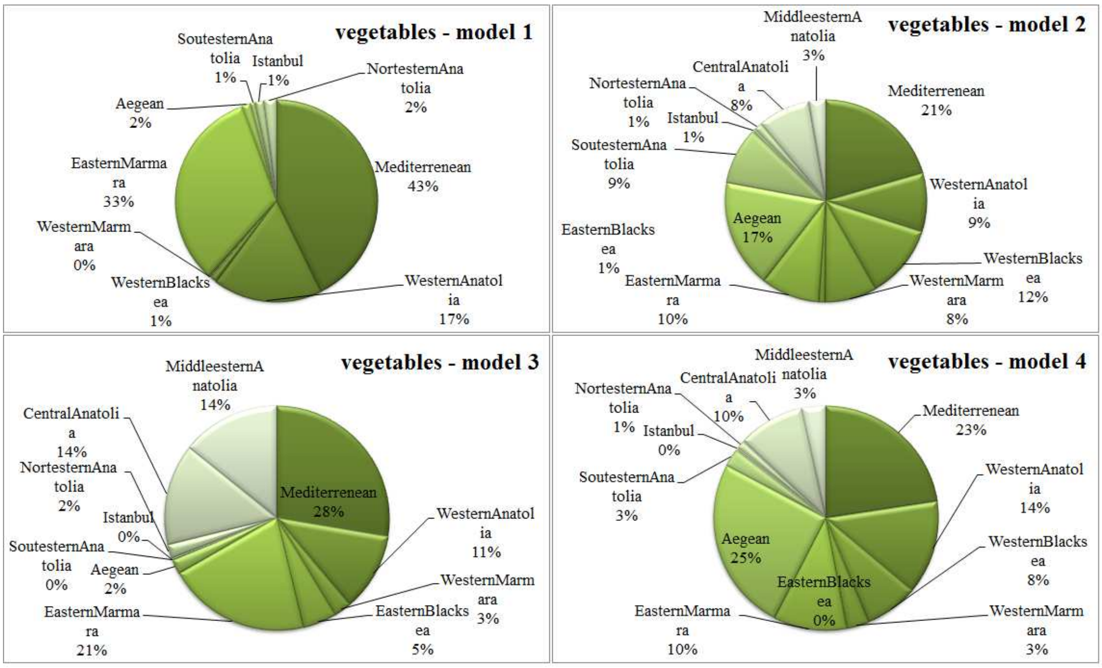

Figure 6.7: Area usages of models for each region to produce vegetables

The most profitable model is model 1 but applicabilities of the models increases from model 1 to model 4 and increasing applicability is an effect of development in models. Differences of area usages offered by models to produce vegetables (Figure 6.7) are cause of the applicability development in models.

As mentioned before, import levels, export demand satisfactions and production depend on area usage results of models (All of decision variables and parameters of models depend on with each other but area usages effect these stated decision variables more). So, decreased or disappeared import levels, high incidence of satisfied export demands and organized production show that models plan area usage effectively.

6.2.4 Net Profit

The objectives of models is maximizing net agricultural profit as mentioned before. Table (6.11) indicates net profit values of models. Model 1 and Model 3 had given highest net profit value. Model 1 does not has any area constraint which make models more appropriated for true conditions and also expectedly decrease net profits of models (also see Section 4.1). So, it was an expected situation that Model 1 has highest net profit. On the other hand, Model 3 has area constraints namely upper bounds of product groups of areas (also see Section 4.3) and it had same highst net profit value with Model 1. The reason of this, defined upper bounds of product groups gave sufficient areas that Model 3 works optimal likewise Model 1. In addition, Model 2 gave a significant negative net profit since the fallowed areas were not used (also see Section 4.2). Moreover, each model was created to stimulate production instead of import. So there is an opportunity cost for unused areas. In other words, fallowed areas caused big economical problem for model 2 and imports and import costs increased because of these unused areas. The fallowed areas can be logically used in production as indicated Model 3 and Model 4 (also see Sections 4.3 and 4.4). While usage of fallowed areas is so important, residential settlements on fertile lands must be out of question. The the constraint of area lower bounds of products in Model 4 decreased net profit but it is acceptable.

	Net Profit
model 1	31,917,410,111
model 2	-52,258,550,187
model 3	31,917,410,111
model 4	30,747,902,848

Table 6.11: Net profits of models(dollar).

6.3 Sensitivity Analysis

As we mentioned before, models have same base structure and model 4 is the most suitable one for our purpose among them. So we make sensitivity analysis by examining the shadow prices of model 4 variables to find ways of increasing net profit of this model. First of all, we will examine shadow prices of total production. Table (6.12) shows 10 products which have highest shadow prices of total production. Increasing production of these 10 products by one ton will increase net profit of model 4 by $39,243. So, it can be considered to increase production to start from product which has highest shadow price. However, increasing production does not mean that these products can be sold. The demand of these products must also be increased by other means, ex. advertisements. If production is more than demand, production surplus occurs.

Product	**Shadow Prices of Production**
pepino	11,000
indor ornamental plants	5,354
rocket	4,484
watercress	3,630
ornamental plants	3,555
nicotina	3,260
walnut	2,100
jeurselamartichoke	2,060
almond	2,000
nigella	1,800

Table 6.12: Shadow prices of total production

Table (6.13) shows ten products which have highest shadow prices of export demand. Export demand enhancing studies can be started to apply from these products, thus net profit can be increased.

Product	Shadow Prices of Export Demand
pistachio	12,160
pepper	10,340
walnut	9,510
almond	8,600
nut	7,000
fig	3,227
plum	2,643
apricot	2,560
nicotina	2,443
coriander	2,380

Table 6.13: Shadow prices of export demand

Thus if we are able to increase the export demand each of these 10 products by one ton, the profit may increase by $60863. So producing and exporting most profitable products, if we can create demand, may lead us to increase our profit more than the one we obtained from model 4.

Chapter 7

Scenario Analysis

The results of models under real conditions were examined in Chapter 6. This time, we examined results of models for different scenarios to make beneficial inferences and suggestions.

7.1 Scenario 1: Increasing yield by 15%

We increased yields of products for all regions by 15% as first scenario analysis. Increasing yields by 15% affected production and net profit positively and also decreased imports as expected. As is seen from Table (7.1) net profit increased 10% for model 1, 7.8% for model 2, 10% for model 3 and 8.5% for model 4 when Scenario 1 was applied.

	Net Profit Under Real Conditions	**Net Profit with Increasing Yields**	**Increasing Rate**
model 1	31,917,410,111	35,139,591,975	10%
model 2	-51,258,550,187	-47,254,901,873	7.8%
model 3	31,917,410,111	35,139,591,975	10%
model 4	30,747,902,848	33,360,233,012	8.5%

Table 7.1: The comparison of net profits under real conditions versus increasing yields(dollar)

Moreover, import levels of some products decreased (Table (7.2)). When Table (6.3) and Table (7.2) were compared, the decrease could be observed. However, import levels of some products did not change, although yields increased by 15%. This situation is evident because some products are imported because of less fertile lands and some others are imported because of their high production costs. For this reason, it is necessary that production costs has to be decreased. External dependence problems of fertilizer and seeds must be solved and modern agricultural techniques must be used effectively. Natural fertilizer usage should be encouraged in order to have organic food and not to import inorganic fertilizers.

	Model 1	**Model 2**	**Model 3**	**Model 4**
cabbage	713002	713002	713002	713002
artichoke	37453	37453	37453	37453
wheat	0	3999873	0	0
millet	0	15981	0	0
carnarygrass	0	3031	0	0
horicot	0	247016	0	0
sunflover	2598256	2598256	2598256	2598256

Table 7.2: Table of total imports of products according to Scenario 1 (ton).

7.2 Scenario 2: Running models with real production amounts

Normally, total production amounts of products had been defined as decision variables in the models. We changed this case situation to take total production amounts of models as parameters instead of decision variables and we analyzed this change as a Scenario. We used real production data in 2013 from FAO and TURKSTAT. The basic aim of this scenario analysis is to observe changes on area usages. Table (7.3) shows these changes.

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Available Area**
Mediterranean	23,385,270	18,697,773	20,648,879	23,385,270	23,385,270
Western Anatolia	34,500,466	23,892,613	34,500,466	34,214,954	34,500,466
Western Blacksea	1,488,764	7,410,123	1,612,259	3,818,766	20,506,420
Western Marmara	15,262,906	13,300,542	13,353,077	15,192,561	15,262,906
Eastern Blacksea	2,763,318	2,645,772	2,763,814	5,828,745	6,757,423
Eastern Marmara	13,111,624	11,891,886	11,364,341	11,509,298	14,501,178
Aegean	11,276,797	18,835,714	9,803,833	16,627,117	28,094,540
Southeastern Anatolia	31,525,928	23,639,574	25,674,954	31,525,928	31,525,928
Istanbul	708,986	706,687	708,986	708,986	708,986
Northeastern Anatolia	356,956	4,014,150	233,114	491,342	12,976,835
Central Anatolia	10,207,773	23,017,565	26,738,100	24,875,908	36,864,042
Middleestern Anatolia	1,724,764	1,724,764	1,724,764	3,011,034	12,971,127
Sum=	146,313,552	149,777,163	149,126,588	171,189,909	238,055,121
Ratio=	61%	63%	63%	72%	

Table 7.3: Comparison of area usages of models and available areas in 2013 according to Scenario 2(decare).

The data on Available Area column on Table (7.3) reflects the cultivated lands in each region in 2013 and it can be easily observed that the models used between 61% to 72% of total real cultivated lands to produce amount of real productions. It can be clearly stated that productions of products can be increased with the help of production area usage reorganization of the models. In addition, all models gave significant negative net profits because of opportunity cost of unused areas.

7.3 Scenario 3: Increasing import costs of products 2 times more

We had increased yields in Section 7.1 and imports of some products had decreased but some of them had not changed. The reason of this is unit import costs are lower than unit production costs for some products. We will examine the results this time when import costs of products were increased 2 times more.

	Model 1	Model 2	Model 3	Model 4
wheat		10,625,742		
millet		15,981		
carnarygrass		3,031		
sunflover		2,598,256	1,861,602	1,861,602

Table 7.4: Table of total imports of products according to Scenario 1 (ton).

The import results of Scenario 3 can be observed from Table (7.4). Unchanged import levels of products (cabbage, artichoke and sunflower) be mentioned in Scenario 1 (Table (7.2)) changed when unit import costs increased. Imports of cabbage and artichoke were set to zero. Furthermore, import level of sunflower also decreased but not to be set to zero. Under Turkey's agricultural conditions, even though fertile lands of Turkey are used effectively by optimization models, import can not be set to zero completely. In addition, production instead of import of some products decreased net profits because of higher production costs:

	Net Profit Under Real Conditions	**Net Profits according to Scenario 3**
model 1	31,917,410,111	31,311,856
model 2	-51,258,550,187	-56,143,076
model 3	31,917,410,111	30,475,483
model 4	30,747,902,848	29,305,975

Table 7.5: Net profits according to Scenario 3(dollar)

7.4 Scenario 4: Increasing and decreasing opportunity costs by 15%

We decreased and increased all opportunity costs of unused areas in regions in this scenario and our basic aim is to observe that changing opportunity costs how to affect net profits of models. As expected, net profits of model 1, model 3 and model 4 did not change because they continued to used all fertile lands in regions for both case. We had mentioned that reason of significant net profit of model 2 was mostly opportunity costs of unused fertile lands. So, changing opportunity costs by 15% affected net profit of model 2 as nearly 12 billion dollars. This situation shows big negative economic effect of unused areas.

Chapter 8

Conclusion

Agriculture in Turkey has lots of problems. Such as; unused modern techniques, cultivatable land losses, low productivity and yield, high production costs, farmers who give up from production, unorganized production and etc. It is not possible to fix all of these agricultural problems with industrial engineering perspective. So we had do focus towards a problem which we will solve and unorganized production was appropriate for this definition. Unorganized production causes scarcity of some products and/or production surplus of some of the other products every year. This problem could be solved with the help of an optimization model. Thus an optimization model was created and it was improved in time. At the end, there were 4 optimization models which have same base structure and some different additional constraints (for detailed information about models see Chapter 4).

Models were tested with real agricultural data in 2013 and there were no mathematical problem for any of them. Moreover outputs of the models were examined deeply and no contradictions were determined.

Additionally, a user friendly decision supporting system (DSS) based on excel vba was created so that models can be used easily. The most beneficial attribute of DSS is numbers of products, regions and product groups can be increased or decreased practically. So they can be applied to some other countries and some specific regions. As a result, an institution which has decision-making authority such as Republic of Turkey Ministry of Food, Agriculture and Livestock can do forecast works of prices, demands and yields for next year and then can offer producers without force that how much land in a region that has to be used to plant a product. Moreover, created DSS helps to be done this job quite easily.

The results of models indicated that agricultural production in fertile lands of Turkey did not satisfy domestic demands completely in spite of the optimal usage of the fertile lands. Residential settlements on fertile lands must be stopped. Fallowed areas should be used for production as well. Population increases and we can not let fertile lands losses anymore every year (also see Chapter 2). Another problem is high production costs. Even though there are sufficient fertile lands in Turkey, high production costs cause the producers dispense with production. As a result of problems import of agricultural products increases.

LP models work well but they can be still improved. Instead of constant parameters, stochastic parameters can provide that better outputs be produced. In other words, linear programming can evolve stochastic programming.

8.1 Future Works

LP models work well but they can be still improved. Instead of constant parameters, stochastic parameters can provide that better outputs be produced. In other words, linear programming can evolve stochastic programming. Moreover, models work for one single year. Instead of this, multi-period models can be created to increase usefulness.

References

[1] Z. Dernek, "Agricultural developments from the establishment of republic to nowadays," *Süleyman Demirel Üniversitesi Ziraat Fakültesi Dergisi*, vol. 1, no. 1, pp. 1–12, 2006.

[2] "Faostat," http://faostat3.fao.org/download/Q/QC/E, accessed: 2015-10-21.

[3] "Faostat," http://faostat3.fao.org/download/Q/QC/E, accessed: 2016-01-23.

[4] "Turkish statistical institute (turkstat)," http://www.turkstat.gov.tr, accessed: 2016-09-12.

[5] S. Lu, Y. Liu, H. Long, and X. Guan, "Agricultural production structure optimization:a case study of major grain pruducing areas, china," *Journal of Integrative Agriculture*, vol. 12, no. 1, pp. 184–197, 2013.

[6] S. Lu, M. Zhou, X. Guan, and L. Tao, "An integrated gis-based interval-probabilistic programming model for land-use plnning management under uncertainty-a case study at suzhou, china," *Environmental Science and Pollution Research*, vol. 22, no. 6, pp. 4281–4296, 2015.

[7] H. Williams, "Farm planning," in *Model Building in Mathematical Programming*, Baffins Lane, Chichester, West Sussex PO19 1UD, England, 1999, pp. 239–240, 277–281, 315–316.

[8] W. Swart, C. Smith, and T. Holderby, "Expansion planning for a large dairy farm," in *Studies in Linear Programming*, North Holland/American Elsevier, Amsterdam, 1975.

[9] Z. Ahmad, M. Jun, M. Abdullah, M. Ishaq, N. Bang, and M. Bunnika, P.O.and Lateef, "Agricultural production structure optimization scheme of punjab (province) pakistan," *Europian Journal of Economics Studies*, vol. 14, no. 4, pp. 198–205, 2015.

[10] A. Haddad and Y. Shahwan, "Optimization agricultural production under financial risk of water constraint in the jordan walley," *Applied Economics*, vol. 44, no. 11, pp. 1375–1385, 2012.

[11] E. Heady and A. Egbert, "Regional programming of efficient agricultural production patterns," *Econometrica*, vol. 32, no. 3, pp. 374–386, 1964.

[12] ——, "Programming regional adjustments in grain production to eliminate surpluses," *Journal of Farm Economics*, vol. 41, no. 4, pp. 718–733, 1959.

[13] J. Glen, "Regional programming of efficient agricultural production patterns," *Agricultural Systems*, vol. 51, no. 1, pp. 317–337, 1996.

[14] "Agricultural insurance pool," https://web.tarsim.gov.tr, accessed: 2016-10-06.

[15] "Republic of turkey ministry of food, agriculture and livestock," https://www.tarim.gov.tr, accessed: 2016-09-05.

[16] "Tarım işletmeleri genel müdürlüğü," https://www.tigem.gov.tr, accessed: 2016-09-05.

[1] [5] [7] [8] [6] [9] [10] [11] [12] [13] [2] [3] [4] [14] [15] [16]

Appendices

Appendix A

Production

A.1 Total production

	Model 1	**Model 2**	**Model 3**	**Model 4**
grape	3196576.0	3196576.0	3196576.0	**3220458.1**
banana	419638.0	419638.0	419638.0	419638.0
kiwi	41781.0	41781.0	41781.0	41781.0
avocado	1741.0	1741.0	1741.0	1741.0
fig	95448.0	95448.0	95448.0	**274027.9**
orange	1692133.0	1692133.0	1692133.0	1692133.0
mandarin	944165.0	944165.0	944165.0	**1026410.5**
lemon	671524.0	671524.0	671524.0	**720199.4**
grapefruit	182735.0	182735.0	182735.0	**220908.0**
bergamot	2000.0	2000.0	2000.0	2000.0
apple	2404349.0	2404349.0	2404349.0	**2845188.4**
pear	432092.0	432092.0	432092.0	**446630.2**
quince	131666.0	131666.0	131666.0	**136275.1**
loquat	50000.0	50000.0	50000.0	50000.0
medlar	20000.0	20000.0	20000.0	20000.0
nectarine	108000.0	108000.0	108000.0	108000.0
peach	615259.0	615259.0	615259.0	615259.0

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Table A.1 – *Continued from previous page*

	Model 1	**Model 2**	**Model 3**	**Model 4**
plum	259294.0	259294.0	259294.0	**295458.5**
apricot	368510.0	368510.0	368510.0	**766271.3**
wildapricot	50000.0	50000.0	50000.0	50000.0
cherry	460436.0	460436.0	460436.0	460436.0
morello	172284.0	172284.0	172284.0	172284.0
cranberry	110.0	110.0	110.0	110.0
oleaster	150.0	150.0	150.0	150.0
jujube	150.0	150.0	150.0	150.0
strawberry	351834.0	351834.0	351834.0	351834.0
raspberry	100.0	100.0	100.0	100.0
blackberry	120.0	120.0	120.0	120.0
berry	65511.0	65511.0	65511.0	65511.0
pomegranate	227389.0	227389.0	227389.0	**379379.0**
persimmon	111.0	111.0	111.0	111.0
carob	14218.0	14218.0	14218.0	14218.0
table olive	546056.0	546056.0	546056.0	546056.0
olive	1343221.0	1343221.0	1343221.0	1343221.0
almond	98204.0	98204.0	98204.0	98204.0
nut	204400.0	204400.0	204400.0	**550523.6**
walnut	227384.0	227384.0	227384.0	227384.0
chestnut	55965.0	55965.0	55965.0	55965.0
pistachio	84977.0	84977.0	84977.0	88272.0
tea	1009686.0	1009686.0	1009686.0	**1180009.7**
chili	71376.0	71376.0	71376.0	71376.0
aniseed	3876.0	3876.0	3876.0	3876.0
cumin	3876.0	3876.0	3876.0	3876.0
raziyane	3876.0	3876.0	3876.0	3876.0

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Table A.1 – *Continued from previous page*

	Model 1	**Model 2**	**Model 3**	**Model 4**
coriander	3876.0	3876.0	3876.0	3876.0
nigella	1376.0	1376.0	1376.0	1376.0
thyme	1376.0	1376.0	1376.0	1376.0
ling	10.0	10.0	10.0	10.0
indorornamentalplants	50000000.0	50000000.0	50000000.0	50000000.0
bulb	50000000.0	619297144.6	50000000.0	50000000.0
ornamentalplants	50000000.0	50000000.0	50000000.0	50000000.0
scallion	102364.0	102364.0	102364.0	102364.0
onion	1671192.0	1671192.0	1671192.0	1671192.0
garlic	81253.0	81253.0	81253.0	81253.0
driedgarlic	93125.0	93125.0	93125.0	93125.0
leek	226711.0	226711.0	226711.0	226711.0
carrot	504741.0	504741.0	504741.0	504741.0
swede	661735.0	661735.0	661735.0	661735.0
redbeet	10.0	10.0	10.0	10.0
celery	10.0	10.0	10.0	10.0
turnip	188237.0	188237.0	188237.0	188237.0
radish	60000.0	60000.0	60000.0	60000.0
tomato	10793223.0	10793223.0	10793223.0	10793223.0
cucumber	1722684.0	1722684.0	1722684.0	1722684.0
gherkin	60000.0	60000.0	60000.0	60000.0
pepper	2088902.0	2088902.0	2088902.0	2088902.0
okra	32801.0	32801.0	32801.0	32801.0
eggplant	811580.0	811580.0	811580.0	811580.0
zucchini	280787.0	280787.0	280787.0	280787.0
pumpkin	403639.0	403639.0	403639.0	403639.0
pease	134253.0	134253.0	134253.0	134253.0

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Table A.1 – *Continued from previous page*

	Model 1	**Model 2**	**Model 3**	**Model 4**
bean	626205.0	626205.0	626205.0	626205.0
pea	60000.0	60000.0	60000.0	60000.0
favabean	38221.0	38221.0	38221.0	38221.0
cranberrybean	15000.0	15000.0	15000.0	15000.0
watermelon	3801380.0	3801380.0	3801380.0	3801380.0
Pepino	1.0	1.0	1.0	1.0
cauli	84365.0	84365.0	84365.0	84365.0
broccoli	84365.0	84365.0	84365.0	84365.0
lettuce	455345.0	455345.0	455345.0	455345.0
spinach	199344.0	199344.0	199344.0	199344.0
gardenoarch	10.0	10.0	10.0	10.0
purslane	5735.0	5735.0	5735.0	5735.0
tabooli	200.0	200.0	200.0	200.0
rocket	150.0	150.0	150.0	150.0
watercress	10.0	10.0	10.0	10.0
mint	40.0	40.0	40.0	40.0
dill	15.0	15.0	15.0	15.0
asparagus	64.0	64.0	64.0	64.0
mushroom	33530.0	33530.0	33530.0	33530.0
wheat	41198520.0	**30304038.7**	41198520.0	41198520.0
corn	6649887.0	6649887.0	6649887.0	6649887.0
riceplant	766157.0	766157.0	766157.0	766157.0
barley	7467482.0	7467482.0	7467482.0	7467482.0
rye	365524.0	365524.0	365524.0	365524.0
oat	234759.0	234759.0	234759.0	234759.0
millet	15981.0	**0.0**	15981.0	15981.0
carnarygrass	3031.0	**0.0**	3031.0	3031.0

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Table A.1 – *Continued from previous page*

	Model 1	**Model 2**	**Model 3**	**Model 4**
tricale	105002.0	105002.0	105002.0	105002.0
sorghum	988.0	988.0	988.0	988.0
potato	3937892.0	3937892.0	3937892.0	3937892.0
broadbean	18729.0	18729.0	18729.0	18729.0
chickpea	542236.0	542236.0	542236.0	542236.0
redlentil	524999.0	524999.0	524999.0	524999.0
greenlentil	150121.0	**0.0**	150121.0	150121.0
vetch	104342.0	104342.0	104342.0	104342.0
greekclover	10.0	10.0	10.0	10.0
chickling	10.0	10.0	10.0	10.0
jeurselamartichoke	10.0	10.0	10.0	10.0
soya	1817894.0	1817894.0	1817894.0	1817894.0
peanut	40000.0	40000.0	40000.0	40000.0
sesame	131804.0	131804.0	131804.0	131804.0
safflover	5.0	5.0	5.0	5.0
cole	363198.0	363198.0	363198.0	363198.0
cotton	1266280.0	1266280.0	1266280.0	1266280.0
hemp	4.0	4.0	4.0	4.0
hash	4.0	4.0	4.0	4.0
nicotina	135697.0	135697.0	135697.0	135697.0
whitebeet	16488591.0	16488591.0	16488591.0	16488591.0
viciasativa	104342.0	104342.0	104342.0	104342.0
clover	509.0	509.0	509.0	509.0
sainfoinseed	3.0	3.0	3.0	3.0
fodderbeet	3.0	3.0	3.0	3.0
sage	3.0	3.0	3.0	3.0
lavender	3.0	3.0	3.0	3.0

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Table A.1 – *Continued from previous page*

	Model 1	**Model 2**	**Model 3**	**Model 4**
melissa	3.0	3.0	3.0	3.0
stinger	3.0	3.0	3.0	3.0
rose	3.0	3.0	3.0	3.0
lupine	3.0	3.0	3.0	3.0
hop	3.0	3.0	3.0	3.0

TABLE A.1: Amount of production of products for each model (ton).

A.2 Production for consumption

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Demand**
grape	2993290	2993290	2993290	2993290	2993290
banana	419638	419638	419638	419638	419638
kiwi	41463	41463	41463	41463	41463
avocado	1714	1714	1714	1714	1714
fig	19180	19180	19180	19180	19180
orange	1411564	1411564	1411564	1411564	1411564
mandarin	413200	413200	413200	413200	413200
lemon	261721	261721	261721	261721	261721
grapefruit	45581	45581	45581	45581	45581
bergamot	2000	2000	2000	2000	2000
apple	2278667	2278667	2278667	2278667	2278667
pear	419507	419507	419507	419507	419507
quince	118566	118566	118566	118566	118566
loquat	50000	50000	50000	50000	50000
medlar	20000	20000	20000	20000	20000
nectarine	100000	100000	100000	100000	100000
peach	580259	580259	580259	580259	580259
plum	233494	233494	233494	233494	233494
apricot	210620	210620	210620	210620	210620
wildapricot	50000	50000	50000	50000	50000
cherry	406969	406969	406969	406969	406969

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Table A.2 – *Continued from previous page*

	Model 1	Model 2	Model 3	Model 4	Demand
morello	170846	170846	170846	170846	170846
cranberry	102	102	102	102	102
oleaster	150	150	150	150	150
jujube	150	150	150	150	150
strawberry	332281	332281	332281	332281	332281
raspberry	100	100	100	100	100
blackberry	120	120	120	120	120
berry	65511	65511	65511	65511	65511
pomegranate	227389	227389	227389	227389	227389
persimmon	1	1	1	1	1
carob	14218	14218	14218	14218	14218
bilberry	0	0	0	0	0
table olive	545995	545995	545995	545995	545995
olive	1273990	1273990	1273990	1273990	1273990
almond	89102	89102	89102	89102	89102
nut	92822	92822	92822	92822	92822
walnut	223357	223357	223357	223357	223357
chestnut	50799	50799	50799	50799	50799
pistachio	81029	81029	81029	81029	81029
tea	1004833	1004833	1004833	1004833	1004833
chili	1376	1376	1376	1376	1376
aniseed	1376	1376	1376	1376	1376
cumin	1376	1376	1376	1376	1376
raziyane	1376	1376	1376	1376	1376
coriander	1376	1376	1376	1376	1376
nigella	1376	1376	1376	1376	1376
thyme	1376	1376	1376	1376	1376
ling	10	10	10	10	10
indorornamentalplants	50000000	50000000	50000000	50000000	50000000
bulb	50000000	50000000	50000000	50000000	50000000
ornamentalplants	50000000	50000000	50000000	50000000	50000000
scallion	102364	102364	102364	102364	102364
onion	1513156	1513156	1513156	1513156	1513156

Continued on next page

Table A.2 – *Continued from previous page*

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Demand**
garlic	81227	81227	81227	81227	81227
driedgarlic	93125	93125	93125	93125	93125
leek	211684	211684	211684	211684	211684
carrot	504741	504741	504741	504741	504741
swede	661735	661735	661735	661735	661735
redbeet	10	10	10	10	10
celery	10	10	10	10	10
turnip	188237	188237	188237	188237	188237
radish	50000	50000	50000	50000	50000
tomato	10187265	10187265	10187265	10187265	10187265
cucumber	1654684	1654684	1654684	1654684	1654684
gherkin	50000	50000	50000	50000	50000
pepper	2020095	2020095	2020095	2020095	2020095
okra	32801	32801	32801	32801	32801
eggplant	798175	798175	798175	798175	798175
zucchini	280787	280787	280787	280787	280787
pumpkin	361008	361008	361008	361008	361008
pease	103212	103212	103212	103212	103212
bean	622905	622905	622905	622905	622905
pea	60000	60000	60000	60000	60000
favabean	38221	38221	38221	38221	38221
cranberrybean	15000	15000	15000	15000	15000
melon	**0**	**0**	**0**	**0**	**1655639**
watermelon	3778453	3778453	3778453	3778453	3778453
Pepino	1	1	1	1	1
cauli	83920	83920	83920	83920	83920
broccoli	83920	83920	83920	83920	83920
cabbage	**0**	**0**	**0**	**0**	**709498**
lettuce	454610	454610	454610	454610	454610
artichoke	**0**	**0**	**0**	**0**	**37452**
spinach	198921	198921	198921	198921	198921
gardenoarch	10	10	10	10	10
purslane	5735	5735	5735	5735	5735

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Table A.2 – *Continued from previous page*

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Demand**
tabooli	200	200	200	200	200
rocket	150	150	150	150	150
watercress	10	10	10	10	10
mint	40	40	40	40	40
dill	15	15	15	15	15
asparagus	64	64	64	64	64
mushroom	33356	33356	33356	33356	33356
wheat	40923388	30304038.7	40923388	40923388	40923388
corn	6649887	6649887	6649887	6649887	6649887
riceplant	667701	667701	667701	667701	667701
barley	7366711	7366711	7366711	7366711	7366711
rye	362881	362881	362881	362881	362881
oat	234739	234739	234739	234739	234739
millet	**15906**	**0**	**15906**	**15906**	**15906**
carnarygrass	**2485**	**0**	**2485**	**2485**	**2485**
tricale	105002	105002	105002	105002	105002
sorghum	986	986	986	986	986
potato	3843396	3843396	3843396	3843396	3843396
broadbean	17754	17754	17754	17754	17754
chickpea	516899	516899	516899	516899	516899
horicot	**0**	**0**	**0**	**0**	**245636**
redlentil	426293	426293	426293	426293	426293
greenlentil	51415	0	51415	51415	51415
vetch	104342	104342	104342	104342	104342
greekclover	10	10	10	10	10
chickling	10	10	10	10	10
jeurselamartichoke	10	10	10	10	10
soya	1804798	1804798	1804798	1804798	1804798
peanut	40000	40000	40000	40000	40000
sunflover	**0**	**0**	**0**	**0**	**2558108**
sesame	129462	129462	129462	129462	129462
safflover	5	5	5	5	5
cole	363198	363198	363198	363198	363198

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Table A.2 – *Continued from previous page*

	Model 1	Model 2	Model 3	Model 4	Demand
cotton	1262167	1262167	1262167	1262167	1262167
hemp	4	4	4	4	4
hash	4	4	4	4	4
nicotina	60017	60017	60017	60017	60017
whitebeet	16488590	16488590	16488590	16488590	16488590
viciasativa	104342	104342	104342	104342	104342
clover	199	199	199	199	199
sainfoinseed	3	3	3	3	3
fodderbeet	3	3	3	3	3
sage	3	3	3	3	3
lavender	3	3	3	3	3
melissa	3	3	3	3	3
stinger	3	3	3	3	3
rose	3	3	3	3	3
lupine	3	3	3	3	3
hop	3	3	3	3	3

Table A.2: Table of production for consumption (ton).

A.3 Production for export

	Model 1	Model 2	Model 3	Model 4	Export Demand
grape	203286	203286	203286	203286	203286
kiwi	318	318	318	318	318
avocado	27	27	27	27	27
fig	76268	76268	76268	76268	76268
orange	280569	280569	280569	280569	280569
mandarin	530965	530965	530965	530965	530965
lemon	409803	409803	409803	409803	409803
grapefruit	137154	137154	137154	137154	137154
apple	125682	125682	125682	125682	125682
pear	12585	12585	12585	12585	12585

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Table A.3 – *Continued from previous page*

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Export Demand**
quince	13100	13100	13100	13100	13100
nectarine	8000	8000	8000	8000	8000
peach	35000	35000	35000	35000	35000
plum	25800	25800	25800	25800	25800
apricot	157890	157890	157890	157890	157890
cherry	53467	53467	53467	53467	53467
morello	1438	1438	1438	1438	1438
cranberry	8	8	8	8	8
strawberry	19553	19553	19553	19553	19553
persimmon	110	110	110	110	110
table olive	61	61	61	61	61
olive	69231	69231	69231	69231	69231
almond	9102	9102	9102	9102	9102
nut	111578	111578	111578	111578	111578
walnut	4027	4027	4027	4027	4027
chestnut	5166	5166	5166	5166	5166
pistachio	3948	3948	3948	3948	3948
tea	4853	4853	4853	4853	4853
chili	70000	70000	70000	70000	70000
aniseed	2500	2500	2500	2500	2500
cumin	2500	2500	2500	2500	2500
raziyane	2500	2500	2500	2500	2500
coriander	2500	2500	2500	2500	2500
onion	158036	158036	158036	158036	158036
garlic	26	26	26	26	26
leek	15027	15027	15027	15027	15027
radish	10000	10000	10000	10000	10000
tomato	605958	605958	605958	605958	605958
cucumber	68000	68000	68000	68000	68000
gherkin	10000	10000	10000	10000	10000
pepper	68807	68807	68807	68807	68807
eggplant	13405	13405	13405	13405	13405

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Table A.3 – *Continued from previous page*

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Export Demand**
pumpkin	42631	42631	42631	42631	42631
pease	31041	31041	31041	31041	31041
bean	3300	3300	3300	3300	3300
watermelon	22927	22927	22927	22927	22927
cauli	445	445	445	445	445
broccoli	445	445	445	445	445
lettuce	735	735	735	735	735
spinach	423	423	423	423	423
mushroom	174	174	174	174	174
wheat	275132		275132	275132	275132
riceplant	98456	98456	98456	98456	98456
barley	100771	100771	100771	100771	100771
rye	2643	2643	2643	2643	2643
oat	20	20	20	20	20
millet	75		75	75	75
carnarygrass	546		546	546	546
sorghum	2	2	2	2	2
potato	94496	94496	94496	94496	94496
broadbean	975	975	975	975	975
chickpea	25337	25337	25337	25337	25337
redlentil	98706	98706	98706	98706	98706
greenlentil	98706		98706	98706	98706
soya	13096	13096	13096	13096	13096
sesame	2342	2342	2342	2342	2342
cotton	4113	4113	4113	4113	4113
nicotina	75680	75680	75680	75680	75680
whitebeet	1	1	1	1	1
clover	310	310	310	310	310

Table A.3: Table of production for export (ton).

Appendix B

Area usages of regions

B.1 Mediterranean

Mediterrenean	Model 1	Model 2	Model 3	Model 4	Real Area Usage
grape		1,402,897.6	1,614,702.6	700,000.0	789,899.0
banana	90,948.9	90,948.9	90,948.9	90,948.9	46,700.0
kiwi		43,028.8		600.0	589.0
avocado				1,900.0	1,899.0
fig				12,000.0	12,016.0
orange	516,524.1			449,933.3	442,091.0
mandarin				290,000.0	293,943.0
lemon		250,102.0	82,279.2	245,000.0	246,433.0
grapefruit	50,563.1			60,000.0	62,156.0
bergamot	532.2	532.2	532.2	532.2	472.0
apple		755,313.9	948,619.1	480,000.0	494,036.0
pear		224,114.1		42,000.0	42,366.0
quince				8,000.0	8,017.0
loquat				11,000.0	11,338.0
nectarine				18,000.0	18,098.0
peach			396,429.8	71,000.0	71,495.0
plum				62,000.0	62,085.0
apricot		344,724.0	344,724.0	200,000.0	206,268.0
cherry		376,218.8			121,562.0

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Table B.1 – *Continued from previous page*

Mediterrenean	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
jujube	347.2	347.2	347.2	347.2	241.0
strawberry	104,806.1			104,806.1	58,919.0
blackberry	90.7	90.7	90.7	90.7	195.0
pomegranate				115,000.0	115,865.0
carob	5,190.9		5,190.9	5,190.9	5,119.0
table olive		1,060,711.1		470,000.0	471,938.0
olive				900,000.0	904,778.0
almond		203,742.7		46,000.0	46,898.0
nut	336,184.2			600.0	688.0
walnut				60,000.0	60,463.0
pistachio				73,000.0	73,861.0
chili		35,143.3	35,143.3		17,955.0
raziyane	26,916.7	26,916.7	26,916.7	26,916.7	13,800.0
ornamentalplants		495.8			1,414.0
scallion			68,470.9		18,997.0
onion			472,983.7		130,619.0
leek	55,812.7	55,812.7		55,812.7	18,954.0
celery	4.1	4.1	4.1	4.1	140.0
turnip			118,986.7		779.0
radish	20,905.9	20,905.9		20,905.9	47,511.0
tomato		698,922.9	1,542,053.9	1,589,650.9	431,364.0
cucumber	337,781.2				95,712.0
pepper	547,262.8	118,346.2		105,021.2	164,491.0
okra		14,285.4		15,892.2	10,935.0
eggplant	167,820.5	167,820.5			75,713.0
zucchini	71,556.3	71,556.3		71,556.3	36,524.0
pumpkin	136,410.6				2,461.0
pease			76,285.7		27,134.0
bean	434,261.4	434,261.4	434,261.4		95,043.0
favabean			46,896.9		23,864.0
watermelon	688,780.6				249,959.0

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Table B.1 – *Continued from previous page*

Mediterrenean	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
Pepino	0.1	0.1	0.1	0.1	10.0
cauli		33,651.8		33,651.8	17,177.0
broccoli		43,985.9		43,985.9	9,092.0
spinach			175,478.9		26,075.0
rocket	96.0	96.0	96.0	96.0	1,100.0
watercress	5.7	5.7	5.7	5.7	1,729.0
mushroom	1,311.1	1,311.1	1,311.1	1,311.1	
wheat	19,678,471.0	15,279,356.1	16,838,122.1	16,838,122.1	7,825,090.0
millet	46,321.7				470.0
sorghum	1,976.0				150.0
broadbean	64,360.8	64,360.8	64,360.8	64,360.8	2,653.0
lavender	19.9	19.9	19.9	19.9	650.0
rose	7.2	7.2	7.2	7.2	23,496.0

TABLE B.1: Table of area usage of Mediterranean Region (decare).

B.2 Western Anatolia

WesternAnatolia	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
grape				170,000.0	194,602.0
fig	1,381.3	1,381.3	1,381.3		10.0
apple				330,000.0	337,181.0
pear				17,000.0	17,990.0
quince				1,300.0	1,379.0
nectarine	19,104.9			6,564.5	121.0
peach				6,000.0	6,168.0
plum				7,000.0	7,574.0
apricot				7,000.0	7,566.0
wildapricot	1,943.9	1,943.9	1,943.9	1,943.9	79.0

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Table B.2 – *Continued from previous page*

WesternAnatolia	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
oleaster	0.5	0.5	0.5	0.5	4.0
pomegranate				1,000.0	1,149.0
table olive		1,019,771.3	596,657.4	15,000.0	16,708.0
olive				3,000.0	3,672.0
almond				19,000.0	19,391.0
walnut				36,000.0	36,406.0
pistachio				1,000.0	1,076.0
nigella	8,935.1	8,935.1	8,935.1	8,935.1	78.0
indorornamentalplants	125.0		125.0	125.0	
ornamentalplants		1,834.6			1,485.0
scallion	46,214.0	46,214.0		46,214.0	13,950.0
onion	365,847.6	115,483.7			102,763.0
driedgarlic	56,133.2	56,133.2		56,133.2	5,966.0
carrot	79,374.3	79,374.3		79,374.3	75,260.0
swede	254,317.8	254,317.8			123.0
pepper		30,244.6	1,131,154.3	935,200.1	22,353.0
favabean	36,645.3	36,645.3		36,645.3	94.0
cauli			57,352.1		170.0
lettuce	164,384.5	135,942.3			28,148.0
spinach		9,327.8		13,113.8	24,341.0
wheat	32,121,085.4	20,552,975.1	32,687,461.7	32,687,461.7	12,509,782.0
rye	1,243,278.9				168,463.0
carnarygrass	15,155.0		15,155.0	15,155.0	600.0
greekclover	83.3	83.3	83.3	83.3	1,458.0
jeurselamartichoke	6.6				520.0
hash	55.6	55.6	55.6	55.6	30,510.0
whitebeet		2,532,420.7			971,041.0
viciasativa	86,233.1				164,777.0
clover	104.6	104.6	104.6	104.6	280,195.0
sage	22.6	22.6	22.6	22.6	30.0
melissa	5.7	5.7	5.7	5.7	145.0

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Table B.2 – *Continued from previous page*

WesternAnatolia	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
lupine	27.5	27.5	27.5	27.5	3,755.0

TABLE B.2: Table of area usage of Western Anatolia Region (decare).

B.3 Western Blacksea

WesternBlacksea	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
grape		977,399.2	2,481,895.2	130,000.0	157,625.0
kiwi				2,200.0	2,298.0
fig				400.0	456.0
mandarin		758,454.7	210,243.7		1,700.0
apple				70,000.0	73,340.0
pear				14,000.0	14,828.0
quince				2,000.0	2,008.0
medlar	115.2	115.2	115.2	115.2	9.0
nectarine				714.0	714.0
peach				34,000.0	34,116.0
plum				3,000.0	3,567.0
apricot				300.0	367.0
cranberry	0.7	0.7	0.7	0.7	33.0
pomegranate				200.0	217.0
table olive				384,366.3	1,508.0
almond	41,089.5			8,070.5	861.0
nut				1,310,000.0	1,310,863.0
walnut				75,000.0	75,429.0
chestnut				4,000.0	4,126.0
ling	28.2	28.2	28.2	28.2	600.0
indorornamentalplants		645.5			0.8
swede				588,208.9	24.0

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Table B.3 – *Continued from previous page*

WesternBlacksea	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
turnip	65,679.3	65,679.3		65,679.3	3,535.0
tomato		889,467.7			185,310.0
wheat	18,568,157.1				7,493,960.0
barley		6,987,032.9	12,278,776.2	12,278,776.2	1,726,383.0
tricale		312,506.0			111,147.0
vetch	784,526.3	784,526.3			301.0
chickling	90.1	90.1			180.0
soya		4,488,627.2	4,488,627.2	4,488,627.2	27,055.0
safflover	25.5	25.5	25.5	25.5	6,255.0
cole	1,046,680.1	1,046,680.1	1,046,680.1	1,046,680.1	613.0
hemp	28.0	28.0	28.0	28.0	7.0

TABLE B.3: Table of area usage of Western Blacksea Region (decare).

B.4 Western Marmara

WesternMarmara	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
grape				120,000.0	133,190.0
kiwi				60.0	66.0
fig				3,500.0	3,965.0
mandarin				15,000.0	16,626.0
lemon			1,942,260.2		
apple	1,102,912.4			50,000.0	54,322.0
pear				9,000.0	9,363.0
quince				1,300.0	1,333.0
loquat		1,603,861.5			
nectarine				13,000.0	13,788.0
peach				64,748.3	50,252.0
plum				9,500.0	9,891.0

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Table B.4 – *Continued from previous page*

WesternMarmara	Model 1	Model 2	Model 3	Model 4	Real Area Usage
apricot				4,000.0	4,493.0
morello	84,743.7		58,283.6	84,743.7	931.0
pomegranate				2,000.0	2,547.0
table olive				509,385.5	182,099.0
olive	2,957,390.5			1,000,000.0	1,001,998.0
almond				26,000.0	26,917.0
nut				800.0	869.0
walnut				83,000.0	83,866.0
pistachio				5,000.0	5,825.0
aniseed	38,760.0	38,760.0	38,760.0	38,760.0	2,307.0
thyme	8,239.5	8,239.5	8,239.5	8,239.5	30.0
bulb		3,014.6			0.3
onion		649,531.3		49,086.7	39,275.0
redbeet	2.8	2.8	2.8	2.8	405.0
cucumber				206,283.1	17,117.0
gherkin	17,142.9	17,142.9	17,142.9	17,142.9	10.0
zucchini			152,601.6		4,199.0
broccoli			103,261.9		616.0
gardenoarch	5.0	5.0	5.0	5.0	10.0
tabooli	139.6	139.6	139.6	139.6	6,401.0
asparagus	164.5	164.5	164.5	164.5	18.0
wheat	4,261,492.4	12,544,868.0	12,942,044.0	12,942,044.0	6,170,506.0
chickpea	3,521,013.0				151,174.0
whitebeet	3,270,896.8				5,550.0
sainfoinseed	2.4				4,420.0

Table B.4: Table of area usage of Western Marmara Region (decare).

B.5 Eastern Blacksea

EasternBlacksea	Model 1	Model 2	Model 3	Model 4	Real Area Usage
grape		1,037,180.0	587,401.1	1,500.0	1,979.0
kiwi				11,000.0	11,073.0
fig				130.0	168.0
orange		665,408.2	665,408.2	1,200.0	1,326.0
mandarin	26,368.2	5,186.4	20,496.6	1,500.0	1,700.0
lemon	87,815.4			50.0	51.0
apple				8,000.0	10,359.0
pear	34,606.1			1,000.0	1,423.0
quince	8,738.1		8,738.1	100.0	117.0
peach				600.0	620.0
plum				1,000.0	1,161.0
apricot				600.0	694.0
cherry	137,813.8			60,676.8	2,572.0
pomegranate	66,702.6			150.0	171.0
table olive	1,221,601.8			36,733.7	1,402.0
nut		2,689,473.7	2,689,473.7	4,236,000.0	4,236,935.0
walnut				14,532.0	13,898.0
chestnut	3,650.0	3,650.0	3,650.0	68.9	126.0
tea	653,941.7	653,941.7	653,941.7	764,255.0	764,255.0
bulb		120.4			
onion		50,201.8	509,987.0		706.0
watermelon		33,934.2			36.0
corn	4,516,185.7				237,346.0
tricale			107,265.9	107,265.9	701.0
chickpea		1,192,476.0	1,511,061.1	1,511,061.1	9,111.0

Table B.5: Table of area usage of Eastern Blacksea Region (decare).

B.6 Eastern Marmara

EasternMarmara	Model 1	Model 2	Model 3	Model 4	Real Area Usage
grape	2,865,599.3			130,000.0	142,383.0
kiwi	14,573.1		14,573.1	7,348.4	7,216.0
fig				20,000.0	20,164.0
apple				85,000.0	87,830.0
pear				92,000.0	92,686.0
quince				30,000.0	30,281.0
nectarine				11,000.0	11,429.0
peach		454,401.0		104,000.0	104,080.0
plum				28,000.0	28,814.0
apricot				400.0	424.0
morello		304,927.4	95,209.8		21,392.0
strawberry		217,076.7	282,597.6		33,709.0
pomegranate		188,704.6	188,704.6	5,000.0	5,751.0
tableolive		825,737.9		450,000.0	473,158.0
olive	635,947.6			90,096.7	1,907.0
almond				4,000.0	4,535.0
nut				1,446,000.0	1,446,147.0
walnut		736,056.4	743,691.7	66,000.0	66,919.0
chestnut				11,000.0	11,895.0
chili	25,491.4			25,491.4	1,200.0
garlic			97,777.4		822.0
driedgarlic			146,193.1		780.0
swede			396,961.6		3.0
radish			30,426.0		547.0
tomato	1,709,411.3			36,644.4	247,261.0
pepper		638,395.7			82,043.0
okra			79,614.1		4,527.0
eggplant			312,386.5	281,515.5	17,524.0
pease	123,735.5	123,735.5		123,735.5	42,038.0
bean				461,123.0	45,585.0
pea			165,745.9		47.0
watermelon			892,761.9		56,765.0

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Table B.6 – *Continued from previous page*

EasternMarmara	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
broccoli	54,149.6				2,986.0
lettuce			61,711.9		31,598.0
purslane	2,450.9	2,450.9	2,450.9	2,450.9	2,177.0
dill	10.9	10.9	10.9	10.9	765.0
wheat		8,400,281.3	10,990,355.3	10,990,355.3	3,857,951.0
corn	6,316,149.8				592,760.0
oat	192,047.2				131,491.0
tricale	281,506.7				10,057.0
cotton	2,280,098.7				100.0
hop	5.7	5.7	5.7	5.7	3,544.0

Table B.6: Table of area usage of Eastern Marmara Region (decare).

B.7 Aegean

Aegean	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
grape				1,100,000.0	1,405,982.0
kiwi				40.0	42.0
avocado	1,001.7	1,001.7	1,001.7	121.7	41.0
fig				400,000.0	441,886.0
orange				90,000.0	104,170.0
mandarin				70,000.0	74,656.0
lemon				27,000.0	27,768.0
grapefruit		89,840.2	89,840.2	2,000.0	2,039.0
apple				160,000.0	135,022.0
pear				18,000.0	18,482.0
quince				10,000.0	10,798.0
loquat	4,851.5	3,382.8	4,851.5	3,689.2	36.0
nectarine		145,552.6	145,552.6	3,000.0	3,018.0

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Table B.7 – *Continued from previous page*

Aegean	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
peach				109,000.0	109,412.0
plum				54,000.0	54,319.0
apricot				18,000.0	18,706.0
cherry		398,373.4	1,048,829.2	587,049.9	314,794.0
raspberry	84.2	84.2	84.2	84.2	32.0
berry	178.2	178.2	178.2	178.2	11.0
pomegranate				93,000.0	93,007.0
carob		58,752.1			
table olive			596,000.9	1,000,000.0	1,084,868.0
olive		7,106,989.4	7,106,989.4	3,000,000.0	3,322,130.0
almond				66,000.0	66,446.0
nut				45.0	45.0
walnut				126,000.0	126,736.0
chestnut				96,000.0	96,333.0
pistachio				24,000.0	24,944.0
coriander	42,593.4	42,593.4	42,593.4	42,593.4	11.0
bulb	33.6		33.6	33.6	
onion				744,352.4	27,567.0
tomato		271,265.6			440,196.0
eggplant				28,013.5	38,529.0
pumpkin			213,791.8	213,791.8	3,716.0
pea	68,886.3	68,886.3		68,886.3	20,365.0
cranberrybean	13,286.1	13,286.1	13,286.1	13,286.1	22,650.0
watermelon		1,050,886.0		1,094,867.5	177,171.0
wheat	24,282,213.3	6,592,826.4	14,531,557.6	14,531,557.6	6,618,188.0
corn		6,297,241.5	144,795.3	144,795.3	781,409.0
sorghum		1,976.0	1,976.0	1,976.0	50.0
jeurselamartichoke		6.8	6.8	6.8	15.0
peanut		107,526.9	107,526.9	107,526.9	14,929.0
cotton	3,681,390.0	4,045,623.0	4,045,623.0	4,045,623.0	826,424.0
stinger	21.4	21.4	21.4	21.4	3.0

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Table B.7 – *Continued from previous page*

Aegean	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**

Table B.7: Table of area usage of Aegean Region (decare).

B.8 Southeastern Anatolia

SoutesternAnatolia	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
grape				1,100,000.0	1,247,195.0
fig				15,000.0	15,148.0
apple			908,882.4	30,000.0	34,945.0
pear			572,307.3	7,000.0	7,057.0
quince		183,634.6		1,000.0	1,070.0
loquat		1,192,881.8			
nectarine				700.0	701.0
peach				1,200.0	1,262.0
plum		685,963.0		18,000.0	18,667.0
apricot				6,500.0	6,988.0
pomegranate				64,000.0	64,714.0
table olive			3,868,054.1	857,718.7	77,711.0
olive				700,000.0	714,288.0
almond			493,487.4	69,000.0	69,738.0
walnut				44,000.0	44,926.0
pistachio		3,034,892.9		2,706,000.0	2,706,398.0
cumin	45,069.8	45,069.8	45,069.8	45,069.8	498.0
garlic	42,563.1	42,563.1		42,563.1	5,091.0
cucumber		416,921.6			41,505.0
pumpkin		285,863.3			68.0
lettuce				180,049.4	5,245.0
mint	22.0	22.0	22.0	22.0	5,414.0
wheat	4,038,445.3	23,434,371.0	25,638,105.0	25,638,105.0	12,739,815.0

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Table B.8 – *Continued from previous page*

SoutesternAnatolia	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
barley	23,153,599.9				4,235,021.0
redlentil	3,431,366.0				2,515,905.0
greenlentil	714,861.9				100.0
peanut	100,000.0				6,305.0

Table B.8: Table of area usage of Southeastern Anatolia Region (decare).

B.9 Istanbul

Istanbul	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
grape				350.0	454.0
kiwi				40.0	44.0
apple				900.0	1,135.0
pear				150.0	151.0
quince				40.0	42.0
peach	82,319.9			3,437.0	19.0
plum	16,172.5		16,172.5	30.0	30.0
apricot	40,055.4				10.0
pomegranate				30.0	30.0
almond				400.0	459.0
nut				21,000.0	21,861.0
walnut		27,074.0	12,704.5	2,500.0	2,522.0
bulb		496.0			
pepper			34,888.0		1,437.0
okra	47,814.9	36,195.0		34,888.0	105.0
cauli	32,139.0				16.0
wheat		643,418.0			345,517.0
barley			645,221.0	645,221.0	60,922.0
oat	490,483.8				9,744.0

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Table B.9 – *Continued from previous page*

Istanbul	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
fodderbeet	0.4				106.0

Table B.9: Table of area usage of Istanbul Region (decare).

B.10 Northeastern Anatolia

NortesternAnatolia	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
grape				9,000.0	9,065.0
apple				35,000.0	38,470.0
pear				3,500.0	3,813.0
quince				150.0	171.0
nectarine				190.0	191.0
peach				2,500.0	2,682.0
plum				1,000.0	1,086.0
apricot				30,000.0	30,742.0
strawberry		103,651.3			
persimmon	2.7	2.7	2.7	2.7	2.0
almond				30.0	39.0
walnut	246,888.2			25,183.8	7,012.0
pistachio				10.0	10.0
ornamentalplants	280.9		280.9	280.9	
pease			209,355.4		18.0
spinach	113,845.8	105,983.0		102,791.6	1,191.0
wheat		6,882,762.7	1,745,431.2	1,745,431.2	3,780,988.0
corn			8,308,162.7	8,308,162.7	29,836.0
barley	2,516,406.3				1,781,641.0
chickpea		3,001,044.2	2,713,599.0	2,713,599.0	5,033.0
soya	10,099,411.1				150.0
sainfoinseed		3.1	3.1	3.1	833,194.0

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Table B.10 – *Continued from previous page*

NortesternAnatolia	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**

Table B.10: Table of area usage of Northeastern Anatolia Region (decare).

B.11 Central Anatolia

CentralAnatolia	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
grape		896,530.0		350,000.0	430,727.0
apple				310,000.0	324,909.0
pear				8,000.0	8,306.0
quince				1,000.0	1,059.0
nectarine				1,100.0	1,142.0
peach				3,000.0	3,042.0
plum				3,500.0	3,949.0
apricot				35,000.0	37,060.0
almond				8,000.0	8,360.0
walnut				30,000.0	31,176.0
pistachio	25,037.4		25,037.4		66.0
cucumber		585,994.9	1,145,401.6	823,495.7	10,471.0
lettuce		90,557.1	402,656.7		2,533.0
wheat	36,114,163.2	2,497,991.4	19,046,663.5	19,046,663.5	12,241,273.0
riceplant	724,841.1	724,841.1	724,841.1	724,841.1	4,400.0
barley		17,376,988.6	11,267,346.5	11,267,346.5	5,058,574.0
rye		1,338,915.8	1,338,915.8	1,338,915.8	606,713.0
oat		771,098.6			210,493.0
whitebeet			2,913,178.6	2,913,178.6	809,943.0
fodderbeet		0.6	0.6	0.6	335.0

Table B.11: Table of area usage of Central Anatolia Region (decare).

B.12 Middleestern Anatolia

MiddleesternAnatolia	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Real Area Usage**
grape				150,000.0	174,815.0
fig				150.0	196.0
apple		1,288,431.0		90,000.0	104,018.0
pear				18,000.0	18,818.0
quince				900.0	939.0
nectarine				900.0	917.0
peach				5,000.0	5,039.0
plum				6,000.0	6,119.0
apricot				840,000.0	842,814.0
pomegranate				500.0	540.0
almond				10,000.0	10,926.0
nut				4,000.0	4,000.0
walnut				89,000.0	89,662.0
pistachio				1,000.0	1,195.0
leek			323,872.9		2,051.0
carrot			681,161.9		516.0
tomato		220,941.0	504,501.8	294,086.6	52,300.0
wheat	9,535,558.8				3,799,741.0
oat		132,719.0	998,974.5	998,974.5	115.0
millet			56,271.1	56,271.1	476.0
tricale			256,327.8	256,327.8	303.0
potato	985,951.9	985,951.9	985,951.9	985,951.9	45,323.0
redlentil		4,565,208.7	4,565,208.7	4,565,208.7	16,266.0
greenlentil			981,183.0	981,183.0	711.0
vetch			1,075,690.7	1,075,690.7	1,440.0
chickling			109.9	109.9	5,200.0
sesame	1,627,209.9	1,627,209.9	1,627,209.9	1,627,209.9	1,402.0
nicotina	822,406.1	822,406.1	822,406.1	822,406.1	84,466.0
viciasativa		92,256.4	92,256.4	92,256.4	30,060.0

Table B.12: Table of area usage of Middleestern Anatolia Region (decare).